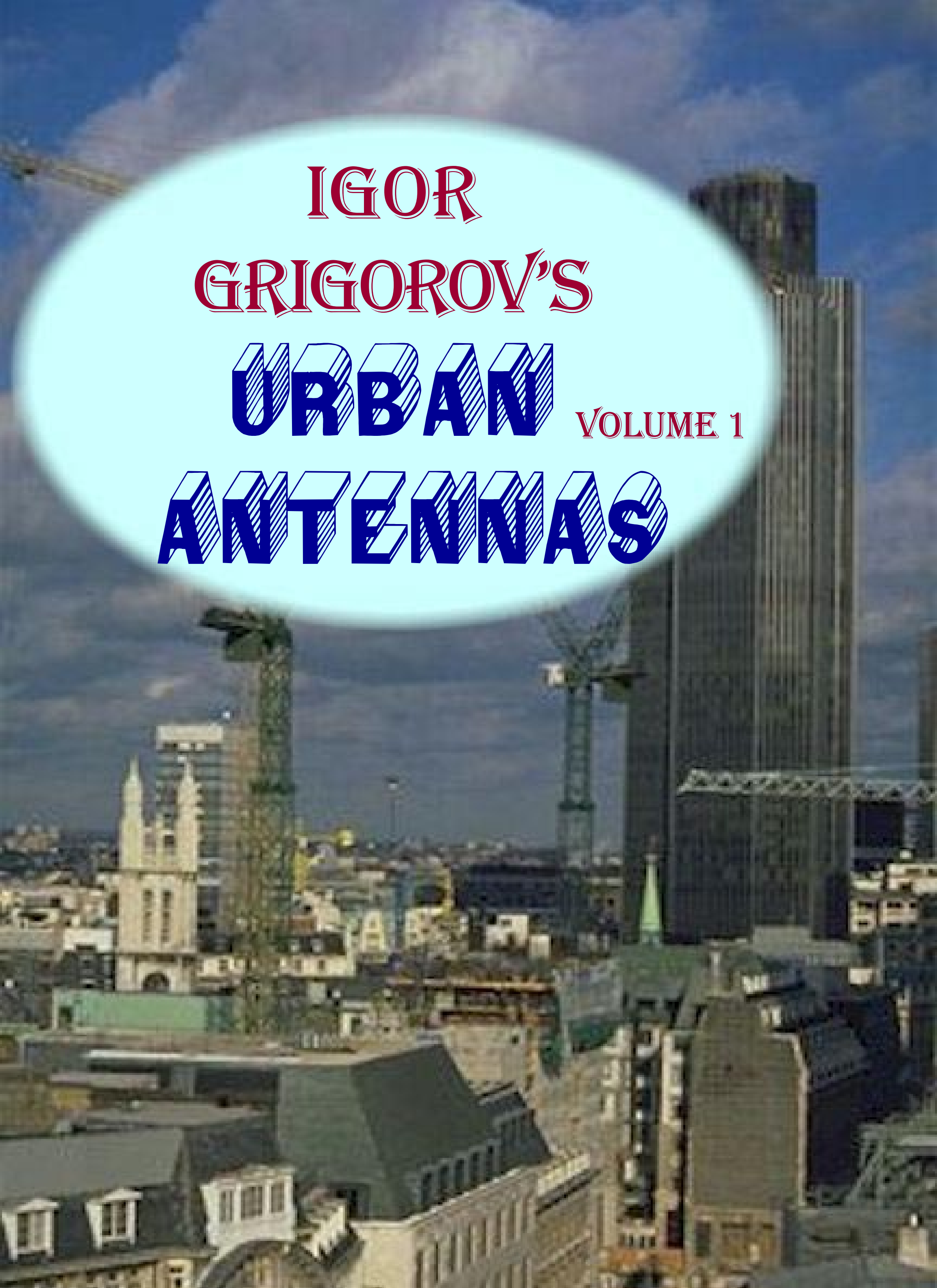
IGOR GRIGOROV'S

URBAN ANTENNAS

VOLUME 1



URBAN ANTENNAS

Volume 1

By Igor Grigorov, RK3ZK

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About The Author

Igor Grigorov has a first class radioamateur license with the callsign RK3ZK. He has published more them 190 articles and eight books for professional and amateur radio. He has received more then 100 radioamateur awards and is an active participant in many QRP contests. Each summer since 1986, he operates either from mountains or from kayaks or simply from various campaigns. For example, in 1991, Igor took part on a radioamateur expedition at Kizhi island. On the expeditions he tries out different antennas and radio equipment. As his primary interest, Igor conducts experiments with "invisible and substitute antennas" which enable him to work from what would seem as impossible places. After a resolution by Russia to use WARC bands and bands 136kHz, CB – band 27 MHz, Igor is one of first to actively work on them.

Igor was born in 1962 in Belgorod, Russia and finished high school there in 1979. After high school, from 1979 to 1980 he worked in the factory ***Energomash*** in Belgorod as a mechanical worker.

In 1980, Igor entered ***Kharkov Institute of Radioelectronics***, where he studied until 1984. Having completed his main body of higher education, during 1984 through 1985 he worked as an assistant engineer in the factory "Sokol" on the assignment of "Signal" and computer management by radio-transmitting equipment of aerial services of aerodromes in the Special Designer Bureau of the factory. In 1985 Igor resumed studies at ***Kharkov Institute of Radioelectronics***, and completed graduate studies in 1987 as a radio engineer-specialist on subjects of radio-transmitting devices and antenna-feeder systems. After graduating from the Institute, Igor was trained as a ***Military Specialist*** for signal intelligence. He then worked as an engineer in the Special Designer Bureau of Factory "Sokol" concentrating on development of digital telephone stations.

In 1990, Igor worked as an engineer at the joint-stock company ***Progress*** on development of transmitter-receiver devices and antenna-feeder systems for 27-100 MHz. In 1992, he worked for the police on control, repair service, maintenance of radio receiving-transmitting devices and antenna-feeder systems for 1-180 MHz bands. At the time Igor was an operator of an emergency service communication station on HF and VHF bands. Since 1998 he has worked in the ***Customs Committee of Russian Federation*** as an engineer on repair, maintenance, installation of transmitting-receiving devices and antenna-feeder systems for 140-180 MHz bands. From the beginning of the year 2000 to the present time, he works in the joint-stock company ***Specradio*** in Belgorod as an engineer for antenna-feeder systems for range 0.2-18 GHz at signal intelligence stations.

Igor is married to ***Alise Kotko*** who attended Belgorod University with post-graduate studies at the Moscow Institute of Pedagogical, followed by scientific work in the shaping of ecological culture of junior school boys in educational activities. She now lectures at Belgorod University.

Best wishes to You, the Reader!

-- HELLO FROM IGOR OF BELGOROD, RUSSIA! --

> > > Click Here to Listen to Audio < < <

Acknowledgements & Author’s Commentary

It is customary to include an acknowledgement when there are contributions made by others who have played an important role in the production of a book, and in this particular case, this book simply would not have been possible had it not been for the influence and dedicated efforts of those credited here.

For more than 20 years of my life I have conducted experiments with antennas and QRP gear. During this time, I have literally conducted and tested hundreds of antennas for amateur radio and numerous other antennas were designed, built and tested for commercial purposes. This experience also included the testing of a variety of amateur radio equipment. At all times, I enjoyed sharing what I learned with my comrades at work and others interested in the hobby of amateur radio. Many of these personal experiences with antennas and equipment designed, built and tested were written about and published in the technical literature of CIS countries while numerous other articles authored were published in various magazines of International QRP Clubs.

I am proud to say this is now the realization of my first book to be published in the USA for the benefit of the entire English-speaking world. Indeed, I am so pleased it is now possible to share my knowledge and experience gained with the radio amateurs throughout the English-speaking world. It has been made possible only due to the coordination of a most complex global effort of Jack L. Stone, publisher of *antenneX Online Magazine*. Working together, we formed a truly International team of special-talented technical editors from both sides of the Globe. At all times, this special team was linked together through the wonders of the Internet — a miracle of the 20th Century! During this complicated logistical effort that stretched out over several months, hundreds of megabytes of data in text and graphics were constantly being transferred between us each and every day of the week. Considering the many edits and re-edits of data, there would be enough to fill several thousand pages of books!

A most valuable assistance was rendered by my friend/translator, Sergey Shamskiy, who had the very difficult task of translating the manuscripts from Russian to English. But, there is a vast difference between “Russian English” and “American English” or the accepted form of English commonly spoken. Thus, the “Russian English” required further transformation into “American English” or a complicated two-stage process involving the Russian and American teams of editors. To the rescue for the “transformation” stage came several US radio amateurs. Mind you, just any editor would not suffice. They had to possess not only proper English language skills, but had to have the necessary technical engineering skills as well in order to comprehend the Russian-English “thoughts” and be able to fluently re-express the thoughts into the commonly-spoken American-English form.

In this special effort has shined most brightly the spirit of cooperation and friendship that exists from within the worldwide community of the radio amateurs. This is greatly in evidence as you read this book. It is with my deepest gratitude that I acknowledge the efforts of these remarkably talented fellows and highly qualified radio engineers who diligently worked long hours as US technical text editors: Gary Nixon (WA6HZT) and Jay Lemmons (N6YIP) who helped with the first chapter; Harold Allen (W4MMC) for chapters 2, 3, 4 and 5; Richard Morrow (K5CNF) for chapters 6; and Tom Cox (KA5NEE) for chapters 7, 8 and 9. Richard Morrow is to be credited for many of the drawings as well. Because of this team, this book was made possible in the English language!

I want to express my warmest appreciation to all my friends who helped as and when they could toward the production of this book I want to express special gratitude to my wife Olesya who provided constant support and encouragement. Without her relentless inner strength and bright, positive attitude to help keep me going, this book would surely not be possible! Consider her a co-author.

And, special thanks to my cat Jore, for allowing me to complete the book. He hates amateur radio and despises all my electronic equipment together with antennas. He bites my antenna and telephone cables, sleeps on my computer monitor, and pulls out the connectors from my transceiver and computer. Any sheet of a paper containing radio text or diagrams, he tends to tear into small-sized pieces. Even now as I write this, he sits on the table and nibbles on the cord of the computer mouse!

So, hopefully Jore will not find ways to hinder Jack Stone, his remarkable team of editors and me as we work toward the release of many more of my books, which we now prepare!

Vy 73s! Igor Grigorov (RK3ZK), Belgorod, Russia, 2001

* * *

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PREFACE

The increasing urban mode of life has touched the radio amateur hobby to a much greater degree than it has most other hobbies. Urbanization of the world's population is growing very rapidly. At the start of the twentieth century only 14% of the Earth's population lived in cities. Then, in the 1960's more than 50% lived in cities. Now, at the beginning of this, the twenty first century, more than 75% of the Earth's population lives in cities.

In the USA, at the beginning of the twenty first century, more than 78% of population lives in cities, and one-half of the USA population now lives in huge cities having more than one million residents.

It is very true that an effective antenna is necessary for radio operations. And it is also true that any effective antenna requires that it be located in a good open space, but space is usually not available in a city. Let's open many of the old communications and engineering books that refer to antennas and see what kinds of antennas they have to offer for radio amateur use. There we will find many effective ones, such as the half-wave dipole, the quarter-wave vertical, the full-size quad, along with many other remarkable antennas that are simple to set-up, and they all provide excellent operation. ***But, alas, they all require a place to mount them!***

In a city, the architectural demands usually do not allow a place for antennas. Where antenna restrictions are imposed, those living in apartments, condominiums, rented flats, hotels, and hostels often do not even dare talk about erecting any antenna for amateur radio operations. In many residential sub-divisions in the USA, even those who own their own home frequently encounter similar restrictions, although some own large lots. As a result, it seems that many radio amateurs do not have any possible way of installing even a receiving antenna, much less a way for mounting a transmitting antenna to interface radio waves with the ether!

In the twenty first century with the process of the world's population shifting to the cities accelerating, ***is it really necessary to stop enjoying our amateur radio hobby? NO!*** I have good news for you! It is still quite possible for us to launch radio waves into the ether with small-sized, imperceptible "invisible" antennas! This book is devoted to my sharing and explaining practical ways of doing this!
In the middle 1970's, when I first started my hobby of operating amateur radios,

there were no problems with installing normal full-scale antennas. Then, as I changed my residence from place to place, and moved to more, more, and even more urban places, I installed more, more, and even more small-sized antennas for my amateur operations. I constructed and tested hundreds of varieties of different types of antennas, which I put up and then hide on my radio set. This experience allowed me to realize I could still launch radio waves by coupling them into the ether with small antennas and still enjoy normal amateur operations, even though none of the neighbors ever suspected that there was a radio amateur working near by.

During the last few years, the ether has become appreciably less cluttered. A large percentage of both the military and commercial stations have moved from the high-frequency short wavelengths to VHF, the “woodpecker” propagation radars that had been contaminating the ether so badly have now been turned-off, and the long wavelength impulse navigation systems have also been turned-off.
Modern radio transceivers ensure both excellent signal transmission and reception, with receivers having very high sensitivity and excellent frequency stability. They enable an operator to gradually reduce the power transmitted into the ether, and ***enable the radio amateur to operate using simple “substitute antennas” to couple signals into and from the ether.***

In this book the descriptions of different types of urban antennas tested by me during my 20 years of amateur radio operations are listed. The construction concept of each of these antennas is made on the basis of a known type of existing antenna, and the types of antennas used as the basis for my various configurations are given. The expositions of single-band antennas for operation on 136 kHz and 27 MHz in city conditions are listed. Many radio amateurs are also fond of operating from campaigns, parks, and forests with QRP gear. In this book many construction questions are answered concerning many small inexpensive antennas for QRP–expeditions, which are easily made, easily erected, and easily tuned, which make it possible to conduct a wide range of experiments. It is possible to say with confidence that in our century, this the twenty first century, ***amateur radio in the city, even in the absence of a good place for antennas, will not die!*** The twenty first century will be a century of small-sized antennas, High-Tech – gear, and, certainly, ***a time for doing many experiments with small-sized antennas designed for operation in city conditions!***

I hope this book gives you, my fellow radio amateurs and experimenters, new ideas concerning construction of small urban antennas that ***will allow you to work within most city conditions, and even occasionally during “impossible” conditions!*** All of the antenna projects published in this book have been assembled and tested by me. I know they are good. You can safely start making any of the antennas described in this book. They all work!

So experiment! And may you have good operation from your cities, too!
-30-

IGOR GRIGOROV ~ 73!

Antenna installation in Ai-Petry QRP-pedition

PART 1

Invisible & Substitute Antennas

PART 1: invisible and Substitute Antennas

Invisible and substitute antennas often are the only types of antennas a radio amateur can place in a city lot, or while living in apartments, condominiums, or other group housing. In constructing invisible and substitute antennas, the following schemes are often used. Using a thread-thin wire, it is possible to erect an antenna outdoors, where a larger diameter wire would be impossible. The small diameter allows the antenna to be virtually “invisible” beyond a distance of 5 to 10 meters, and only an occasional glint of sunlight reflecting off the bare wire might give it’s location away to the outside world. Substitute outdoor antennas, which are visible from the side, can be used for amateur radio communication and often resemble TV antennas. You might wish to use a wall-mounted short vertical with matching device that will allow it to be tuned to resonance in the amateur bands. One basic tenet of construction with regard to any such short vertical is to make it the greatest possible length to begin with, and whenever possible, under a the outside corner of a house as a mounting location. Classic substitute antennas used for such bands as Long Wave are typically represented by a random wire and matching devices; these low frequency antennas, in fact all invisible or substitute antennas, should be kept away from nearby metal objects which can leech power from them and drastically decrease their efficiency and effectiveness.

If an outdoor antenna is not feasible at all, your only realistic alternative is to use and indoor antenna. These antennas behave differently than their open-air mounted counterparts, and require extra effort to get them to perform. Being inside a home or attic is not a good place for antennas, as the materials of the house bleed away signal strength, making the antennas less efficient than if they were mounted outdoors. Also, they will generate RF interference to nearby devices in the home, as well as pick up interference; receiver sensitivity may suffer as well. Working in such close quarters, high power operation is not advisable, or really possible. When using indoor antennas, windows and walls (if not concrete construction) are most popular.

Other popular construction methods include taking advantage of existing metal structures as radiators; downspouts, window sills, just about everything has been used. This form of construction lends itself to using copper and aluminum items primarily, as iron objects are very lossy as radiators, but can always be used as a last resort. These types of antennas develop high voltages on transmission lines, and care must be taken that they are as well matched as possible to avoid damage to your final amplifier.

PART 1: invisible and Substitute Antennas

In my opinion, it is not at all necessary to use the best materials you can find (expensive coax cable, ceramic insulators, large diameter conductors, etc.). All things being equal, completely acceptable results can be had using inexpensive coax or transmission line, hand made insulators, and thin wire.

Be very careful to keep the antennas away from where they may be touched by people or animals, or arc over to nearby materials, as there are large voltages on these antenna elements, that can cause severe burns or start fires. In other words, put these antennas where there is no chance of accidental contact.

"Try and hide them, but I shall find them!"

CHAPTER 1 - INVISIBLE ANTENNAS

There are many occasions when Amateurs are not able to erect an outdoor antenna (or at least one that is visible). And, that last statement is the key: Make the antenna invisible! Of course, these are compromise antennas, not capable of performance on the order of the large commercial antennas, but can be relied upon to provide good performance in just about any situation.

Herein is a collection of antennas I feel are suitable for homes, apartments, or just about any circumstance where another type of antenna installation is not possible. It is my hope that one of these construction ideas will fill your unique antenna needs now and in the future.

Invisible Asymmetrical Antennas

To understand the operation of a vertical antenna in a room, we shall analyze the operation of the vertical antenna in an ideal environment. In that ideal environment, the radiating element is situated, or worked, in tandem against an ideal ground, or reflecting surface, as seen in **Fig. 1.1a**. In this perfect system, the radiated signal (or displacement current, Idis) flows without loss back to the radiator, making it a totally efficient radiating system. The input impedance of such an ideal 1/4 wavelength vertical antenna system is 36 ohms.

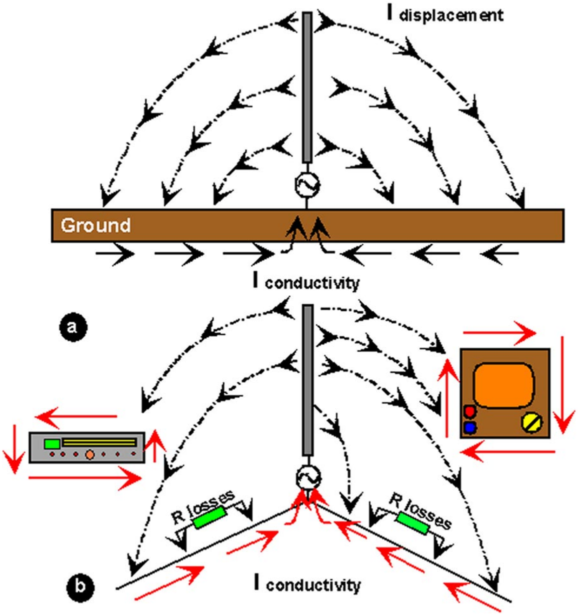


Fig. 1.1 Vertical asymmetrical antenna

In constructing a vertical antenna in a room, it is important to note that its operation will be sharply different than the ideal antenna system due to the antenna's "neighbors", and one of the biggest changes will be its input impedance. This is due to the ground system being less than ideal, and your best effort may include counterpoise wires running around the room. This will still be a lossy ground system (R losses) returning complex reactance components back into the antenna system. The effect will physically be expressed in magnifying of an entering active and reactive impedance of asymmetrical substitute antenna.

It is possible to refer to losses in an earth system as ***supportive return currents***. As is shown in **Fig. 1.1b**, the radiating element of the antenna system does not receive supportive return currents from nearby metal objects; in fact, those currents never make it past the objects and are lost. These objects can be, and are found, everywhere in a room: TV sets, VCRs, mirrors, and even power cords. Physically these foreign objects can be presented as loads with different impedance, hooked up in bridge to the antenna's wire and to the antenna's grounding system. It makes a reduction of input impedance of an antenna and importation into the antenna's impedance reactive component, more often affecting the capacity part of resistance.

Another thing to note about this type of installation is that outside objects can have an influence on the input impedance, reducing its impedance and efficiency. As a result, the impedance is usually 20 to 40 ohms, with a capacitive component of the same order. If the impedance of a 1/4 wavelength indoor antenna is greater than these values, an error may have been made in the construction of the antenna, an object in the room has been moved or changed, or a calculation error in the antenna's dimension has probably been made. The presence of a significant reactive induction part in the antenna's impedance too indicates a possible error in the construction of the antenna.

Substitute asymmetrical antennas located in concrete buildings always have lower input impedance as contrasted to by asymmetrical antennas located in brick or wooden buildings.

There are some circumstances where vertical indoor antennas are possible. Simply by confining your operations to the upper HF bands (21 and 28 MHz), a quarter wavelength wire can be suspended from the ceiling or attached to a wall (**see Fig. 1.2**). However, on bands of 20 meters and below, there isn't always room to accommodate a full size quarter-wavelength wire. In these cases, a zigzag antenna offers a solution (**see Fig. 1.3**) . For the very low bands, like 80 and 160, meters, using a zigzag pattern to string over walls and ceiling is a possibility (**see Fig. 1.4**)

Fig. 1.2 A ceiling antenna

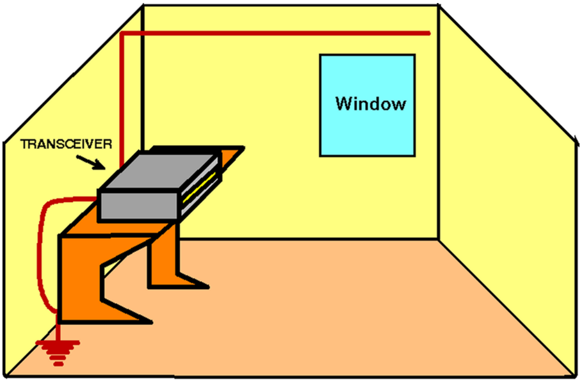


Fig. 1.3 A zigzag ceiling antenna

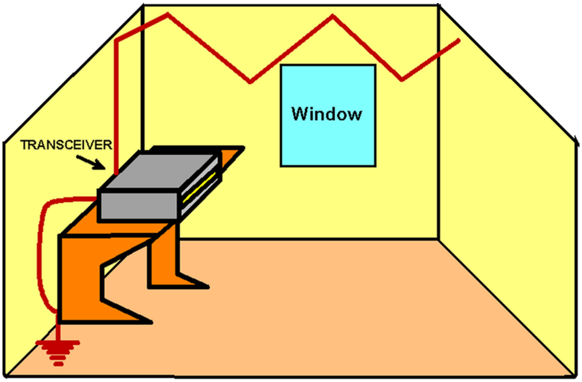
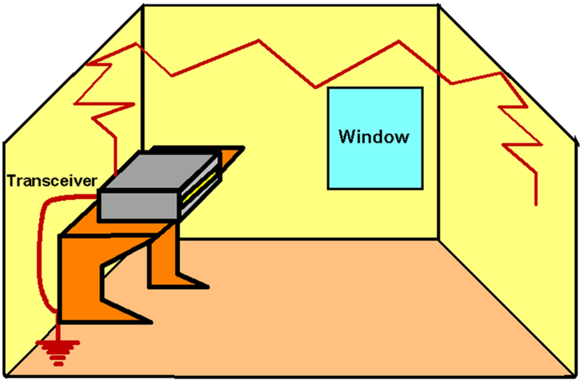
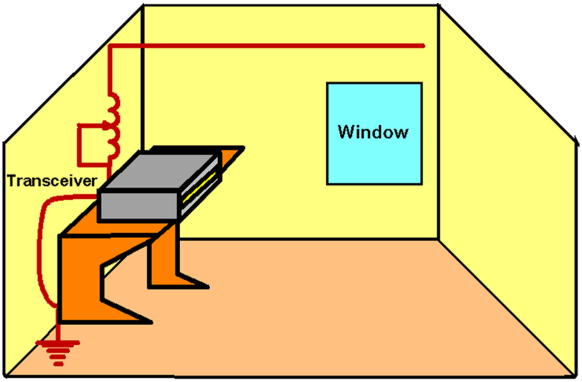


Fig. 1.4 A zigzag walls- ceiling antenna



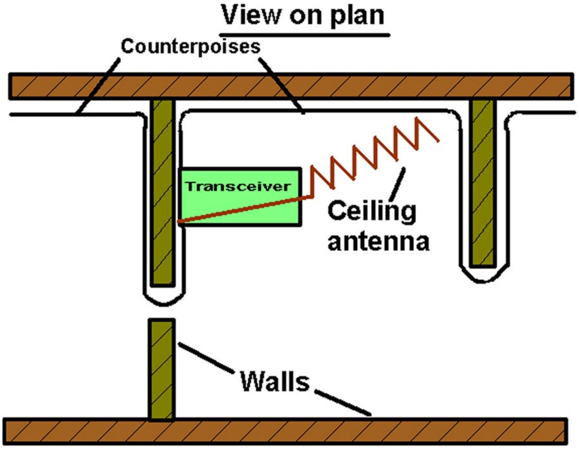
Good low angle radiation can be expected from the antenna in **Fig. 1.2.** The antennas shown in **Figures 1.3** and **1.4** do not provide low angle radiation, but are functional none-the-less. The antenna shown in **Fig 1.2** will work well for 10 to 20 meter operation with a length of 2.5 to 5 meters, while adding a switchable inductance on the order of 100 uH will increase the operating range to 12 to 160 meters (**see Fig. 1.5**). Of course, due to its short nature, it will be progressively less efficient as you operate lower in frequency.

Fig. 1.5 A ceiling antenna for 12-160 m



The role of a good ground when using antennas of this type cannot be over emphasized. Without adequate grounding, RFI and TVI can be extreme. If the metal tubing of a heater or waterpipe is available, they will give the best result and are preferred, although they may not eliminate interference problems. One option that may provide relief is to lay several quarter wavelength counterpoise wires out on the floor or under a rug. They may also take the shape of the main antenna, or follow the perimeter around several rooms (**Fig. 1.6**).

Fig. 1.6 A grounding system for indoor antenna



The antennas introduced in **Figures 1.3-1.5** are best suited to the upper floors of buildings as they tend to produce strong interference to radio, television, and other audio devices. It may be best to operate such antennas late at night to avoid interference problems.

Another thing to be aware of is that human bodies and large or spreading plants can influence the operation of such an antenna, as can large nearby conductors. Most of the interference is confined to an area of 2 to 3 times the length of the antenna. It is very difficult to predict exactly how an antenna of this type will actually perform, given all of the variables involved, once it is installed in its new location.

Some lesser-used items that have been pressed into indoor antenna service in the 10 to 40 meter range have been bed springs, or doors and room perimeters and diagonals with thin copper or aluminum foil strung around them.

A door antenna (**see Fig. 1.7**) of this type is fairly efficient on 10 or 15 meters with a short wire feeding it in its corner (1 to 2 meters in length), and can be made to work down to 40 meters with longer wires feeding it.

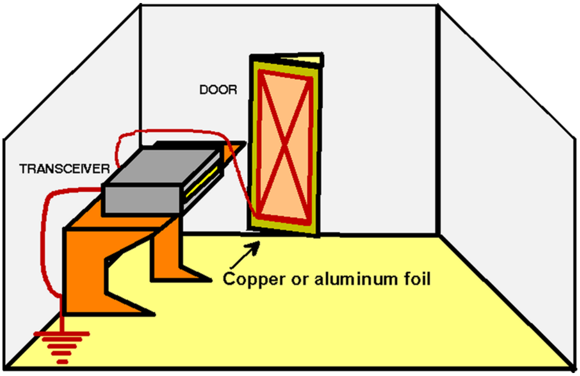
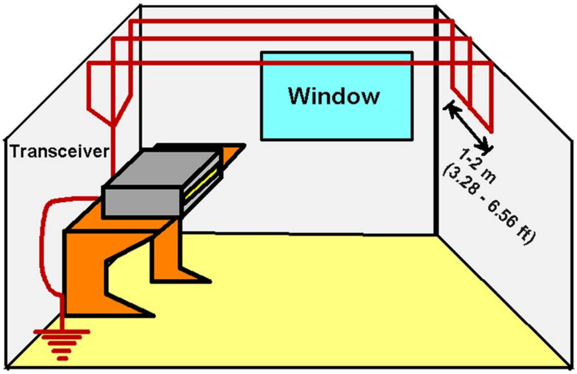


Fig. 1.7 A broadband door antenna

It is possible to use a wall - mounted wideband antenna (**Fig. 10.8**). It works well at ranges from 0.2 to 10 times the length of the antenna (i.e., if overall length of antenna = 10 meters, the antenna works well on ranges from 2 up 100 meters). The construction of the line used should have a minimum of three conductors, and is preferably made of copper or aluminum foil.

Fig. 1.8 A wall-mounted wideband antenna



Indoor antennas are affected by everything around them, be it human, animal, plant, furnishing, or construction. Further, it is difficult to feed high power to these antennas, as they are capable of destroying nearby receivers at levels of 1,000 watts or more if the receivers are randomly tuned on a transmitter frequency. And, they will suffer efficiency losses in concrete buildings.

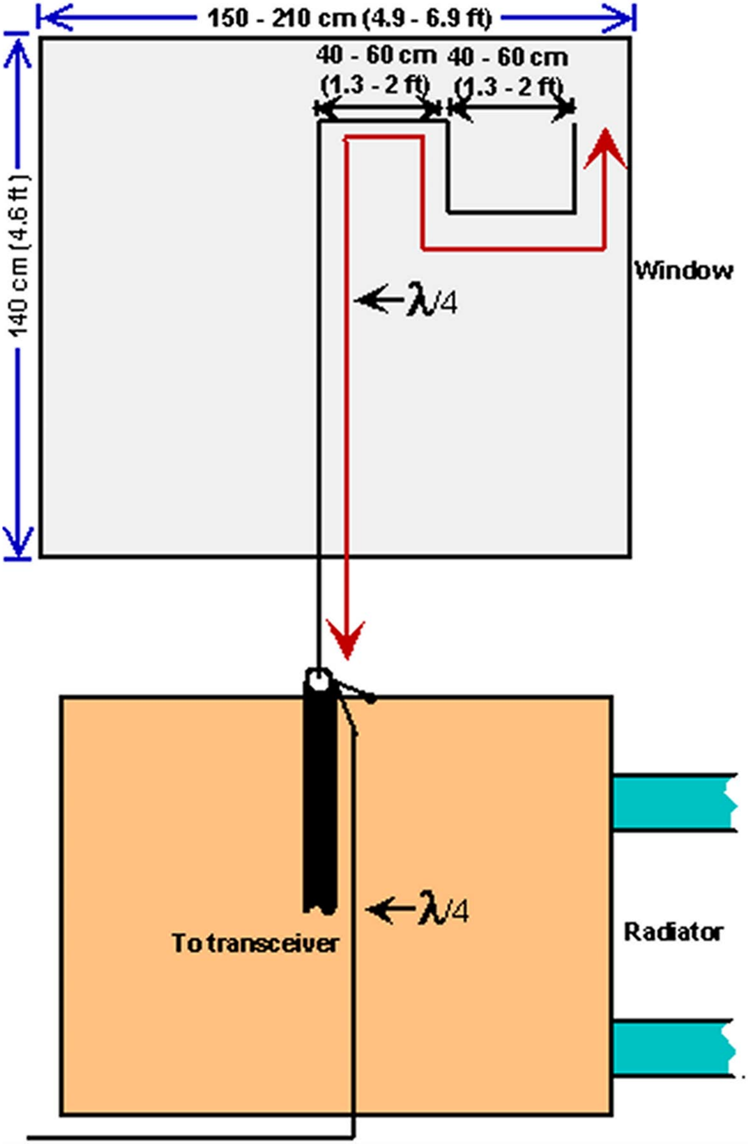
Backup Room HF Antenna

In contrast to the problems faced in constructing indoor antennas, antennas that are constructed outdoors also face both natural and manmade attacks. It may be a passing storm or neighborhood children that bring down your antenna, and it's not always easy or possible to quickly repair them. Then you wind up missing schedules and good DX opportunities.

It is not advisable to construct an outdoor antenna fed with an individual coax cable for a band you don't frequently use, or where there is no propagation when you are typically on the air. It is better to use this coax cable for an antenna more frequently used for your choice of operation, rather than using a substitute antenna for a seldom-used range.

An invisible window antenna is shown in **Fig. 1.9**. The antenna represents the quarter-wave radiator which is bent in a "meandering" fashion. It is located in the geometrical center of the window. For installation of this antenna, the window's dimensions should be about 140x210 cm. The antenna is installed on the outer side of the frame and does not hinder the operation or function of the window. The antenna element can be crafted from flexible copper wire of 1 to 2 mm, covered with plastic insulation. The wire is fed through the frame to the center conductor of a coax cable and the braid of the cable is connected to a heater creating a ground for the antenna. At the point where the cable braid is connected to the heater, a quarterwave counterpoise wire is also connected (see **Fig. 1.9**).

Fig. 1.9 A window substitute invisible antenna



Measuring this quarterwave antenna with an impedance bridge shows its impedance is resistive with a value of 30 ohms at 10 meters and 40 ohms at 20 meters, with small capacitive component of its impedance lying in range of 10-20 ohms. The antenna's bandwidth is 900 kHz on 10 meters and 600 kHz on 20 meters.

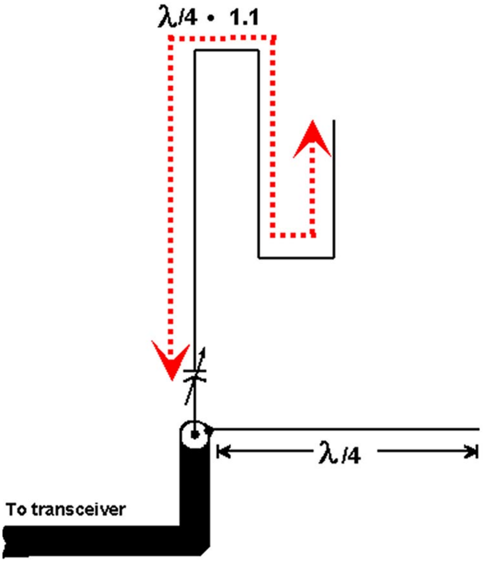
Increasing the amount of counterpoises and increasing of the distance between the meandering points of the antenna's wire have not improved performances for the antenna. For feeding the indoor antenna, a 50-ohm coaxial cable is well suited. Data for various lengths of the radiator and ground system in different ranges are shown in **Table 1.1.** Once the antenna is installed, check the VSWR in the amateur band chosen and take readings in the middle of the band. If the resonance of an antenna is below frequency of the amateur range, shorten a centimeter at a time until resonance at mid-band is achieved. Installing an antenna based on the data shown in **Table 1.1,** once resonance of the antenna at the beginning of an amateur range is found, finding the mid-band is easy.

Table 1.1 Length of Radiators of a Window Antenna

Band (m)	**Length (cm) of Radiators and Counterpoise**
20	**506**
17	**398**
15	**336**
12	**294**
11	**260**
10	**252**
6	**141**

The use of 75-ohm coaxial cable usually necessitates the use of a matching capacitor. An example of how this is achieved is shown in **Fig. 1.10**. The radiator length is 1.15 times the length of a standard quarter wavelength element. Aerial capacitor of 100 pF should be enough capacitance on 10 and 15 meters, while 150 pF should probably be used on 17 and 20 meters. You can bridge a small fixed capacitor, such as a small ceramic type, with the aerial capacitor to achieve the total capacitance needed. There is no high voltage on this variable capacitor, therefore it can have a small clearance between plates, and it is even possible to use a ceramic tuning capacitor.

Fig. 1.10 Window antenna fed through coax cable by a characteristic impedance of 75 ohms

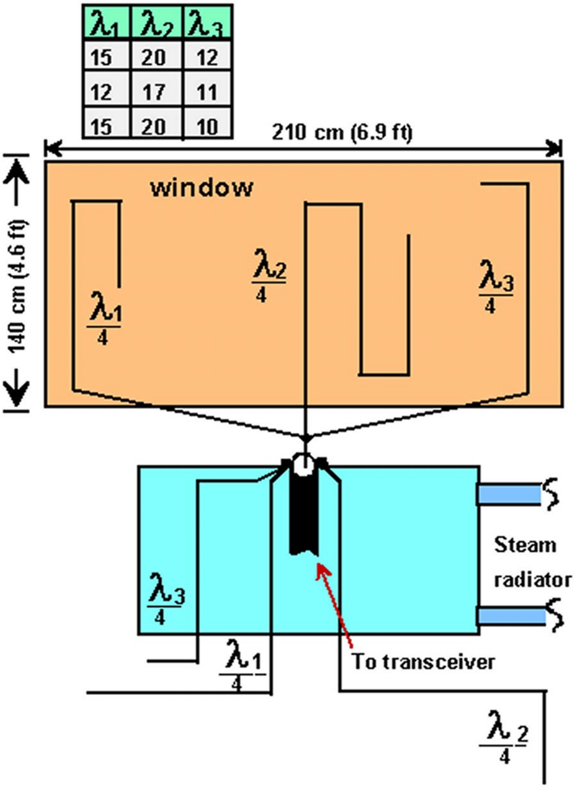


You may use this circuit to match to 50-ohm cable as well, although the difference in performance between VSWR 1:1.5 and 1:1.2 will not be noticeable. This antenna will develop high field strength in the room where the window is located and can cause heavy interference to any audio and video equipment. It is best if this antenna can be located in a room where there are no other electronic devices to suffer from interference. This antenna is effective on both upper and lower stories of a structure. It can, however, pick up stray noise from either the surrounding area or its counterpoise connection. Also note that most of the radiation from the antenna will be in the direction the window is facing with little or no radiation in other directions.

On-the-air testing from the sixth floor of a nine floor building, this type of antenna was compared to a λ/4 vertical antenna mounted on the roof. It was 1 to 3 S units below the vertical in all cases, referenced to the S meters of the amateurs involved.

An attempt was made to make a three-band version of this antenna. For this antenna, three conductors were located on the window with the bridge connected to them by cable. My version of the three-band window antenna is shown in **Fig. 1.11**. The distance between the wall of the house and then ends of the antenna was 40 centimeters. As a counterpoise for low band operation, the antenna was a λ/4 wire run along the base of a wall of the room. Counterpoise wires for the upper bands were placed 2 cm from each other, running along the base of another wall of the room with a length of λ/4 for their respective bands. The antenna itself exhibited a resistance of 30-36 ohms when tested with an impedance bridge. It had a capacity resistance of 20-30 ohms indicating this antenna would match well to a 50-ohm cable.

This antenna was mounted on the sixth floor of a nine-story building and was tested against a roof-mounted λ/4 vertical on the same building and was down 3 to 5 S units below the vertical. The three-band radiator lengths are shown in **Table 1.1**. Start by tuning the lowest band first, and recheck all SWR readings when done. If an impedance bridge is available, it is preferred over a simple VSWR meter.



λ_1	λ_2	λ_3
15	20	12
12	17	11
15	20	10

Fig. 1.11 Three-band window invisible antenna

The construction of a dual band antenna is feasible with a window width of only 140 centimeters, lending itself well to use on a balcony perhaps. Fishing line can be used to extend the radiating elements and the use of end insulators are not needed.

This antenna is for all practical purposes an "invisible" espionage antenna as even from the street they are very difficult to spot.

Tape Antennas

When substitute or invisible antennas are installed either at a fixed location or at a temporary location, often there are problems with the antenna shifting frequency after installation. Almost unavoidably, such antennas are placed in an environment containing RF absorbing objects. The resonant frequency, in contrast to what the theoretical calculations indicate will shift down in frequency and retuning the antenna becomes necessary. Wire substitute antennas are particularly affected by the closeness of RF absorbing materials as well as the presence of the operator. This causes the resonant frequency to shift away from the desired operating frequency which causes the antenna to not work satisfactorily. As a result of all of these destabilizing factors, installation of one type of substitute antenna or another in different locations will likely incur problems with achieving proper resonance on the desired frequency of operation. To reduce the influence of these detuning factors on the antenna and to improve operation, an alternative choice is to use broadband tape as asymmetrical radiating elements.

An asymmetrical vertical antenna made from aluminum foil of the type used for wrapping food was tested. On one side of the foil, Scotch tape 10 cm (3.9 in) wide was placed. The antenna was then located on the wall of a room. The ground plane of the antenna was made by using a length of foil 5 meters (16 feet) long, which was installed along the bottom of the wall of a room. The diagram of this antenna is shown in **Fig. 1.12.**

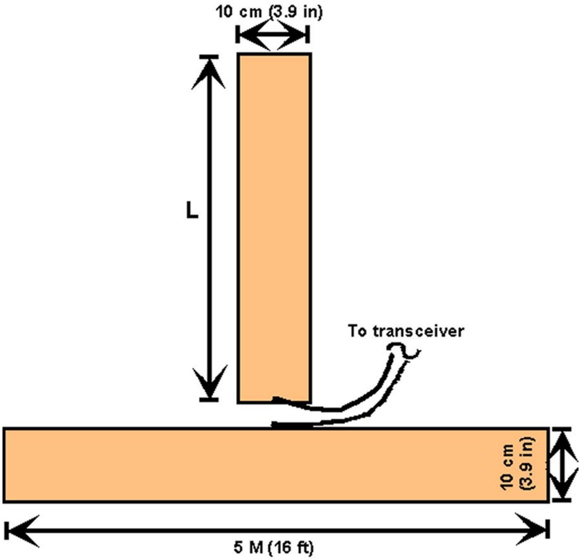


Fig.1.12 Tape asymmetrical vertical antenna

This antenna was constructed for primary operation on the 21 MHz amateur band. The length (L) of the antenna was 3.5 meters (11.5 feet). The input impedance and resonant frequency of the antenna was measured with an RF bridge and determined to be Z = 38 ohms, Rf = 19.2 MHz. A secondary resonance was located at 26.4 MHz and the input Z = 350 Ohms. To resonate at 21 MHz, the top of the antenna was rolled up as shown in **Fig 1.13.**

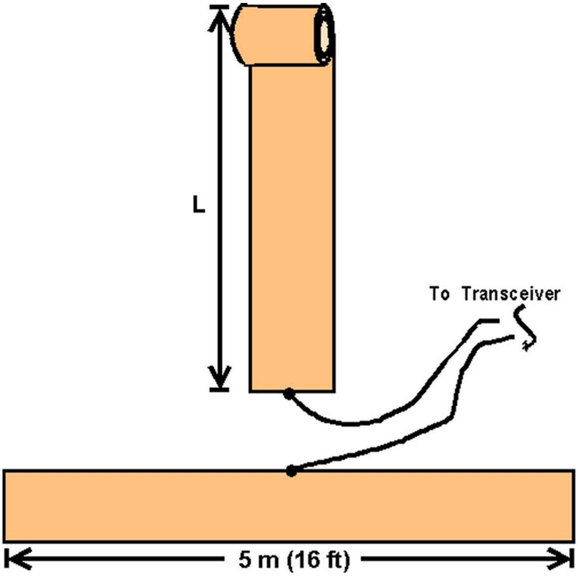


Fig.1.13 Tape asymmetrical vertical antenna with end wound in roll

When the length was 3.1 meters (10 feet) the resonant frequency was raised to 21.1 MHz and the input Z was = 39 ohms. The secondary resonance was increased to 28.1 MHz and the input Z was 350 ohms. During my experiments of installing this antenna on walls of rooms of different locations around RF absorbing objects as compared to open space installation, its resonant frequency varied by an insignificant amount. This indicates that the tape antenna can be used in many locations with different conditions surrounding the antenna with minimal affect on the antenna. It also means that when installed, there will be only a minimum amount of tuning required to resonate the antenna to the proper frequency.

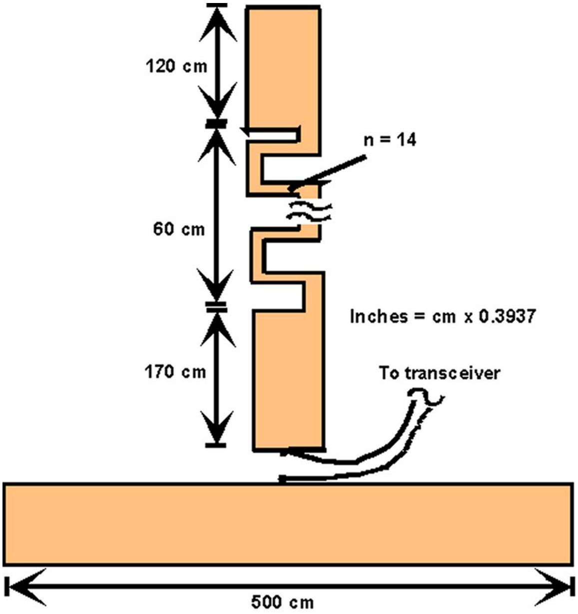
For feeding the antenna on both ranges of 21/28 MHz, it is possible to use a twisted line with a characteristic impedance of 130-160 Ohms electrical length on quarter wave for upper antenna range. For a feed line with an impedance of 130-160 Ohms, a length of regular AC power cord with small diameter conductors was used. The impedance of the cord was determined by the following method: 1) a length of power cord not less than 1 meter was connected to the RLC meter and left open on the opposite end and the capacitance of the line is measured. 2) next, the open ends of the line are shorted and the inductance is measured. With the capacitance and inductance of the length of line determined, the impedance can be ascertained with the standard formula below.

$Z = \sqrt{(L/C)}$,
Where Z is the impedance in Ohms,
L is the inductance in Henries, and
C is the capacitance in Farads.

The above will define the impedance of the line being used in place of a normal feed line accurately enough for amateur radio use. In this case this will result in a very good impedance match for the antenna being used on both 21 and 28 MHz and also to match the coax and output of the standard 50-75-ohm impedance of the transceiver. As experienced in actual practice for operation on a range of 28 MHz, it was found best to use an antenna with a length of 3.1 meters. In this case, the strength of receiving and transmitting signals from a tape antenna with a length of 3.1 meters versus a tape antenna length of 1.9 meters increased the signal by 1-1.5 dB. For feeding the antenna in this case, it is possible to use a twisted line with characteristic impedance of 130-160 ohms electrical length on quarter wave for the 28 MHz range.

The tape antennas can be tuned to a higher frequency by rolling up the antenna tape material and shortening it to the proper length. If it is necessary to operate on a lower frequency below the lowest resonance, it is possible to do this by making a cut in the foil for the addition of a loading coil as shown in **Fig. 1.14**. In the case of the antenna shown in this drawing, it had a resonant frequency of 18.1 MHz. The input impedance was measured with the help of an antenna bridge and was measured at 38 ohms. This comes nearer to the theoretical input impedance of a vertical asymmetrical quarter-wave shortened antenna. The number of turns on a coil **n** with a length of 60 cm (24 inches) was 14 turns. The second resonant frequency was at 25.2 MHz and the input impedance was 350 ohms. This antenna worked well on the amateur bands at 18 MHz and at 24.9 MHz.

Fig.1.14 An antenna represented an aspect of an inductance coil



To feed this antenna on both bands it is possible to use a twisted line by characteristic impedance of 160 ohms and built as described previously. The electrical length of the line is equal to λ/2 on the 24.9 MHz band.

The bandwidth of the antennas shown in **Figs. 1.2-1.4** is not less than 1.2 MHz between 1.4:1 SWR points and the variation of the input impedance is much less due to the inital low input impedance of the antenna. On the bands where the input impedance is high, the bandwidth was no less than 1 MHz. For more exact tuning of the antenna in the upper frequency ranges, make sawtooth cuts in the upper part of the antenna. These cuts are shown in **Fig. 1.15** This will cause the resonant frequency to increase. These sawtooth cuts will cause a small decrease in bandwidth. The sawtooth cuts should only be made in the top element of the antenna. No change of this nature should be made in the lower part of the antenna.

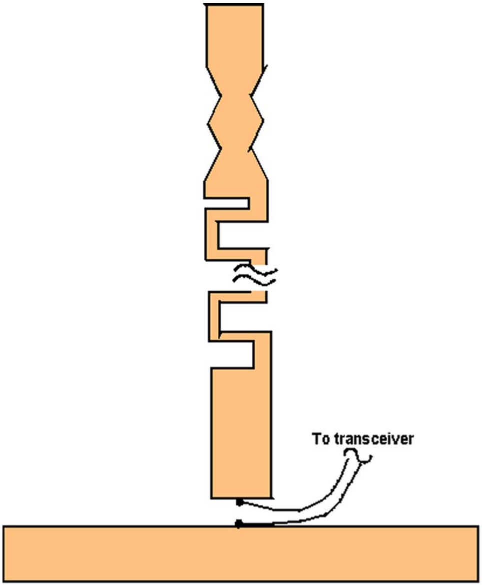


Fig. 1.15 Antenna shown as an inductance coil with upper edges in the shape of a saw

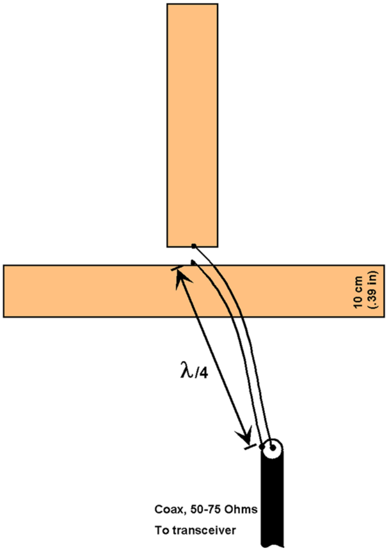
In **Table1.2**, the lengths of an antenna L and the resonant frequency of the antenna is exhibited for the antennas illustrated in **Figs. 1.2 – 1.4**.

Table 1.2 Parameters of the tape antenna

Parameters Of Antenna From Fig. 1.12		Parameters Of Antenna From Fig. 1.14
L = 3.5m	L = 3.1m	
Freq = 19.2 MHz Za = 36 Ohms BW = 1.2 MHz	Freq = 21.1 MHz Za = 36 Ohms BW = 1.2 MHz	Freq = 18.1 MHz Za = 38 Ohms BW = 1.2 MHz
Freq = 26.4 MHz Za = 350 Ohms BW = 1 MHz	Freq = 28.1 MHz Za = 350 Ohms BW = 1 MHz	Freq = 25.2 MHz Za = 350 Ohms BW = 1 MHz

The feed line of the tape antenna can be made from a symmetrical 2-wire line with an impedance of 130-160 ohms. The length of the line is equal to a quarter-wave length in the upper frequency range of the antenna. This is shown in **Fig. 1.16**. The 2-wire line is connected to a coaxial cable of 50-ohms impedance and with an electrical length greater than 20-30% of the half resonant wavelength on the lower range of operation. In this way it is possible to satisfactorily match a dual band antenna on both operating ranges.

Fig. 1.16 Feeding the two-band tape antenna



The tape antenna can be built with the radiating element at the end of the foil ground plane in addition to being located in the center. It is desirable that the distance from the radiator to the edges of the tape ground be not less than 1.5 meters (4.9 feet). If the room has a lot of RF absorbing material, the antenna and its radiating field must be placed as far away from them as possible.

The tape antenna does not always need to be arranged in the middle of the grounding tape or foil. It can be arranged in relation to its edges as well. It is desirable that the distance to the edge of the earthing, or grounding tape, is not less 1.5 meters. This allows the antenna to be placed in a location, within a busy room, that is farther away from people or other interfering objects.

A directional antenna that will work on 21/28 MHz may be built of tape although it will exhibit rather weak directional characteristics. This antenna configuration is illustrated in **Fig. 1.17.** In this case, passive reflector elements for appropriate ranges within 21 and 28 MHz are made from the same tape foil that the radiator is made from and the whole antenna can be placed on the walls of a building or home. It should be understood, however, that the construction of a tape foil directional antenna will not result in a highly effective directional antenna due to the compromises that are necessary in the construction of this type of antenna. Some directional characteristics will be present which is helpful in reducing interference.In **Fig. 1.18** the simplified version of a directional tape antenna is exhibited which may be used as a beam antenna for operation on 21/28 MHz and 18/25 MHz. In this case, the length of a grounded foil receives better when a bit greater than 5 meters. When employing the beam version, the best placement is around the window or similar spot where the antenna will be subjected to the least amount of RF absorbing objects.

Fig. 1.17 The tape directional antenna system with passive reflector elements

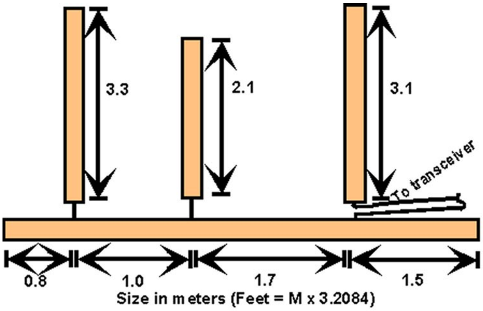
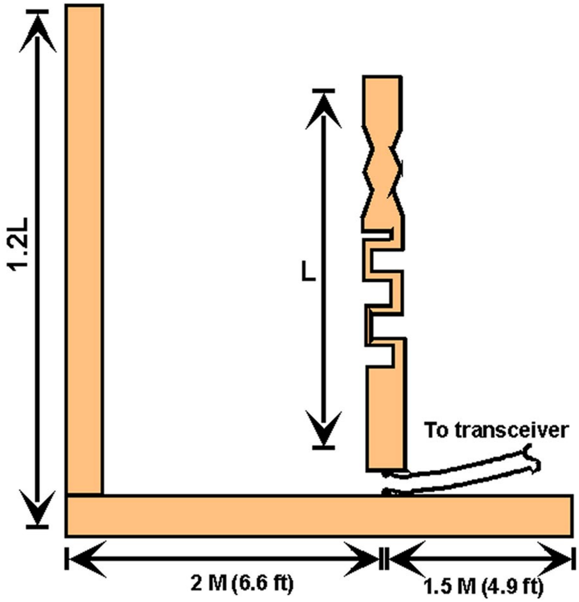


Fig. 1.18 The simplified tape directional antenna system



The experiments with tape antennas described have shown that the construction of invisible tape antennas capable of operating two separate amateur bands is possible while more than two may not be feasible without retuning. However, it is easy to tune such an antenna for operation on multiple bands by merely rolling up (or down) part of the radiating element. For the lower frequencies, a loading coil can be used to load up the tape element. By experimenting with this type of antenna from various familiar locations, it becomes easier to install the antenna in many other fixed locations as experience is gained with each unique installation. This type of antenna can be placed in a fixed but unnoticeable location on the wall of a room in a hotel, behind cabinets or curtains. This technique is very convenient when traveling. Bear in mind, the use of this type of antenna does not allow for permanent outdoor installation as the aluminum foil will deteriorate rapidly due to the weather. The principles given here are presented to describe the construction of the tape antenna for use primarily on the lower bands. However, other higher frequency ranges, such as the VHF can also make use of this type of antenna.

Invisible Antennas

Indoors, if the home is not made of concrete, it is feasible to install a wall-mounted antenna. It can be made from small diameter aluminum wire, which is readily available at many hardware stores. The wire can be glued to a wall and then painted, making it become truly “invisible”.

This antenna can be constructed in dipole and single-wire form. A single-wire version can be connected directly to a transmitter. As the foil can be curved in any direction, any configuration is possible and many are acceptable, such as a direct link (**Fig. 1.19a**), bent (**Fig. 1.19b**), “U” shaped (**Fig. 1.19c**), or “L” shaped (**Fig. 1.19d**).

Clips on the antenna’s feed line are attached for easy connections to a wall baseboard installation. Another method is to make use of a false AC wall socket to provide connections to the antenna.

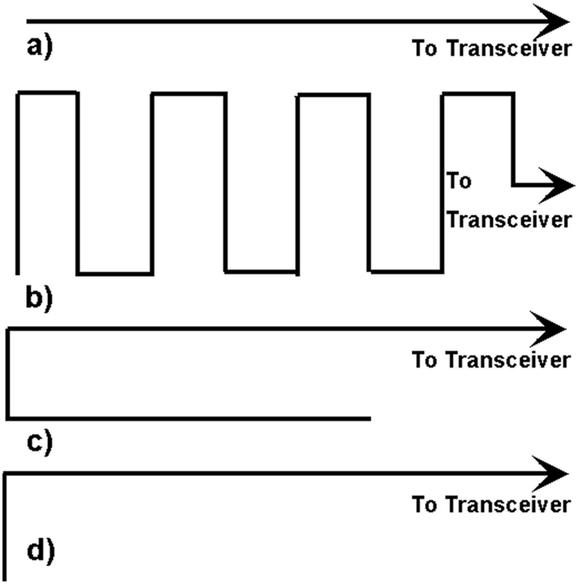


Fig. 1.19 Invisible wall-mounted antenna

The use of symmetrical antennas offers many operating options to the radio amateur. One can make a full size dipole antenna using an unrolled tape, foil, or wire (**Fig. 1.20a**) or minimized as in a zig-zag “meandering” fashion (**Fig. 1.20b**). The clips on the cable from the transmitter to the antenna can be plugged into a false AC socket of the AC main. Then, using foil, create feed lines for the antenna. Using 1 cm wide foil strips spaced 10 cm apart will give a feed line impedance of 300 ohms. This is particularly handy if the antenna is on the opposite wall from where the radio is located (**Fig. 1.21**). The dimensions of the dipole constructed from foil, both unrolled and zig-zaged, are similar to the dimensions of the usual dipole. The shortening factors for a length of foil, 1 cm wide, is approximately 0.94 on frequency 28 MHz and 0.96 on frequency 7 MHz.

Fig. 1.20 Symmetrical invisible wall-mounted antenna

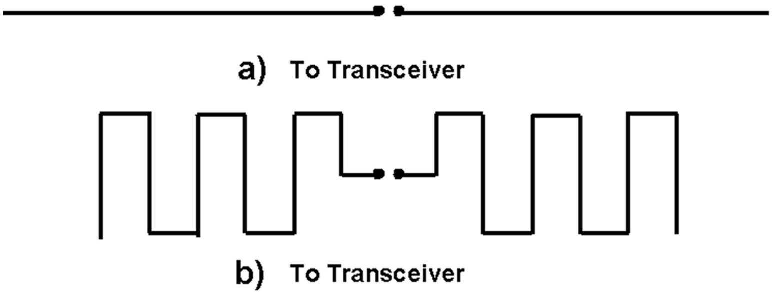
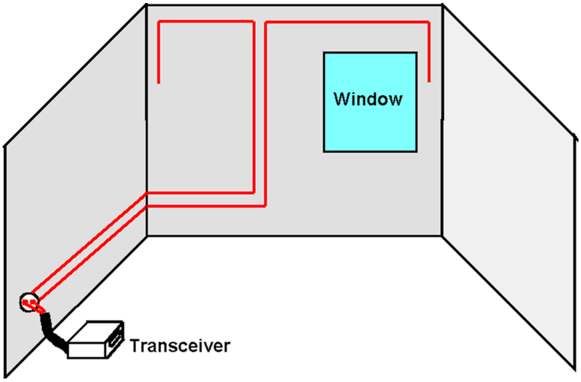


Fig. 1.21 Symmetrical invisible wall-mounted antenna with a two-wire feeding line

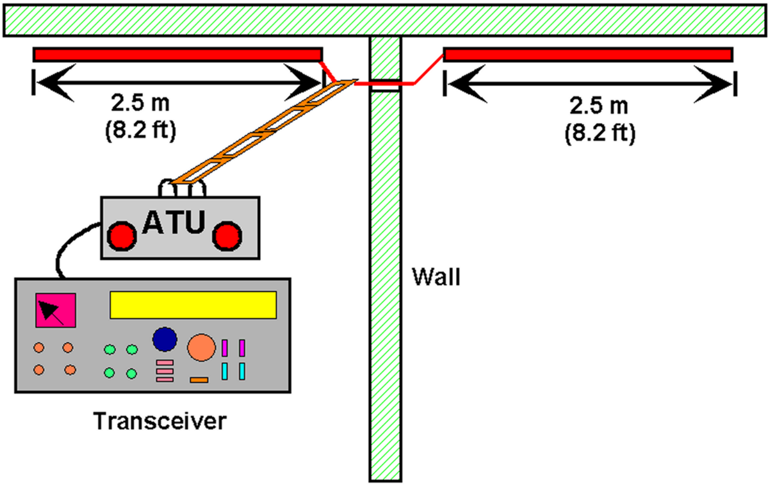


This antenna, in the form of glued wallpaper painted a matching color, and having leads disguised under the false AC socket, is really invisible and allows amateur operation from places where the installation of a visible outdoor antenna is prohibited. But, it is essential to resolve any interference problems one would expect from such an antenna in the area immediately adjacent to it. It is best these problems are resolved at the time of initial installation.

Eaves Antennas

In wooden and brick buildings it is quite possible to use the eaves of the structure to enclose an invisible antenna. Most construction materials and practices do not drastically hinder this antenna's performance. One of the simplest, and most efficient substitute, or invisible antennas, is a "symmetrical substitute eave antenna" fed with an open feeder line.

Fig. 1.22 Eaves Antenna



Two metal eaves of approximately 2.5 meters long may be fed with an open wire line of 300-600 ohms. This allows the use of standard twisted wire cables or homemade transmission lines made from inexpensive telephone twisted cable. Such antennas work well on 6 to 15 meters—fairly well on 17 and 20 meters—only modestly well on 30 and 40 meters. This type of antenna requires an antenna tuner.

If, however, the antenna needs only to be configured for a single band, one can feed it with coax cable. To tune the antenna to resonance using pigtails, hook them to opposite ends of the eaves (**Fig. 1.23**). Using loading coils, one can tune such an antenna to resonance for operation on 80 and 160 meters. To accomplish this, string a wire along several eaves (**see Fig. 1.24**) and use a steam water pipe line, cold water pipe or some other similar type of ground.

Fig. 1.23 Eaves antenna tuned to resonance

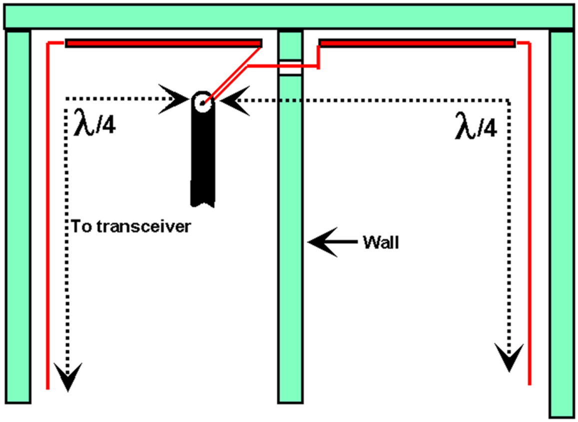
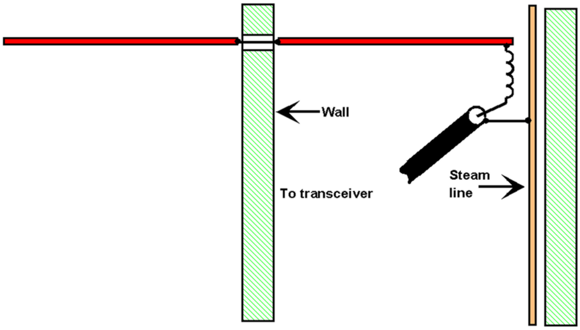


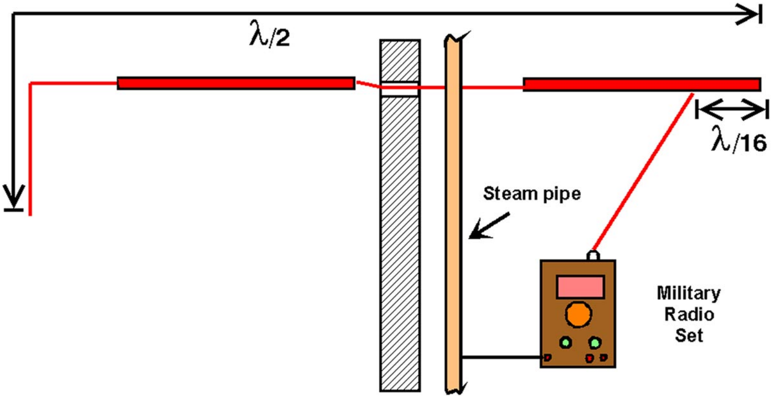
Fig. 1.24 Eaves antenna for low HF ranges



This creates an asymmetrical horizontal antenna. By changing coils or tuning the inductance of the coils, one can operate other HF bands. For a good quality of antenna “ground”, make use of the building’s water or heating pipes. This helps reduce the interference problems of TVI and RFI in the area.

When operating the antenna using a transmitter with high impedance output (such as some surplus tube transmitters) it is best to use an eaves antenna of the WINDOM type (**Fig. 1.25**). Grounding is essential for the best antenna performance. Again, in most circumstances a water pipe or the heating system makes a good ground.

Fig. 1.25 Eaves antenna – The WINDOM



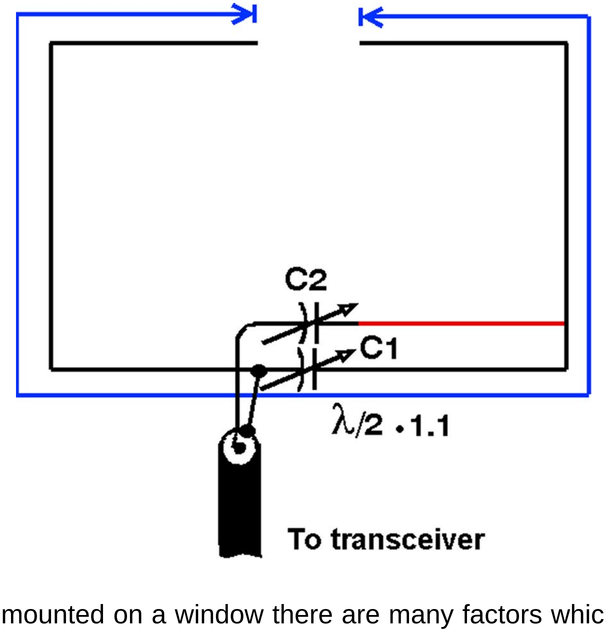
Using a wire antenna of a large diameter under the eaves gives greater bandwidth and is easier to set up than a thin wire antenna. You should not operate this type of antenna at high power because of potential RFI and TVI. Though grounding is generally essential, use of symmetrical antennas may allow good performance without a ground.

The eaves antennas are part of a class of antennas referred to as “invisible substitute antennas”. They are inexpensive and easy to construct and use common materials. The least desirable part of installing these antennas is drilling a hole in the wall. Make this hole at the height of eaves. If this is not possible, run the feed wire though a window to reach the radio room, but this method is less desirable.

Invisible Antenna for Upper HF Ranges

An invisible antenna can be designed that is easily installed, tuned and tested for use in the upper HF ranges. Such a design is simple to tune with either a 50 or 75-ohm coaxial cable. The use of the gamma match will allow the matching of either 50 or 75 ohm coax to the antenna. **Fig. 1.26** shows the circuit for just such an antenna design. The antenna represents a shortened dipole of about 1/2 wavelength. Capacitor C1 tunes this shortened dipole to resonance. The antenna schematic shows how to install an antenna of a fixed length and how to tune up the antenna to resonance. If the installation is planned for a building that contains steel reinforcement within the walls, it is important to remember that the metal will influence the tuning. The same applies to metal windowsills and heating radiators all of which will change the resonant point of the antenna.

Fig. 1.26 A window invisible antenna

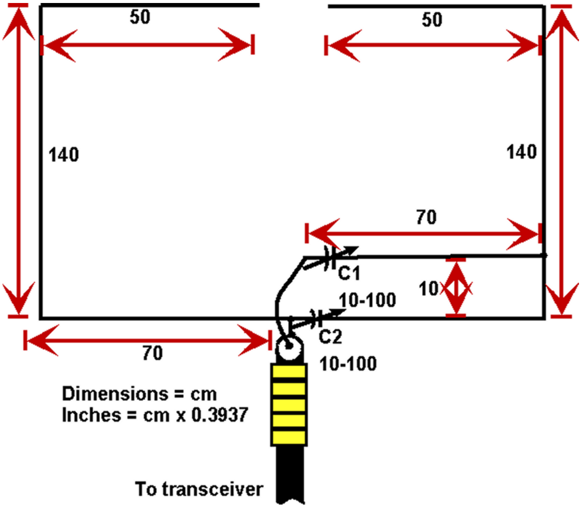


Capacitor C2 is adjusted for minimum SWR. An RF bridge is recommended for tuning accuracy. When the antenna is inductive, the length of the gamma match is shortened, if the antenna is capacitive, then the gamma match is lengthened. The dimensions of the gamma match shown here is for 50-ohm coax.

The tuning capacitors C1 and C2 are soldered to a printed circuit board in a box and mounted under the windowsill. The dipole is a symmetrical antenna, but when mounted on a window there are many factors which destroy the symmetry of the antenna. This poses no big problem. Installing five ferrite toroids decouples the coax cable. Each toroid is just big enough to slide over the coax cable and can be secured in place with Scotch tape. The antenna was made from a flexible multi-conductor plastic insulated copper wire with a diameter of 1 mm.

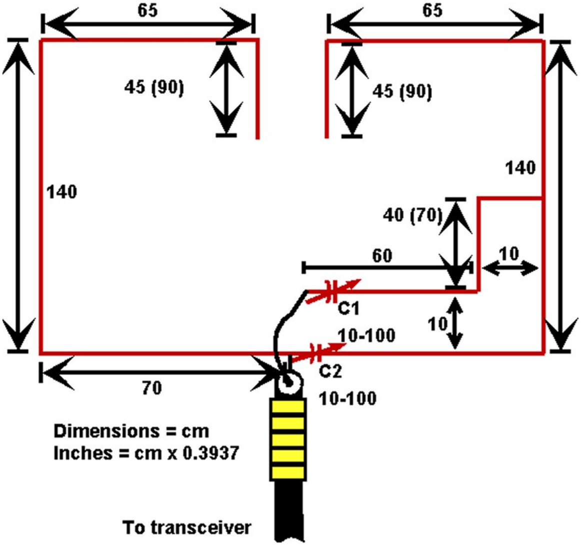
Let's consider some practical construction aspects of these antennas. The construction of an antenna for operation on the 28 MHz band is shown in **Fig. 1.27**. This antenna was designed for a window that is 140 cm by 150 cm. The exact dimensions are shown in **Fig. 1.27**. It is easily tuned for resonance on the 10-meter band by adjusting C1 and the antenna is matched to 50-ohm coax by adjusting capacitor C2 to an SWR less than 1.5:1 within the 28-29 MHz range.

Fig. 1.27 Window invisible antenna for a range of 10 meters



Dimensions for 21 and 24 MHz are shown in **Fig. 1.28**. The window dimensions are 140x150 cm. The dimensions shown in brackets are for the 21 MHz range. By construction of the antenna exactly according to the given dimensions will allow the antenna to be easily tuned to resonance in both bands, 21/24 MHz, and it can be matched to 50-ohm cable. The SWR is under 1.4 on both bands.

Fig. 1.28 Window invisible antenna for ranges 12 and 15 meters



Experiments were conducted with the objective of making a dual band antenna.

Experiments were done to determine the feasibility for modification of a single-band window antenna to become a dual-band antenna. To make this work, lengths of wire connected to the antenna by alligator clips are used to extend the antenna. A compromise length of 120 cm is used for the overall length of the gamma match. The problem with this dual-band antenna configuration is that the additional wires must be removed or added back for the band changes. The gamma match also has to be retuned for each band change. The wire extensions should be held up with nylon cord. The antennas for the bands of 28, 24 and 21 MHz were designed for a window of 140x150 cm but larger windows can be used. The main concern in installing antennas of this type is symmetry of construction.

With larger windows, one can make antennas for lower bands. The antenna for 18 and 14 MHz were built in a 140x210 cm window and the dimensions are detailed in **Fig. 1.29**. The dimensions shown in brackets are for the 14 MHz band.

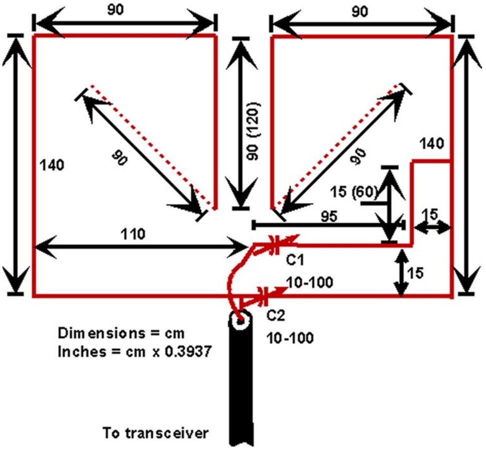


Fig. 1.29 Window invisible antenna for ranges 17 and 20 meters

The construction of an antenna for 14 and 18 MHz does not differ from construction of an antenna on the higher bands and again, a nylon cord is used to hold up the antenna extensions. In all cases, insulators are not used in the construction of these antennas. SWR on 14 and 18 MHz in my installation was not worse than 1.3:1.

Comparison testing of these antennas was made against a dipole on the roof situated so the main directional lobes of the dipole were orientated in the same direction as the window antenna. It was determined that the window antenna ws 1to 2 S units below the reference antenna on 14 MHz and 1 S unit below on other ranges. The reference dipole was mounted 4 meters above the roof. The window antenna was on the 6th floor of a 9-floor apartment building. The invisible antenna had a main lobe in the direction away from the building and almost no radiation in the direction toward the insides of the building. When powering 50 watts into the antenna, there was strong TVI and RFI in the area around the antenna. The capacitors C1 and C2 are both air dielectric with a clearance of 0.5 mm between plates. On the 14 and 18 MHz bands a fixed 68pF capacitor was bridged acrossed the variable capacitors.

Magnetic Window Antenna

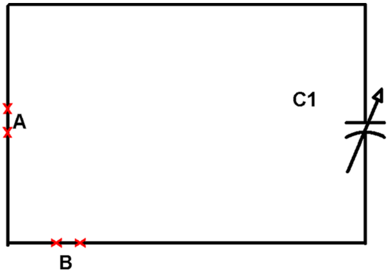
The size of a standard window opening can allow for placement of a magnetic antenna for operating on three bands: 160, 80 and 40 meters. The difficulty comes in making a satisfactory match for operation on all three of those bands. Depending on the construction, the imput impedance on all three bands will vary.

For greatest efficiency, the magnetic antenna is usually fed in its geometrical center of the antenna (**Fig. 1.30**) at points “A”. This is not an opimum matching method and should not be used unless there is no other choice. If the feedpoint is at point “A”, the optimum matching by simple methods will only work on one band, thus a transmitter or gamma-matching network usually handles the matching problem. Best results are obtained by using transformers with ratios of 4:1 and 9:1. In this case, this permits the optimum matching of the higher impedance of the coaxial cable to the lower feed point impedance of a magnetic loop. When changing bands, the matching will no longer be optimized on the new band. For transmisson, additional tuning is required of the matching network for satisfactory operation. But, the construction of broadband transformers with the ratios of 4:1 and 9:1 is difficult when high efficiency is desired.

My experiments have shown that by feeding the side of a magnetic loop antenna at point “B” (**Fig. 1.30**) through a simple broadband transformer with a ratio of 1:1, it will be able to obtain satisfactory matching in three adjacent ranges of operation. These broadband transformers are simple to build.

Many may argue the theoretical considerations of this configuration from different points of view and suggest different reasons why this will or won’t work. But, for radio amateur purposes, it is quite feasible to realize the real results and not worry about the theoretical disputes of this concept.

Fig. 1.30 Window magnetic antenna



The magenetic antenna made from the dimensions shown in **Fig. 1.31** has been tested. The antenna was fed with a handwound transformer using the ferrite yoke from the horizontal deflection transformer of a color TV set as the core which had an approximate permeability of 600. The transformer is shown in **Fig. 1.32**. The primary winding is 12 turns of the antenna wire. The antenna was made from multi-conductor copper wire about 1.5 mm diameter. The secondary winding was made from 12 turns of center conductor from a length of coaxial cable, with the braid removed. Electrical tape was used to hold the wires in place.

Fig. 1.31 Window magnetic antenna with side power supply

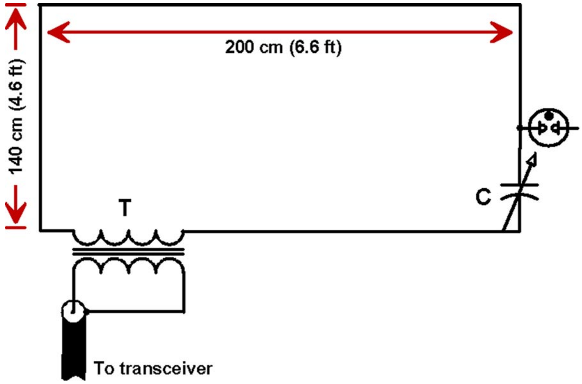
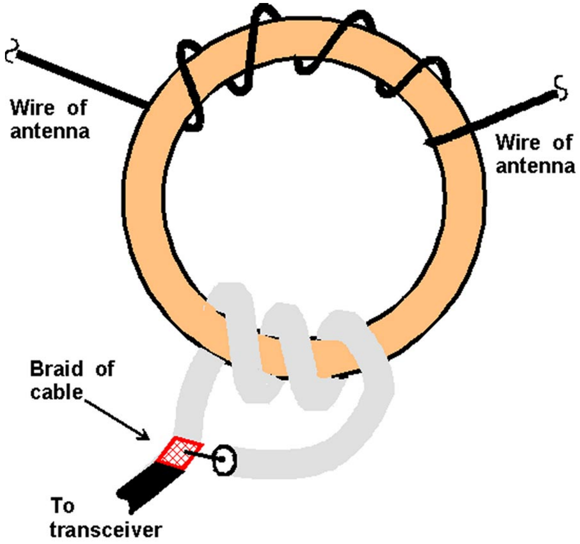


Fig. 1.32 Transformer for window magnetic antenna



The transformer is set on one end of the windowsill and the antenna tuning capacitor on the other. The capacitor should be placed on an insulated base. It is also desirable to use an insulated tuning stick, such as the plastic barrel from a pen on the shaft, to eliminate the effect of body capacity when you tune the antenna. I used a variable capacitor from a school physics lab. Such capacitors can be bought cheaply from catalogs. These capacitors have a clearance of more than 2 mm and they work perfectly at the high voltages found on magnetic antennas. In **Table 1.3**, the capacitance values for the tuning of the antenna on different ranges of operation are shown.

Table 1.3 Data of a variable capacitor of a magnetic window antenna

Band (m)	Freq (MHz)	Capacity C (pF)
160	1.9	330
80	3.6	180
40	7.05	20

Since the maximum capacity of the school capacitor given to me was 200 picrofarads, in order to operate on 160 meters, another capacitor had to be bridged in parallel with clip-on leads. To tune the antenna to resonance, one end of a neon bulb was clipped to the variable capacitor and would light up with increased brilliance at resonance. The SWR with 75-ohm coax feedline was no higher than 2:1 on all bands. The antenna can handle up to 200 watts with the components used.

As expected, the antenna generates a significant amount of TVI in nearby televisions, but aside from that concern, this antenna can be considered in the class of invisible antennas. The wire on the window frame is practically invisible and the transformer and capacitor can be hidden behind curtains or covered with a cardboard box.

The directional pattern of this antenna depends on the layout of the room and other building characteristics. Experiments will need to be made to make this determination.

The antenna will have a high angle of radiation which will enable short path QSOs to take place at distances up to 1000 km. When the antenna is installed on upper floors of apartment buildings, DX QSOs are very possible as there are no side lobes from this antenna.

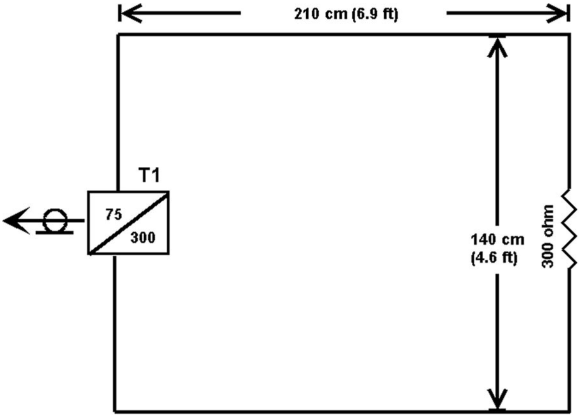
When this antenna was compared to a long wire of 41 meters, the magnetic antenna was 3-5 S units down in signal strength from the LW. Since the antenna is contained inside a room, it cannot be damaged by the weather or vandalized. This antenna can be used as a backup antenna when the main antenna is damaged and unusable.

All-Band Invisible Antenna

In a radio amateur installation, it may be desirable to have some sort of substitute antenna for operating on all bands. Such can be provided by an invisible antenna. The added protection from weather and other factors that might damage an outdoor antenna are also a plus. Additionally, these substitute antennas can be inexpensive, quickly constructed, easily installed and tuned, unlike most outdoor antennas.

From experience I have found it possible to create such antenna! An example of such an all-band invisible antenna is shown in **Fig. 1.33.**

Fig.1.33. All-band invisible antenna



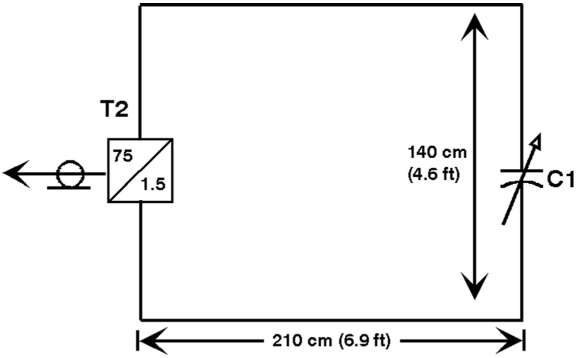
This antenna is constructed with an insulated conductor 1 mm in diameter and mounted on the perimeter of the window. On the one end of the loop is a loading resistor of 300 ohms. On the other end is the feed, which through the broadband transformer of 75/300 ohms is connected to the transceiver. Such a configuration is basically a version of a short ***Beverage*** antenna. In this practical construction approach, it is best to use a load resistance of 300 ohms. It will help lower the voltage on the antenna, which in turn will lower interference to audio and video equipment. With a load of 300 ohms, the construction of the broadband transformer will be easier than one for a load of 600 ohms.

Despite of the apparent ease of construction, this antenna works quite effectively. The antenna efficiency for this antenna is practically equal to the relation of power acting on its input and powers dispersed by the load. Built as described, the antenna efficiency is shown to be 2-3 % on 1.9 MHz, 4 % on 3.5 MHz, 8 % on 7-10 MHz, 12 % on 14 MHz, 14 % on 18-24 MHz and 20 % on 28 MHz. The basic antenna radiates at high angles to the horizon, which is good for short-path QSO. In practice it was discovered that the antenna does indeed work well for long-distance and short-distance QSOs in the upper HF ranges and short-distance QSOs in low HF amateur ranges. When the more distant station was several hundreds kilometers away, the reported signal was 59. At the same time, a close 5-10 kilometer station reported a weak signal intensity of S3-S4.

As ranges are changed there is no need to modify the antenna setup which allows the antenna to work well using a transceiver with 50-ohm output. Spanning more than one window, which lengthens it, can boost the efficiency of this Beverage mini-antenna. As antenna efficiency in the ranges of 1.9-7 MHz is rather small, an attempt was then made to improve it. For this purpose, the wire loop used for a

Beverage antenna was switched to become a magnetic antenna as shown in **Fig. 1.34.**

Fig. 1.34. An invisible magnetic antenna



Capacities needed for resonance frequency are shown in **Table 1.4**

Table 1.4. Capacity of the antenna capacitor for operation in different ranges

Band (m)	Freq (MHz)	Capacity C (pF)
160	1.95	350
80	3.65	200
40	7.05	25

Though, theoretically, such an antenna should also work more effectively than a Beverage antenna, in practice during the construction of the magnetic antenna it was necessary to overcome some difficulties.

For magnetic loop antennas, establishing a correct matching is one of the hard parts. In this particular case it was necessary to use the broadband transformer of 75/1.5 ohms, which is not optimum for all ranges of operation of an antenna, both on design execution, and under the relative matching of resistances. There were complexities with application of the capacitor tuning, because the air capacitor with a large clearance between plates was necessary.

Under comparison testing of a Beverage antenna and magnet antenna it was found that the magnetic loop antenna achieved a level of 2-3 S units as contrasted to the Beverage antenna. Some problems to expect when operating a magnetice loop is that while changing bands you must retune. When doing this, there will be a great amount of interference with other nearby electronic equipment.

Let’s consider construction of transformers for this antenna and a switching device. The practical implementation of the 75 to 300-ohm transformer has been repeatedly described in avaliable literature. For this particular antenna, a homebrew transformer was made from 20x3x115 mm size ferrite plates with a permeability of 600. These plates can be slavaged from an old receiver or they may be purchased separately. They are commonly found as ferrite antennas in transistor receivers but are widely sold if they cannot be salvaged. The transformer is made from eight plates, which are held together by glue or silicone sealer (**Fig. 1.35**).

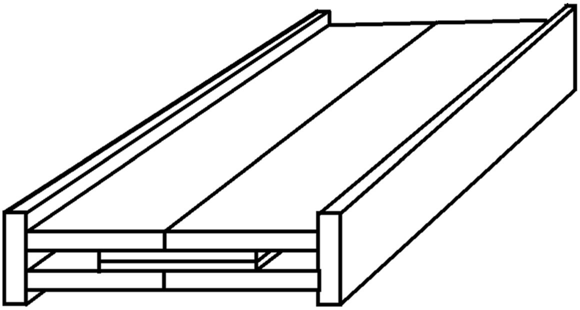
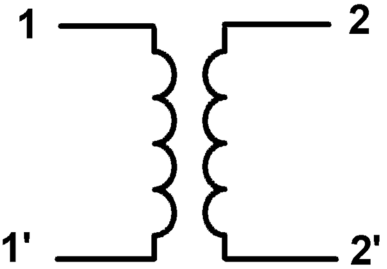


Fig. 1.35 Construction of the core of the transformer of an invisible antenna.

The schematic of the transformer is shown in a **Fig.1.36a.** The winding of the transformer is made from two coils wound with wire of 1 mm diameter 1mm with plastic or Teflon insulation (**Fig. 1.36b**). The connections of the windings are shown in **Fig. 1.36c**.

Fig.1.36a The transformer for this invisible antenna



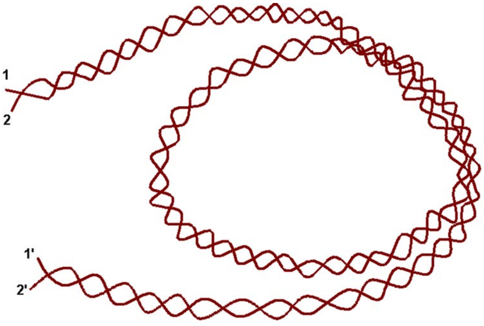
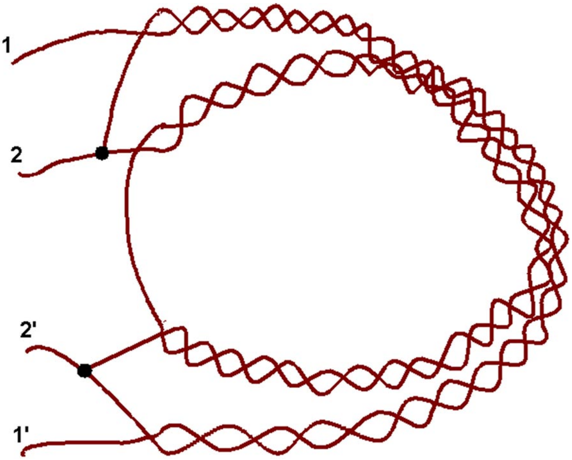


Fig. 1.36b A Coil for the transformer



Fug. 1.36c Coil for the transformer showing connections

This is a classic matching RF transformer with a 1 to 2 turns ratio and a 1 to 4-impedance ratio. The first winding will be a stepup winding of 300 ohms. The second winding on center is cut and the test leads are soldered accordingly to each other for making a single-turn loop. Thus, the secondary winding of the matching on 300 ohms contains 2 turns and the primary winding of the matching on 75 ohms contains 1 turn.

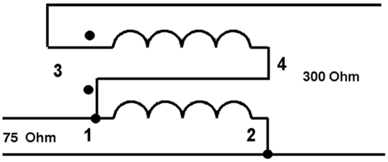
When measured, the transformer works without a waveform distortion up to 200 watts of power. Table 1.5 illustrates the efficiency of the transformer. As can be seen, this transformer is most effective in the upper parts of the HF amateur range. Usage of the magnetic loop in ranges of 1.9-7 MHz is quite reasonable.

Table 1.5 Antenna factor of transformer of 75/300 Ohms

Band (MHz)	1.9	3.5	7.0	10	14	18	21	24	29
Eff’y (%)	51	62	63	75	75	78	80	85	90

For power levels up to 25 watts it is feasible to make a simplified matching transformer. Its schematic is shown in **Fig. 1.37**. It contains 10 turns of two wires of 0.5mm diameter each winded together (1 winding on 1 cm) and spooled uniformly on a length of a ferrite plate with a permeability of 600 and dimensions of 20x3x115 mm. Before winding the ferrite, it is necessary to wrap the plate with Scotch tape to prevent arcing of the winding near the edges. SWR of the antenna using the transformer with 8 ferrite plates is not worse than 1.5 in all bands of operation. With the transformer using one ferrite plate, the SWR reached 3:1 on 30 MHz, 2.5 on 7 MHz and not worse than 1.5 on 1.9-3.5 MHz.

Fig.1.37 Simplified construction of transformer of 75/300 ohms



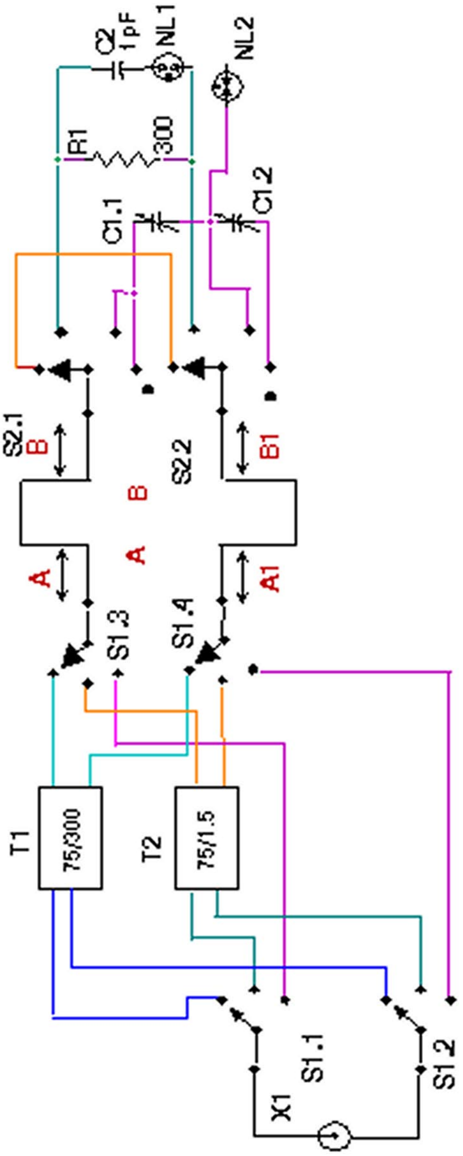
The transformer of 75/1.5 ohms was made on the ferrite core structurally similar to the one that the transformer of 75/300 ohms (**Fig. 1.35**) was made. But this transformer contained 4 coils consisting of flexible 1 mm copper wires with plastic insulation. Thus, one wire winding was a primary winding of 75 ohms, and the second wire in the center was cut and soldered with appropriate end leads as shown in **Fig. 1.36**. As it is shown, the primary winding contains 4 turns and a secondary winding (1.5 ohms) of 1 turn. It must be understood that although this transformer will match 75/ 1.5 ohms, it will not be optimum for a magnetic loop antenna.

This transformer works satisfactorily in the frequency range of 1.9-7 MHz. In that range, SWR was not worse than 2.5, and with the help of a tuner installed immediately adjacent to the antenna, the SWR can be reduced to 1:1.

It is difficult to estimate the antenna efficiency of the transformer and magnetic loop system on these ranges. In the low HF amateur bands from 1.9-7 MHz, the vertical angle of radiation of a Beverage antenna and the magnetic loop antenna are almost identical. A comparison was made between a Beverage and a magnetic loop antenna for both SWR and signal strength. It was concluded that the antenna efficiency of the magnetic loop antenna is higher.

This magnetic antenna system does not require use of balancing devices nor does it need to be grounded. The common grounding must be limited to the transceiver. The full diagram of the antenna system is shown in **Fig. 1.38**.

Fig.1.38 Principal diagram of an invisible window antenna



As you can see from the schematic, S1 changes the input matching between 75/300, 75/1.5 and direct. Switch S2 changes from resistive to capacitive termination for switching operating mode as a Beverage antenna or magnetic loop antenna. Also, switch S2 provides the option of closed or open positions on the end of the loop. It was done by me for any experimenters with the loop. Many other options may be experimented with on the S1 and S2 switch!

With an antenna tuner one can either short the terminating end of the loop or leave it open as allowed by S2.

With switch S.1 in position 2, the 75/1.5-ohm transformer is in place and with S2 in position 3, a capacitive termination is set up. In this position, operation on 1.9-7 MHz is possible. It may be necessary to increase the capacity of a variable capacitor to achieve resonance on a range 1.9 MHz.

Neon bulb, NL1 is used to show resonant tuning when operating as a Beverage antenna and NL2 shows resonance in the magnetic antenna mode and if not lighted during the transmission mode, it indicates that the tuning capacitor is broken down. The NL2 light indicator is to help ensure that the variable capacitor does not break down during tuning to resonance.

The switching circuits were assembled in boxes made from printed circuit board material soldered together and located approximately 80 cm from the center of the symetrical antenna “A” and “B”. In this case, it is important only that conductors A, A1, B and B1 are of identical length. To keep the antenna invisible, you can mount the switching devices below the windowsill.

The capacitor should have a large dielectric turning knob for reduction of hand capacity effect when tuning the antenna. The copper of the switching box with S2 is not grounded. The 300-ohm load for the Beverage antenna can be made from a number of 2-watt resistors.

The copper of the switching box with S.1 is grounded to the exterior braiding of the coaxial cable.

Though this antenna is not the best for those exotic DX QSOs, it will always support operations in the event of a main antenna failure. Keep in mind that the radiation pattern is not exactly the same for the magnetic antenna mode as for the Beverage antenna. This can be used to an advantage in selecting or rejecting a signal by switching between modes.

Invisible Substitute – The DDRR Antenna

In urban surroundings, the DDRR antenna may be installed on a balcony. The antenna described here is built using the balcony rail as a ground surface and the antenna’s wire is mounted above it. The length of the antenna’s wire should be at least 0.2λ. The metal railings of the balcony should be grounded to the building’s electrical ground. This improves the overall performance of a DDRR antenna and helps make the antenna electrically safe.

The multi-conductor wire of an antenna can be best be made from a thick coaxial cable. As the perimeter of modern balconies reach from 3.5 to 12 meters, one can install an antenna to operate from 6 to 40 meters. The schematic of a balcony DDRR antenna is shown in **Fig. 1.39.**

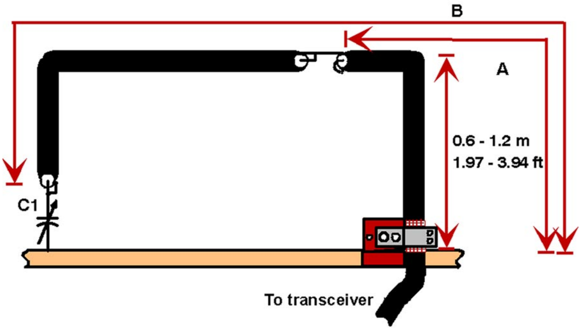


Fig. 1.39 A balcony DDRR antenna

The clamp ensures reliable contact to the braiding of the coaxial cable at the antenna base. Through the second clamp a reliable contact to the metal balcony is ensured. The clamps are connected together. The DDRR antenna is usually fed through a coaxial cable by shunt feed. It is known that the shunt very slightly reduces radiation of the antenna. To reduce this loss, the transmitter power can be fed to the antenna through a coaxial cable as shown in **Fig. 1.39**. Another advantage to this method of feeding the antennas is that it reduces induction components in the input impedance.

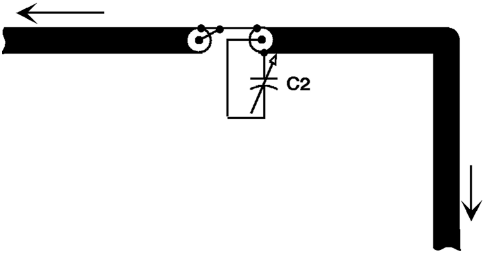
For proper feeding of the antenna it is necessary to carefully to select distance “A” (**Fig. 1.39**) for minimum SWR. In **Table 1.6** examples of distance “A” are shown where matching with a 50-ohm coaxial cable is theoretically possible if the antenna is installed at the height of 1 meter above the ground plane. At the real antenna installation it will be necessary to experiment and locate the proper distance of the coax. The location for the connection of the coax center conductor can be determined by measuring from the antenna base.

Table 1.6 Data for shunt feeding of a DDRR antenna

Band(m)	A(m)	B(m)	C1(pF)	C2(pF)
40	1.2	7.5	450	100
40	1.0	5.0	450	200
30	1.0	5.0	300	100
30	0.7	4.0	300	150
20	0.7	4.0	250	100
20	0.6	3.0	250	150
17	0.5	3.0	200	100

If the SWR is greater than 2:1, when using the dimension “A” from **Table 1.6**, you can remove the outer plastic insulation on a length “A” and shorten the inner conductor to another point on the braid to achieve minimum SWR. A modified version of the matching capacitor type can be used as shown in **Fig. 1.40**. This matching is less effective than a simple connection of the center conductor of a cable to the braided wire of the antenna. The maximum capacity of a tuning capacitor for different frequencies of the antenna operation is shown in **Table 1.6**. Capacity of the end capacitor of a DDRR antenna (**Fig. 1.39**) can be 2-3 times less than capacity of this matching capacitor.

Fig. 1.40 Tuning of the shunt of a DDRR antenna by a capacitor



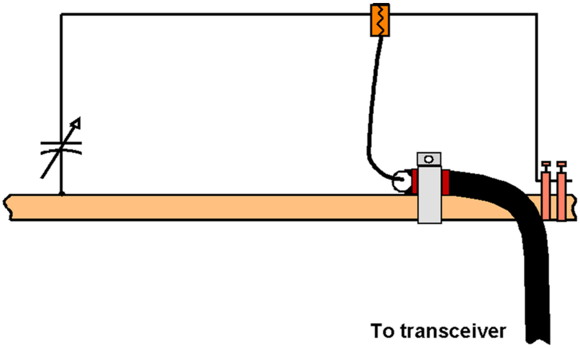
The tuning of the antenna to resonance is done at its end capacitor. Even with only 10 watts fed to the antenna, the voltage on this capacitor can be as high 1000 volts. The capacitor should be of excellent quality and the tuning of this capacitor should be made safely accessible, therefore be sure to use an insulated shaft and knob. The variable matching capacitor C2 does not need tuning once set up and may be changed to a fixed capacitor after the antenna is properly configured.

When installed on a high balcony, this antenna cannot be seen from the street and therefore is considered an invisible substitute antenna. Although it may not perform as well as a full-size antenna, the balcony antenna does make an excellent substitute antenna when choices are limited. The DDRR antenna is a mono-band antenna, but by reducing the value of capacitor C1 the antenna will be able work on ranges where its lenght is not more than 0.12λ when compared to the antenna wire of the DDRR. On the band within 0.12λ, performance of this antenna will be poor.

A multiband antenna is shown in **Fig. 1.4**1. The antenna is made from a thick aluminum wire 6 to 12 mm in diameter. A length of copper tube may be used also. The wire is clamped to the balcony rail at one end with two clamps. If the rail is not too large, then brass clamps may be used of the type for making ground wire connections to water pipes. The cable braid connects electrically to the balcony rail with the help of the clamp. Other methods can be used to provide reliable electrical contact to the rail.

The feed point connects to the antenna using a large “alligator clip” to allow easy adjustment for minimum SWR. The installation of the antenna on a balcony makes it easily accessible to adjust for optimum matching and tuning of the antenna by adjusting the variable capacitor and feed point.

Fig. 1.41 A multi-frequency band DDRR antenna



Invisible Antenna Using a Steam Heating System

Many apartment buildings have a steam heating system throughout the building. These pipes can be used as a good substitute invisible antenna for an amateur radio station.

The antenna is simple to make. Drill two holes through the wall so you can connect two heating pipes together with short jumpers and clamps (**Fig. 1.42**). To electrically split the pipe at the feed point, chokes are constructed on sections AB and A1B1. Three sections of ferrite chokes are made on each pipe by wrapping the pipe with five sections of ferrite bar (**Fig. 1.43**). The bars have a permeability of 600 and measure 20 by 3 by 115 mm. The bars are primarily used for the manufacture of ferrite antennas in handheld transistor radio receivers. These ferrites are inexpensive and can be bought from catalogues.

First, wrap the pipe with medical cloth tape and then attach the ferrite with more tape. Wrap each choke with cotton cord (diameter 3-6 mm) to hold them in position when the pipes are heated, because tape with not ahere to the pipes when heated. The electrical connection to heating pipes can be made with a clamp.

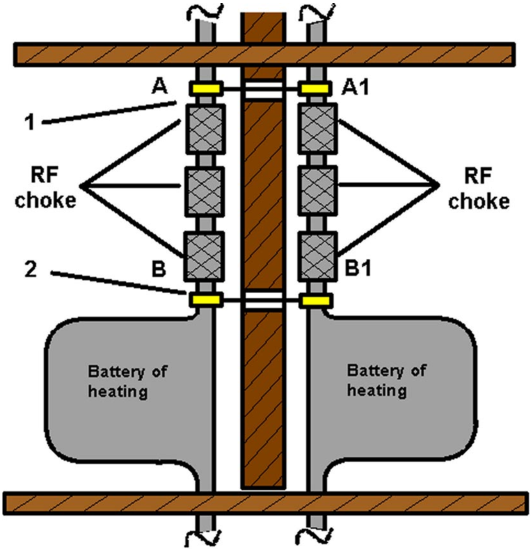
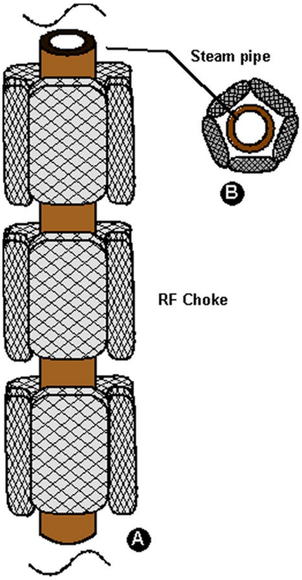


Fig. 1.42 Invisible antenna on the basis of batteries of heating

Fig. 1.43 Choke of an invisible antenna



When the chokes are finished, connect a high-frequency bridge to the pipes at points 1 and 2 (**Fig. 1.42**) and measure the impedance at frequencies of interest. This is done determine whether the resonance of this antenna system falls within a radio amateur band. I have made several antennas of this type and have never seen the resonance of the system within an amateur band at first try.

For operation of this antenna it is necessary to use a matching network for feeding. Connect to points 1 and 2 with two short conductors to the matching network and feed the matching network with a small length of coax, or about 5 to 10 meters from the transceiver.

This type of antenna usually has some self-resonances on different frequencies. One will need to measure the resonance frequencies and passband of the antenna on those frequencies.

The bandwidth increases as the Q drops, but this also means a loss of effeciency. Though we cannot reduce these losses, to be able to estimate them would be useful to determine the antenna effciency to know the level of power needed for amateur operation. In my case, the passband of the antenna was 300 kHz on the lower bands and reached several megaherz above 10 MHz. The input impedance at the resonant frequencies for the antenna was in the 30 to 100-ohm range. Above 25 MHz, the antenna was useless. In this range, the metal pipes cause a broadband resistive load. It demonstrates the amount of large losses of RF power present in this type of substitute antenna system.

From my observations, the overall performance of this antenna is identical in ferro-concrete buildings and brick buildings. At any rate there seems to be no large variance in the estimated signal strength in different types of buildings. A drawback with this antenna system is the presence of a great amount of interference to and from electronic equipment such as radios and televisions. Because of this, the best time to use this antenna is very late at night when most people are asleep and their radios and televisions are turned off. Also the refrigerator and other appliances (even far from the transceiver) will most likely cause reception interference. But, signal reports with this antenna were only 3 to 6 S units below a 41-meter long wire antenna.

Do not drive this antenna with more than 100 watts because of the possibility of a burn when touching the heating system from RF voltages. By making the chokes a matching color, or if the pipes are hidden with furniture or shutters, this antenna can be made unobtrusive and is another antenna option in the invisible antenna class.

Invisible Radar antenna under sphere

CHAPTER 2: HIGH-ALTITUDE INVISIBLE ANTENNAS

We shall consider antennas suspended at a height of more than 10 meters above ground, made using wire so thin that they seem to be “invisible” to any casual unaware spectator, as High-Altitude Invisible Antennas (HAIA). These types of antennas are the ones that are most frequently thought to be the simplest invisible antennas. The expense of the materials used, consisting of very thin wire and small-sized antenna insulators, is very small for such antennas. They are practically invisible from ground level, from lower floors, and even from adjacent floors of those buildings where they are mounted. They are literally out of sight!

Constructions of high-altitude invisible antennas

An antenna such as “Windom” can be suspended high in the air between two buildings (see **Fig. 2.1**) and fed with a single-wire line. By careful selection of the length of the antenna, it can be used to work on several amateur frequency bands or ranges of frequencies. Another simple HAIA, such as a long wire (LW) antenna is shown in (**Fig. 2.2**). Such an antenna can be matched to work on practically any amateur band, or range, by using an impedance matching unit such as a “transmatch”. Usually, the length of wire needed to feed the transmitter can be 82, 41, or 21-meters long. But, the antenna can still be made to work well using other lengths.

Fig. 2.1 An invisible “Windom” antenna

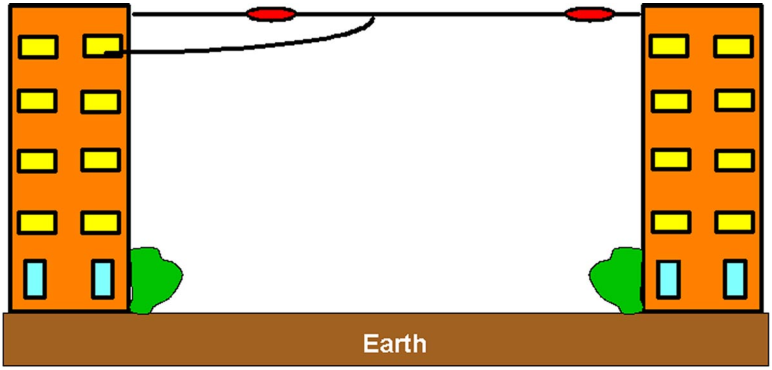
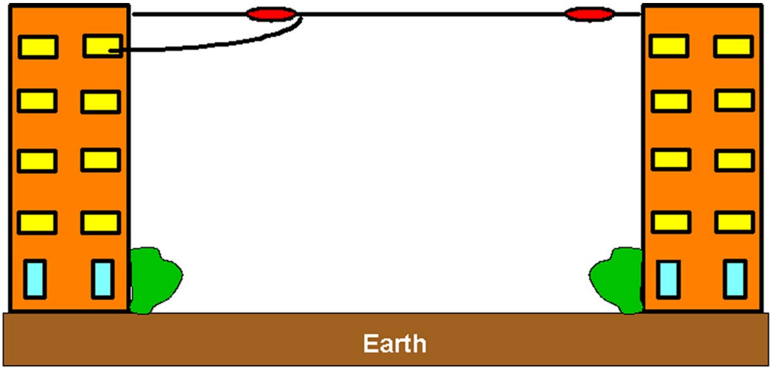
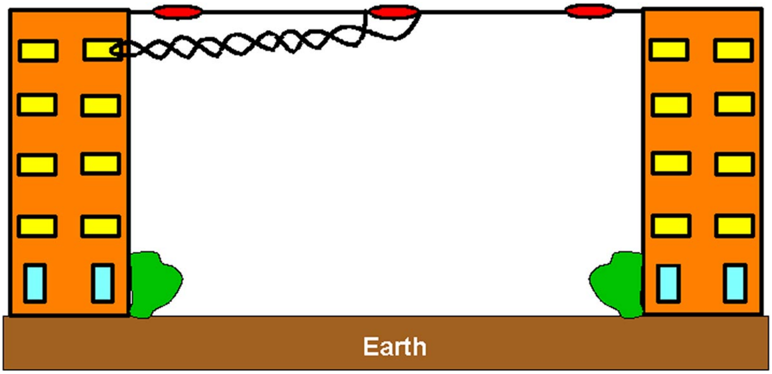


Fig. 2.2 An invisible LW antenna



It is quite possible to use single-band half-wave dipole antennas having an impedance input near 75 ohms (**Fig. 2.3**). Such antennas can be fed through a twisted-pair type of telephone line. This wire can be easily dispensed from spools during installation. But, if it is not possible to get some twisted-pair telephone wire, then a pair of wires obtained from a telephone multi-pair cable, or even twisted electric lamp cord (zip cord) can be used as RF feed lines to the antenna.

Fig. 2.3. An invisible center-fed horizontal dipole antenna



The use of full-scale frame antennas is inconvenient when making HAIAs because of their small mechanical strength and their need to be supported by several guy-wires or lines. Using a frame antenna decreases the chances of the antenna being invisible. For this reason, rhombic antennas do not make good HAIAs. However, an “invisible” version of the Beverage antenna can usually be placed on a roof in such a way that it will not be visible from the ground level.

It is frequently possible to suspend a HAIA between two high points in tall trees, or between high points of adjacent buildings, or on an “ L-shaped” building as shown in (**Fig. 2.4a**). One can also install a sloped antenna (called a “sloper”) at a position between a high-rise building and a lower building in a manner shown in (**Fig. 2.4b**), having the ends of the antenna supported on a roof by any convenient means (even with the help of a weighted object). Such antennas can be used for any type of operation, but they can be especially useful during emergency operations when the main antennas are damaged by a storm and emergency communications are essential.

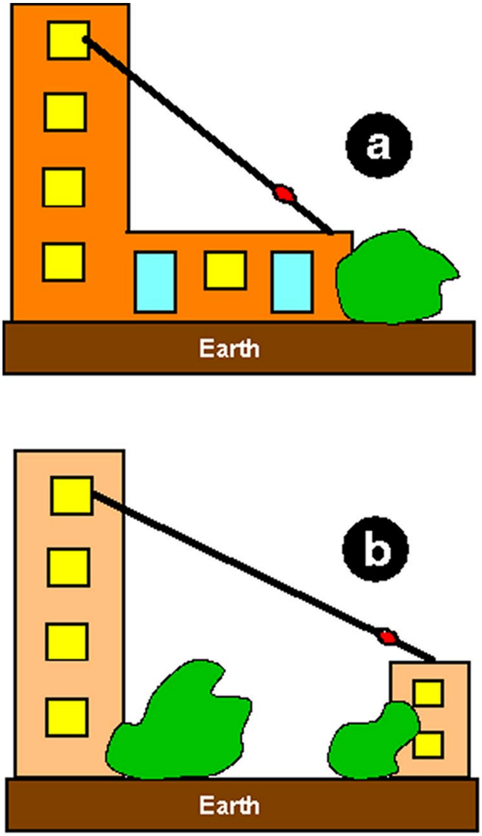


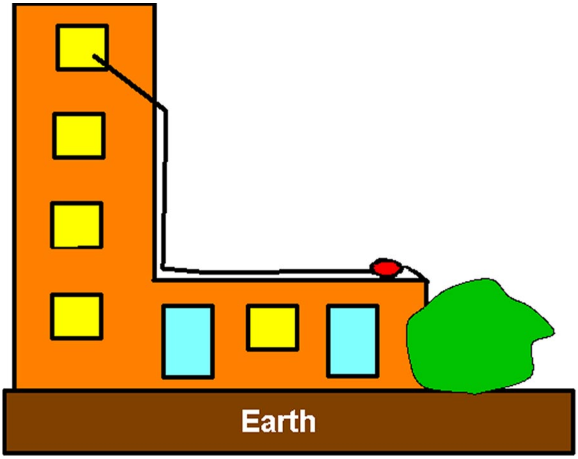
Fig. 2.4. An invisible sloper antenna

When a sloper antenna is to be put on a roof during emergency conditions, a length of the type of wire to be used to make the antenna elements should be kept handily stored on a spool, or reel. Then, some object, such as a small brick or rock weighing enough to be easily thrown onto a roof, is knotted to the end of the an antenna wire through an insulator and guy wires and, depending on the strength and skill of the radio amateur, it is thrown or slung on the roof of a nearby house. Once secured on top of the roof, the antenna is ready for operation.

Later, after signing off and closing down operation, the antenna can, if desirable, be considered disposable and left in place. Since the cost of a thin wire and a small weight is so minor, cost is just not a factor even if it becomes necessary to erect and abandon one of these invisible antennas every day. If any of the thin wires are left at the location, it will probably be considered as rubbish, and be swept-up as trash, without anyone having any suspicions about a transmitting antenna having recently operating there. Of primary concern though would be if the abandoned wire created a possible hazard to others. In such case, the wire should be removed to avoid causing the possibility of harm or accidents.

If there is an exit onto a roof of an L- shaped building, it may be convenient to operate such antenna on the air by attaching the wire onto a wall of the building (**Fig. 2.5**). A conductor mounted along a wall of a building is likely to go unnoticed. An antenna installed in this manner is also more stable in the event of strong winds.

Fig. 2.5. A folding invisible sloper antenna



A progressive wave (APW) is a very simple wideband antenna. It can be made from a strong wire having high electrical resistance. This type of wire, using varnished insulation, is sometimes used to make wire resistors or to make ballast-powered inductance coils for electro-technical devices. The APW antenna can be made according to **Fig. 2.2** from wires having a common pure resistance of 50-150 ohms. In the 1.8-30 MHz bands APW will have load impedances within 200-500 ohms (depending on the direct current resistance of the wire being used and on the frequency range of operations) with the antenna being matched over a broad band of operating frequencies. A simple broadband balun transformer of 1:4 or 1:6 can be used to feed this antenna from a transceiver with a 50-ohm final stage.

The operation of this antenna is similar to a Beverage antenna, but due to irrevocable losses with any lengths of this antenna, it is theoretically less effective than the Beverage antenna. However, I tested this APW antenna, and to my surprise it seemed to be a rather practical alternative. To increase the antenna efficiency, make the first part out of common copper wire, and the remaining part from the type of wire having high resistance.

Materials used to make a HAIA

To make a HAIA, enameled copper wire having a diameter of from 0.3-0.6 mm may be used. A smaller diameter wire has the advantage of being harder to spot from a distance over 10 meters, but has the disadvantage of being weak and likely to break. The larger diameter wire is stronger but it's easier to see. Because of the weakness of small diameter wire, it is difficult to build the invisible antenna shown in Fig. 2.1, Fig. 2.2, and Fig. 2.3 if the overall length is more than 50-meters.

The antenna shown in Fig. 2.4 can have lengths as long as 100-meters as determined primarily by its wind resistance. The wire of this type has a highly reflective varnish insulation, which strongly reflects sunshine thus possibly increasing the chances of being detected in sunny weather. If there is the slightest chance of spotting this antenna wire, then that will defeat the objective of making an invisible antenna.

During my experiences, I had very good results using a HAIA made from a German-made wire having a diameter of approximately 0.4 mm that has a sky-blue varnished insulation. When a coil of this electrical starting control wire was utilized the wire's blue color practically blended in with the sky's background. Upon disassembling different industrial electric starting controls, I found a selection of other colors besides sky-blue and varnished insulation such as red, green and gray. Unfortunately, I have not seen these different colored wires for sale yet on the open market. If these particular wires are mainly found in German electro-technical devices, one will have to search for a supply or use some other type of wire with similar colors.

The antenna insulators used in a HAIA should be strong and sufficiently invisible from a reasonable and suitable distance. After performing experiments with different types of homemade insulators, I realized that empty rods from ballpoint pens are a good approach for making insulators. A heated needle can burn holes in the edge of the rods where the wires can be fed and tightened at a spacing of 3-5 cm, as shown in Fig. 2.6. After burning, the hole has strong edges that are not easily cut by either an antenna or guy wire.

Fig. 2.6. Antenna insulators for a HAIA

Then there are gray or sky-blue rods (with ink removed) with thicker edges, which are much stronger mechanically.

The thick rods removed from gel pens are mechanically stronger than ballpoint pen rods, but because they are larger they have more wind resistance and they are certainly more visible. The thin-walled rods worked all right though.

I have made and tested insulators from Plexiglas, PC boards and other different types of plastic tubes. Nevertheless, the insulators I made from ballpoint pens rods have shown themselves to be best in actual operation.

Guys can be made from wires having a diameter a little bit greater than the wire used for the active element of an antenna. Guys made from fishing line may be invisible, but when operated in sunlight will become fragile and weak over time. This line will also work poorly after being exposed to a frost. The guy wires made from a thin Capron cord (such as synthetic, nylon cord) will eventually become visible because dust will stick to the entire length of line. Being so sticky (like paste or glue!) these guys will really become visible during a snowfall. Therefore, if the antenna falls under its weight it will most certainly reveal the presence of entire antenna system and the station!

A twisted pair telephone line, having a characteristic impedance within 50-70 ohms, is ideal for feeding dipole antennas having the same impedance. Unfortunately, this wire is too noticeable to use and its use for a HAIA would not be wise. Use of antennas with single-wire feed lines is preferable despite being known for creating more TVI.

Parameters of a HAIA

Despite the unconventional type of construction used to make a HAIA, many parameters of these antennas are actually close to having parameters similar to their normal analogs. When using a thin wire antenna, the factor used to correct the element length for the end effect is close to 0.96-0.98. When single-wire antennas, such as a HAIA, are free-floating at heights greater than 10-meters, their load impedance exceeds 700 ohms and can even reach 800-900 ohms when located at heights greater than 30-meters. As the surface of a conductor is small on which the conduction currents flow, the ohmic resistance of an antenna is augmented and results in lowering its efficiency.

As such antennas usually have large input impedance, the reduction of antenna efficiency in this case is not too great. Because of the small diameter of its wire, it is necessary to restrict the transmitted power, as large currents can melt and fuse the copper wire antenna. In my experiments the power fed into these antennas has been limited to 200 watts. This is as safer operation for these types of antennas. At first, I used wires having a diameter of 0.5 mm, but as thinner wire was used for these antennas, it clearly became necessary to reduce the transmitted power.

Really HAIA – the cord from mountain train

CHAPTER 3: SUBSTITUTE ANTENNAS

Radio amateurs living in condominiums, flats, apartments, hotels, hostels, and even in some residential sub-divisions that may have restrictions against antennas often do not have any known options of erecting a useful antenna unless they are able to obtain special permission to install them. Even then, some amateurs do not have the materials to make antennas or the money to buy them even though they may possibly have a place to mount them.

On the other hand, even if they happen to be one of those radio amateurs lucky enough to own a big “antenna farm” full of many types of large antennas, it is still very wise and desirable to always have a simple compact “substitute antenna” available for radio operation in the event of emergencies such as fire, electrical or ice storms, power outages, or for any number of other reasons.

In this chapter some simple substitute or back-up antennas are described that are not so exacting in their requirements of the parts needed to make antennas. In addition, suggestions are given for finding a place to install them once they are made. Such antennas can be installed on a balcony or on a wall of a building where they will be less accessible to the deliberate destruction that often happens to antennas openly installed on a roof.

Attention is also given to country antennas. These antennas can be made very inexpensively. To the radio amateur, their cost will be so insignificant that they can even be abandoned and left for rubbish if need be.

The radio amateur can put up and own a substitute antenna made to best suit his own local mounting conditions by using the principles of construction described in this book telling how to make “substitute antennas”.

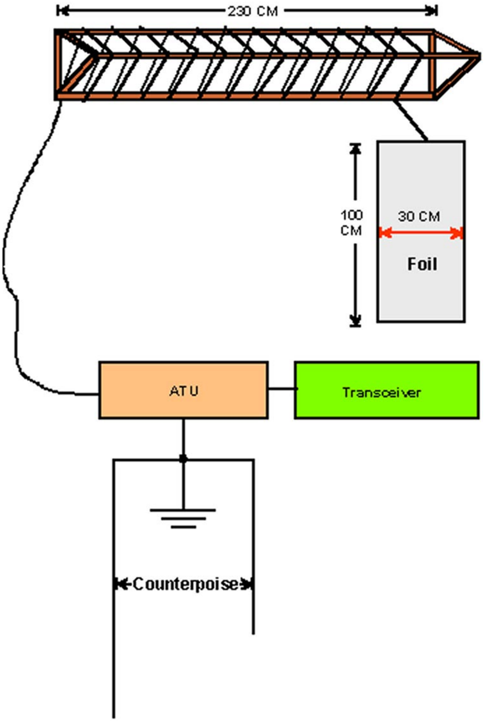
Substitute a single-wire antenna

It is not always possible to have an ideal location to erect a normal antenna. But even if one is installed, it may fail as a result of natural and human factors. So, I have built a simple single-wire antenna in a room window. While this type of antenna may not provide excellent performance, it can serve well as a valuable supplementary antenna for radio amateurs when the main antennas cannot be used. The construction of this antenna is shown in **Fig. 3.1**.

On the outside of a wooden window a triangular wooden frame was mounted: each side of the triangle was 30-cm long. Wound on this triangular form was a 1-mm diameter copper wire having an overall length of 40 meters. This length includes the pigtail wire leading from this inductor "coil" to a transceiver. From one end of this coil, a wire was connected to a 30x100-cm sheet of aluminum foil. The foil was pasted onto the inside of the window to protect it from exterior environmental effects. The wires connecting the foil to the antenna should be made long enough to allow the window to be opened.

This triangular form with the wire coiled on it was installed outside of the upper part of the window. The wire connecting the other end of a coil to the transmitter was kept as short as possible. A transmitter having 50-ohm output impedance should be used to drive this antenna, otherwise, use some impedance matching device.

Fig. 3.1 A single-wire substitute antenna



For the antenna to operate effectively, a good RF ground is very necessary. A full-size counterpoise is certainly preferred, but a substitute "ground" may have to be used.

It is important that the antenna system be connected at least to the room's (hot water or steam) heating radiator (usually located under windows) that has pipes or tubes which can be used as as a solid substitute "ground" connections. In addition, at the very minimum, use a counterpoise system that consists of at least one λ/4 long counterpoise wire for each desired operating band of frequencies.

Or, if a λ/4 counterpoise cannot be provided, instead use an "artificial ground" device with a thick wire (such as braid from thick coax) hooked up to it. The wire can have a length of at least 5 to 15-meters. The unattached "free" ends of the counterpoise wires should be carefully protected with insulation and not allowed to make actual contact with metallic objects or any part of any person. **CAUTION:** There can be a dangerously high RF voltage existing on the free ends of these wires while transmitting. Shock and fire hazards can exist!

When using a series RF antenna current meter in the antenna circuit, it can be observed that a good properly matched counterpoise can cause the antenna's current to increase by a factor of two as compared to only using the room's heating radiator pipe for a substitute "ground" connection. This antenna can perform well in all the 10 through 160-meter amateur bands!

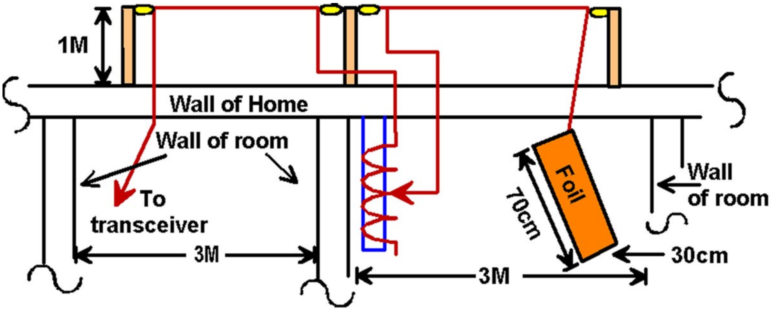
When comparison testing was conducted on a wire substitute antenna against a LW with a length of 41 meters, the wire substitute antenna was 6 "S"-units under the LW on 160 and 80-meters, 5 "S"-units on 40-meters, and 2 to 4 "S"-units on the other bands.

As contrasted to an antenna hanging in free space, the single wire substitute window antenna had part of its "coverage pattern" shielded or blocked by the building, where the antenna did not radiate effectively. Therefore, in order to estimate the antenna's radiation effectively, radio contacts were made only in the directions that were not blocked but were "visibly clear" from the antenna. Even though the results were certainly not absolutely correct, they were still useful. Delivering more than 200-watts of RF power into the antenna resulted in strong TVI near the antenna's location. By reducing the power to 50-watts it was still quite possible to successfully work on the air, especially on frequencies higher than 7-MHz.

All-band substitute antenna

The all-band substitute antenna described here again does not operate as efficiently as other types of full-scale antennas, but at the same time, it can provide reasonable and satisfactory operation on all amateur HF bands (as well as the 27-MHz CB band). This antenna does require the use of a matching device. The antenna shown in **Fig. 3.2** is mounted on the outside of window frames. Doing this considerably reduces the chances of it being destroyed by by-standers, as sometimes happens when placed in other locations that are not normally visible from the operating position. This way too, it is also easy to visually check on its serviceability.

Fig. 3.2 All-band antenna



This antenna uses a 1 to 2-mm diameter wire kept spaced 1-meter away from the windows and wall using wooden (or plastic) sticks as mini-masts. The antenna wire is fed out of the lower corner of a window of the first room and is routed to where it reaches the wall of a second room, where it is then routed into that room via a hole in the corner of the wall. There it is connected to a series-loading inductor coil mounted on the wall adjacent to its window frame. It is connected, with the help of "alligator" clip-leads, to select portions of the loading-coil. This makes the coil a variable inductor (sometimes called an antenna "lengthening" coil).

The other end (the output side) of the loading-coil is connected to a wire that passes out through the same hole in the corner the wall. This output wire then passes across the building's wall, and through a window frame, goes into a second room.

In the second room, a 30 by 70-cm piece of aluminum foil is attached to a wall. The foil is used as a capacitive load for the end of the antenna. It is necessary to place an electrically strong dielectric, such as polyethylene, under the foil. Instead of a foil, it is also possible to use a plate of single or double-surfaced printed circuit board having approximately the same size. The antenna connects to it via a flexible wire that allows the window to be opened easily.

An RF voltage indicator in the form of a neon bulb (or a small discarded fluorescent tube) is attached, depending on the transmitted power, either on the foil or near to it, with the help of Scotch tape. If it is necessary to increase the sensitivity of this RF-probe, solder a 5 to 20-cm length of wire to one of the bulb's electrodes. Do not couple the bulb any closer than necessary to provide a linear brightness indication. Coupling it too tightly can result in saturation of the sensor, which prevents seeing a clear indication of a peak voltage. The initial setup is made by tuning the transmitter and antenna system to result in the bulb having a maximum peak glow.

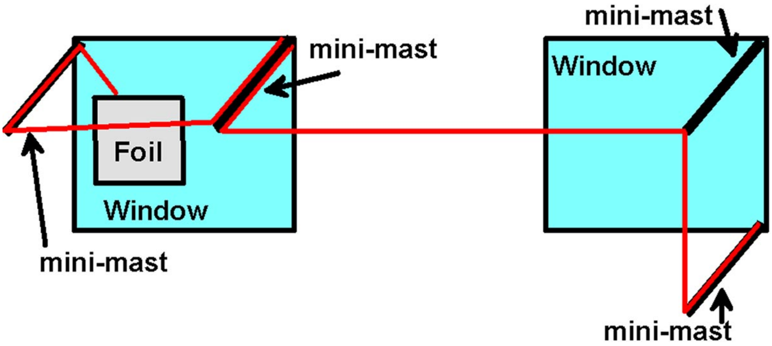
The relative maximum current indication on an RF current meter coincides with the maximum glow and with best radiation. Both “peak” indications occur at maximum radiated power, and either one can be used to indicate the “peak” final tuning for a given antenna configuration at a given frequency.

Keep in mind that the RF current meter’s indication provides a relative reading and that its indicated value at another frequency or with any change in the antenna system’s configuration (including a loading-coil tap-position change) cannot be used to compare the antenna’s absolute efficiency, or the absolute power being radiated, between the two configurations.

Stated another way, at a given frequency any changes to the transmitter and to any portion of the antenna system made on the transmitter side of the RF current meter to yield a higher current, represents a true increase in radiated power. On the other hand, if changes to the antenna system are made beyond the RF current meter (in the case where the antenna loading-coil is placed in the circuit after the RF current meter and a different coil-tap is selected) then the “peak” relative indications (yet still useable for best tuning), cannot be used to compare the best absolute efficiency of the two configurations. For this reason, the RF current meter is more valuable if it is located beyond the variable loading-coil or item being adjusted.

The exterior of an antenna on the part of a street is shown in **Fig. 3.3**.

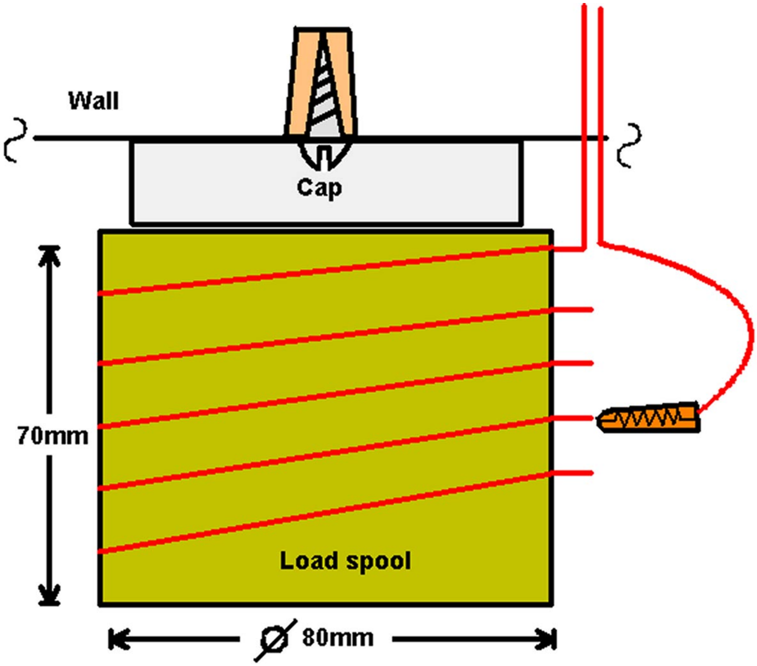
Fig. 3.3 An outside view of the exterior part of the antenna



The inductor coil “L” can be wound on a coil form consisting of an empty glass jar having a diameter of 80 mm. 80-turns of 0.8 mm diameter wire are wound over a coil form length of 70 mm with a coil tap contact point being provided every eight turns as the coil is being made.

The jar’s lid (preferably non-metallic), which can serve as a method of mounting the jar coil to the wall, is attached to a preferably non-ferrous screw (brass being preferred) to a short piece of wooden rod that had been inserted or interposed into a hole in a concrete or brick wall as shown by **Fig. 3.4**. If a metallic lid and a ferrous screw are used, then when power above 100 watts is applied, there is a danger of overheating and causing damage to the wooden rod and plastic jar. The coil is then attached to its jar coil form by being tightly turned onto its lid.

Fig. 3.4 Strengthening of the antenna loading-coil

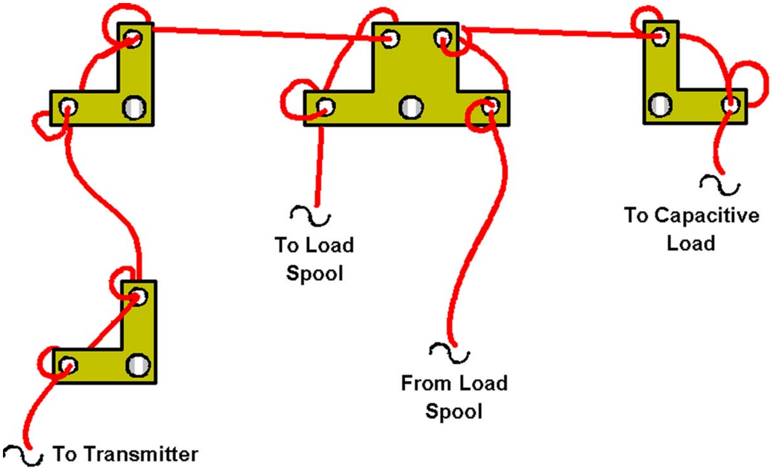


Switching between coil-taps, in order to select an optimum value of antenna loading-coil inductance is done with the help of “alligator” clip-leads. The coil’s output lead connects to the antenna and goes outside through the hole in the wall toward the end-loading foil capacitor.

The wire goes through a hole in the wall or window's frame in an insulator, made from a coaxial cable with its braid removed to provide high-voltage insulation.

On the ends of the mast, stick insulators made from PC board material, similar as shown in **Fig. 3.5**, are used. There can be large high-frequency voltages on the antenna wire beyond the loading coil when transmitting. Therefore, very good insulators should be used in the part of antenna.

Fig. 3.5 End insulators for the all band antenna



Good grounding is necessary for the best operation of this antenna. This can be done to a limited extent by using the room's heating radiator pipes as a substitute "ground" connection. It is possible to use a limited quality "of ground" by placing at least a 20-meter length of wire installed on a wall's baseboard.

The antenna is connected to a tuner by a short 2 to 3-meter length conductor (**Fig. 3.6**). This wire can radiate strongly and contribute to strong TVI near the transmitting site. For more options, the antenna as shown in **Fig. 3.7** can be fed through a short 2 to 3-meter long piece of coaxial cable, or a twisted open line, or through a two-wire line (like telephone distribution wires, such as "Noodles"). The open link can have a length up to 6 meters.

Fig. 3.6 Antenna connection to the transceiver

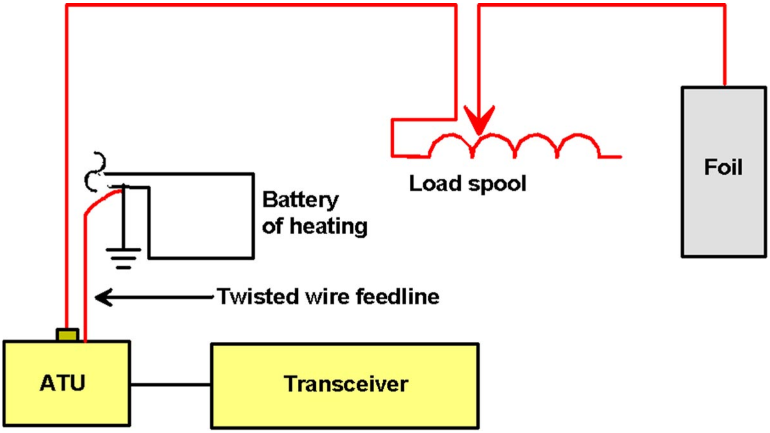
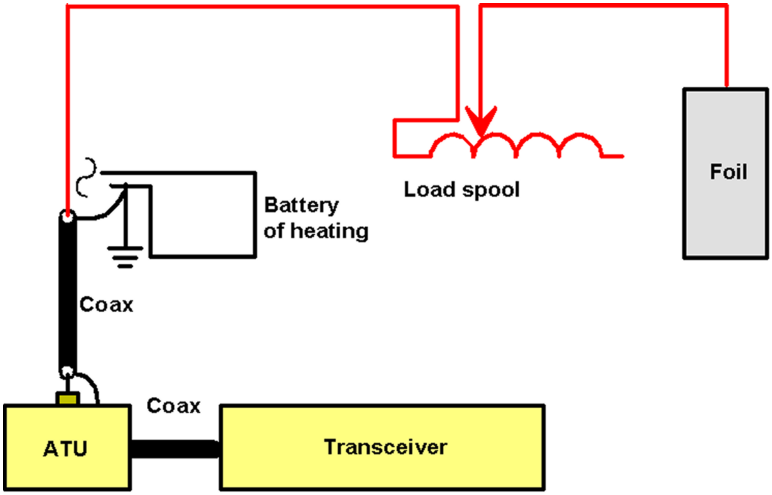


Fig. 3.7 A method of feeding an antenna to reduce TVI



It is necessary to conduct a preliminary setup test with this antenna prior to its operation. For this purpose, select the best tap on the antenna’s loading coil and tune the tuner for a maximum current flow into the antenna and check for the maximum glow on the neon bulb. An antenna can have some setup variations occur even within the same frequency range or band. During operations, it is necessary to tune and use the settings at which the neon bulb glows the brightest. **CAUTION:** Do not switch coil tap positions on the antenna's loading coil when transmitting as it can have a painfully high-voltage on it. It is optional whether to use an RF current meter in the antenna. If located beyond the adjustable loading coil, it will indicate a maximum "peak" for all configurations, both for the tuner and antenna's loading coil.

Upon comparing this antenna to a 41-meter long wire antenna, it was found to be 1 to 3 "S"-units weaker than the long wire antenna on the 10 and 20-meter bands. It was 4 to 5 "S"-units weaker on the 30 and 40-meter bands, and it was 5 to 7 "S"-units weaker on the 80 and 160-meter bands. But, at the same time, during good radio propagation conditions with only 50 watts, it was able to contact another station on the first call attempt. The antenna's directional radiation pattern is almost circular, except where it was reduced on the side blocked or shielded by the building. When set up correctly, this antenna does not cause strong TVI.

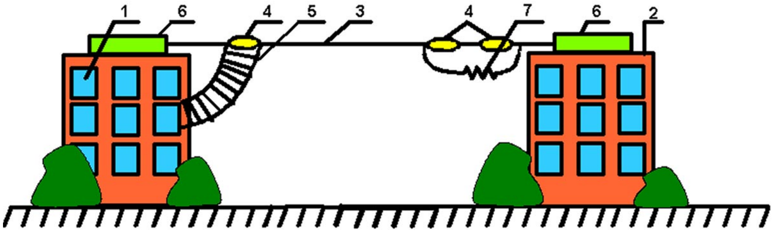
Urban progressive-wave antenna

In urban conditions it is difficult to have an efficient antenna even on one range or band of frequencies, let alone on several bands. Often there are objections to installing a tower or any mast on a roof and with mounting a coaxial cable feed line on a wall of the building (especially when its necessary to get the landlord's permission).

But there is a solution. If the radio amateur lives in the multi-story building close to another multi-story building, it may be feasible to install a simple but effective progressive-wave antenna (PWA) between them. The schematic is shown in **Fig. 3.8a**, and the construction is shown in **Fig. 3.8b**.

Fig. 3.8a Urban progressive-wave antenna

Fig. 3.8b Urban progressive-wave antenna



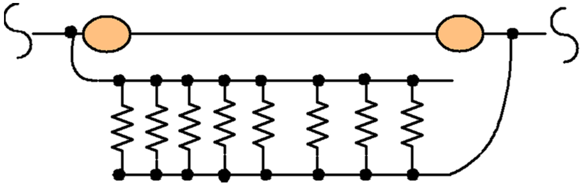
A progressive-wave antenna (PWA), item 3, installed between buildings 1 and 2 (shown as items 1 and 2 in **Fig. 3.8b**) that are spaced 20 meters or more apart. The antenna (item 3) requires a strong wire. It is desirable to use bi-metallic (copper over steel) wire; however, any copper wire having a diameter greater than 1 mm can be used. The wire is suspended on insulators (item 4). The antenna is fed from one end through an open transmission line (item 5), which is connected to the antenna by one feed line conductor, then connected to a metal guy wire by the other feed line conductor (item 6). In turn the conductive guy wire is “grounded” to the metal roof of building 1 (item 1) that serves the role of a radio frequency ground. In the event a metal roof is not available, it would then be necessary to connected to some of the building’s accessories, such as a building stack components or metal plumbing pipe, which usually stick up through the roof of a building.

If none of these options are possible, then it may be necessary to make an “artificial ground” using insulated copper or insulated aluminum wire(s), having a length no shorter than the main antenna. The wire(s) can lie on the surface of the roof or be placed inside the building’s loft or attic. However, it is desirable that the wire(s) be stretched out as much as it is possible in one direction to improve efficiency, even if more difficult to install. The more wires used, the better. If more than one wire is used, it is desirable that each wire be fanned out in a different direction (for each wire) as straight as possible from their common connection point.

However, with a compromise in overall antenna efficiency, insulated counterpoise wires can be placed in letter-shapes of U, L, M, or S. Though not recommended, insulated counterpoise wires could even be lowered into plastic plumbing vent pipes. But doing this could couple more electrical noise from the building into the antenna system, and conversely, may likely introduce more TVI into the building (as well as introducing a possibility of igniting raw sewer gasses) when transmitting.

On the other end of the antenna is a terminating resistive load (item 7). When located four or more meters above the ground’s surface, a progressive-wave antenna has an impedance of about 600-ohms (which does NOT increase with increased height. The load terminating resistance should match this by matching the value of the characteristic impedance. The practical example of this load configuration is shown in **Fig. 3.9**.

Fig. 3.9 Example of a load resistor configuration for a progressive-wave antenna

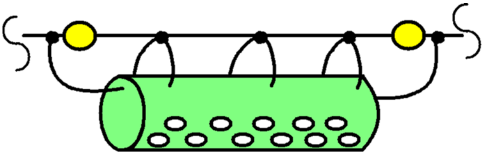


The antenna on the end of the load is “broken” by two insulators. On one end the antenna wire is connected, and on the other end of the insulators the other wire is connected to the metal roof of building 2 (item 2). If a metal roof is not available on building 2, then the same directions as given for building 1 for obtaining a substitute for a metal roof apply here, too.

The load is made using a network of many 2-watt resistors in a parallel configuration. The total resistance of this resistor network should equal 600-Ohms. When making a terminating load resistor network, it is necessary to take into account that the power rating of the terminating load resistor network should be calculated to dissipate at least 30% of the maximum transmitter power. For example, a terminating load resistor network load made from 30 individual non-inductive 18,000-ohm 2-watt resistors in a parallel network circuit can safely dissipate 60-watts. This allows almost 200-watts of RF power to be fed to the antenna without the terminating load resistors burning out.

The load resistors are placed vertically and their wire leads are soldered to 1-mm diameter copper wires. After that, the load resistor network is located in a protective plastic tube (**Fig. 3.10**).

Fig. 3.10 Plastic tube protector for a progressive-wave antenna’s terminating load of resistors



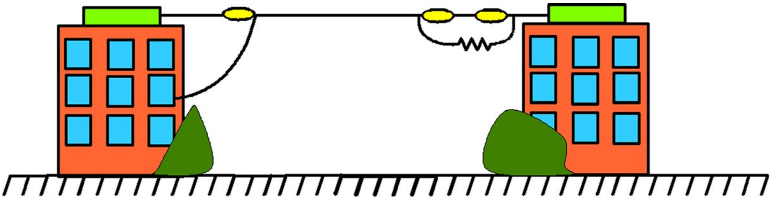
Holes were drilled in the bottom of the protective plastic tube, and the leads of the tube are coated with polyethylene caps made by melting plastic jar covers. **CAUTION:** Do not use wood to cap the tube. It is possible to destroy a tube by a cap made of wood. Wood can expand with moisture and burst it.

It is undesirable to try to completely hermetically seal the terminating load resistor network. The terminating load resistors heat during transmission times and causes the air within the tube to expand, thus creating a "breathing effect" through microscopic holes in the tube. Breathing out will take place when transmitting because the heated air expands out of the "sealed" tube. Later, when not transmitting, the tube starts cooling, contracts, and "breathes in". The internal air pressure falls, resulting in a suction that pulls in moist air from the outside atmosphere. Incomplete sealing allows the moisture to be condensed and collected on the load resistors, causing them to eventually fail.

In contrast, if drain holes are made in the bottom of the load protector tube, then there can be a convection of air during heating, and the load will dry itself along with the protective plastic tube enclosing it.

The antenna should be placed between buildings so that the open feed line can go straight into the room where the radio is located in a small corner. If the antenna were brought directly into a room without using a transmission line, as shown in **Fig. 3.11**, the interference to TV and other electronic devices could be high.

Fig. 3.11 A progressive-wave antenna with a single-wire feed line



Do not be afraid of feeding an antenna with open line. It has advantages contrasted to a coaxial cable for feeding. Open line feeding permits using simple multiple-band antennas. The line has a characteristic impedance of 600-ohms which can be easily matched to pi-network circuits used in many vacuum tube output transmitter stages. If the radio amateur uses a transceiver without a vacuum tube power amplifier, using either a manufactured or homemade tuner (circuits that are commonly discussed in detail in much of the radio amateur literature) makes it possible to match the transceiver to an antenna.

Now available in many electronics supply stores, there is an electrical double-wire conductor in plastic isolation with large distance between cores, which has a characteristic impedance close to 600-ohms. This wire ideally approaches the impedance needed to feed from power amplifiers. But after a few years of operation in the open air with exposure to UV radiation from the sun, it becomes unfit for use.

One option is to use a homemade open-line transmission line. A version of link construction is shown in **Fig. 3.12**. The compression struts were made from printed circuit board material. The leads of the compression-struts were made using a grinding stone to form the slots (see **Fig. 3.12a**). The conductors were made from a copper wire having a diameter of 1 mm. On an installation site for insulators, the wire was striped and soldered to a double-sided foil printed circuit board. On each side of the insulators U-shaped grips, made from 1-mm copper wire, were soldered to provide the best strengthening for the link to compression-struts (**Fig. 3.12b**). Printed circuit board insulators were installed every 50-centimeters apart for a line using rigid copper wire. Soft multi-conductor wire and soft single-conductor wire (for example, especially burned or removed from a burned-out transformer) will not work because of the possibility of the line twisting and shorting-out the conductors. If soft copper wire were used, it would then be necessary to space insulators much closer than 50-centimeters apart. After installation, the homebrew line should be stretched straight and taught to help prevent twisting and danger of shorting.

Fig. 3.12a Self-made opened line

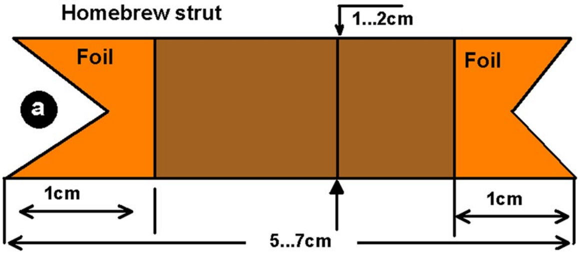
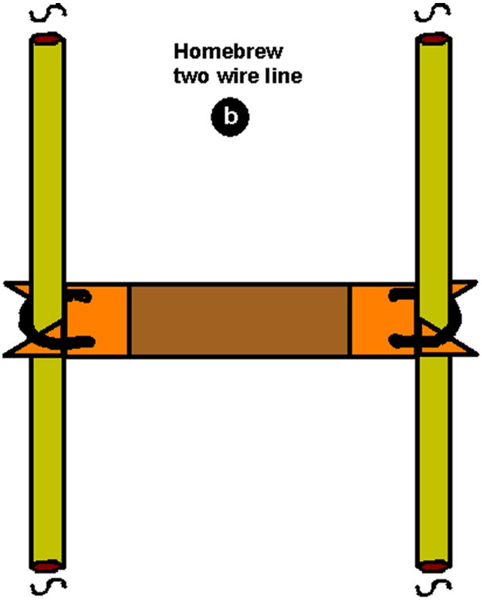
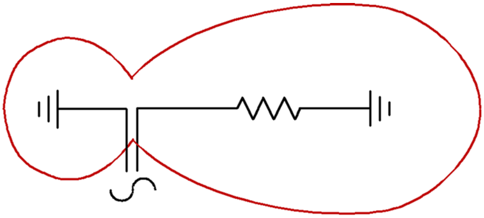


Fig. 3.12b Self-made opened line



The antenna works well over a very wide frequency range of 1.9 to 50 MHz. Its directional radiation pattern diagram is shown in **Fig. 3.13**. It does depend on a length of wire to provide quality grounding on the side of the load and on the side feeding the antenna. The better the quality of grounding on both sides, and the longer the antenna, the smaller the back lobe radiation will be and the greater the side lobe radiation will be.

Fig. 3.13 A progressive-wave antenna's directional characteristics

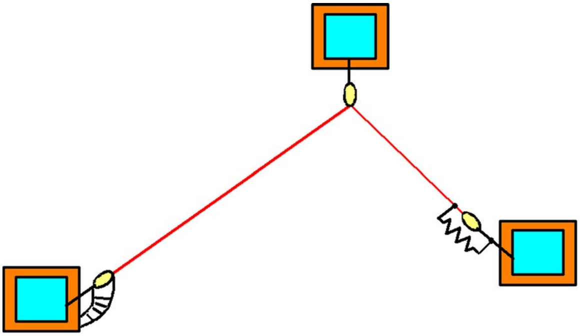


Having a poor quality of grounding (at building 2) on the side of the terminating load resistor results in a larger antenna radiation pattern back lobe, and a smaller front lobe. Having poor grounding (at building 1) on the side of the feed line the antenna efficiency diminishes and the back lobe increases.

This antenna can be universal and can used for operation on all HF amateur bands. When installing remember that it is necessary to use wire and insulators capable of sustaining the weight of the antenna and surviving strong winds. After building this antenna, it is still possible to increase the lengths of the wires in order to tie the PWA (progressive-wave antenna) between additional buildings as shown in **Fig. 3.14**.

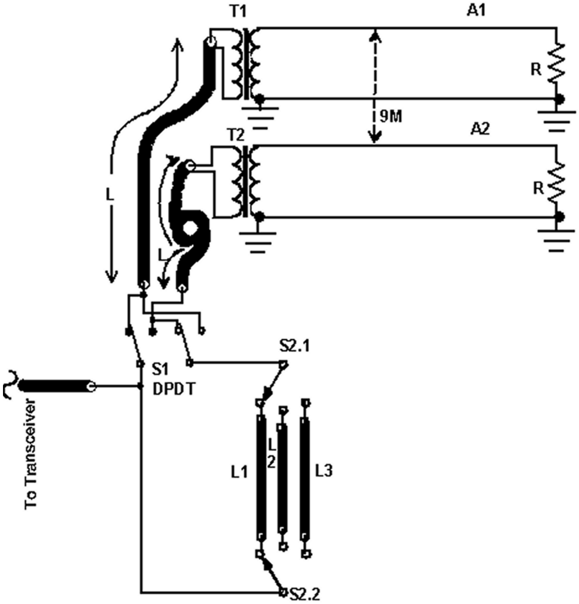
A PWA system with selectable directional patterns

Fig. 3.14 A progressive-wave antenna placed between three buildings



The simplest broadband antenna system providing operator selectable directional radiation can be constructed on the basis of two Beverage antennas. These antennas are identical. They are connected in parallel on two counter patios of multi-story buildings. The feed lines going from the transmitter to the antennas should have identical length. In place, the transmitter output is divided between two antennas. One feed goes directly to one antenna feed line. The other signal is fed through a phase-shifter made on the basis of a coaxial cable having a different feed length, which then feeds the phase-delayed signal to the other feed line. The antennas are connected in a parallel circuit. The schematic of the antenna system is shown in **Fig. 3.15**.

Fig. 3.15 A PWA system with a selectable directional radiation pattern

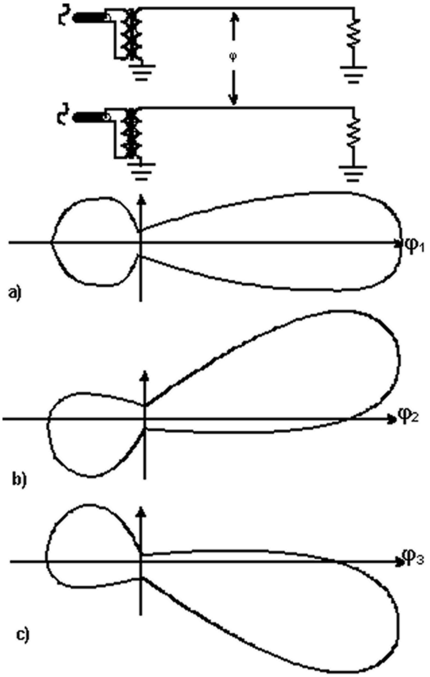


For antenna feeding and phase-shifter, one can use coaxial cables having any equal characteristic impedance. The lengths and numbers of phase-shifter cables selected determine the amount of contacts required of the switch and the bands of frequencies of operation of an antenna. If it is necessary to work effectively only on a fixed single band (for instance on 3.5 MHz, 7 MHz, etc.), the coaxial cable lengths can be made to differ by l/8 for the selected frequency.

For broadband operation, the lengths of switched cables selected by the switch position, can be calculated with the following procedure. It can be assumed that the antenna will work over the range of 10 to 80-meters, with the average wavelength of operation of the antenna being 30-meters. This wavelength of operation of an antenna is divided by the amount of switch contacts (commonly an RF switch with 10 contacts): for example: 30 meters/10 contacts = 3 meters.

This indicates we stake progressive lengths of feed line, each having a step increase of 3 meters over the previous length. The first provision of the switch is zero, i.e., without a pigtail. Continuing this progression to the final one allows the switch to control satisfactory operation of the antenna. By switching in phase delays (that result from inserting various lengths of cables), we can shift a lobe's directional radiation pattern of the antenna system in a horizontal plane. Depending on the controlled variation of the progression of phase delays in these feed lines, the directional radiation pattern of the antenna varies as shown in **Fig. 3.16**. By switching the phase-shifter from one antenna to other antenna, the antenna's directional lobe pattern is changed to the other side. With such scanning techniques, it is theoretically possible to introduce accessible changes to the scanned directional lobe pattern with up to 6 dB variations.

Fig. 3.16 Antenna directivity diagram



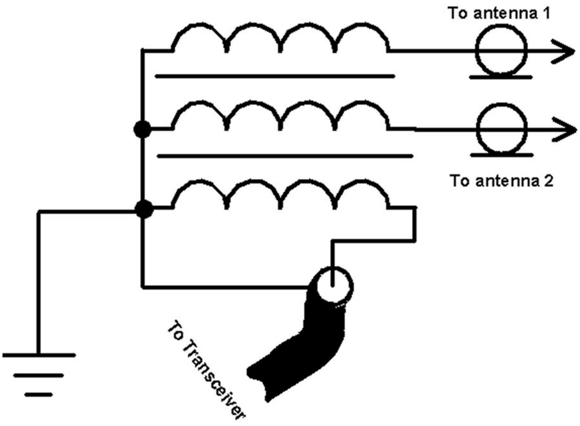
By increasing the overall performance of the antenna system and increasing the variation between the minimums and maximums on the directional radiation pattern, it is desirable to include a matching transformer (see **Fig. 3.17**). The transformer's windings can be tri-filar wound on a ferrite core (such as a yoke from a color TV's deflection system). The amount of coil turns required is from 10 to 20. A smaller number of coil turns are preferable for operating the antenna system on the higher frequency amateur bands, and a larger number of coil turns are preferable for operation on the lower frequency bands. It is possible to use a 0.5 to 0.8-mm diameter wire to make the transformer. The amount of twisting is one twist per 0.5 cm. The winding should be evenly distributed over the ferrite ring core.

This antenna system is a substitute for a beam antenna. It will not allow one to enjoy full directional operation, which can be provided by special beam antennas (such as by a Yagi), or may be provided by compact fractional wavelength transmitting loop antennas. But it can allow one to understand the advantages of directional antenna systems and, still further, to motivate one to conduct experiments with loops and beam antennas on a higher level.

Asymmetrical outdoor antennas

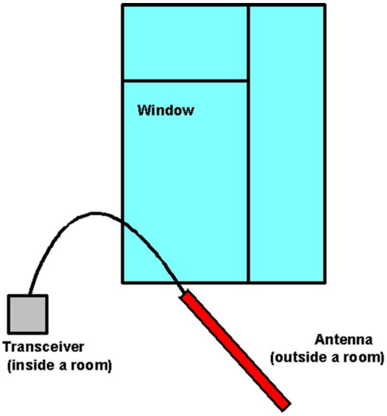
The outdoor antenna is necessary when operating from a concrete building that contains metal reinforcing bars (such as rebar). In this situation, using the building's accessories for a ground system, can essentially give a received signal strength level an increase up to 2 "S"-units. It is possible to connect it directly to a balcony, having a metal porch roof or balcony and rails that are coupled electrically to the building's metal frame. Then it's necessary to determine which type of antenna is most expedient to use: a simple whip (**Fig. 3.18**), elongated whip (**Fig. 3.19**), or a broadband whip antenna (**Fig. 3.20**).

Fig. 3.17 Matching transformer



In transmission mode, the antenna shown in **Fig. 3.18** is very effective. Its active radiating pole, pipe, or rod element, including the wire needed to connect it to the transmitter, should be a quarter of a wavelength long at the selected operating frequency. In the range of 15 to 160 meters, this is impracticable. Instead, use a short 2 to 3-meter long pole, pipe, or rod for the active antenna element that can be matched with the help of a variometer, having inductance adjustable from 1 to 100-microHenries. Such an element is convenient to make. For example, it can be made using aluminum antenna mast material, thus permitting one to adjust its height. The variometer is connected directly to the transmitter output. It is probably necessary to space

Fig. 3.18 Simple whip



the antennas shown in **Fig. 3.19** and **Fig. 3.20** further out from the building's wall.

The broadband vertical exhibited in Fig. 3.20 ensures a more broad passband as compared to the antennas configured in Figs. 3.18 and 3.19. But this antenna is more complicated to make. It is recommended for construction by only those radio amateurs who possess sufficient experience with the installation of these wall-mounted antennas. When using the broadband vertical together with a matching device or lengthening spool, its dimensions for the 6 - 160 meter range of operation should be built with a width of 1-1.5 meters and mounted at a height of 2- 4 meters.

Fig. 3.20 Broadband whip antenna

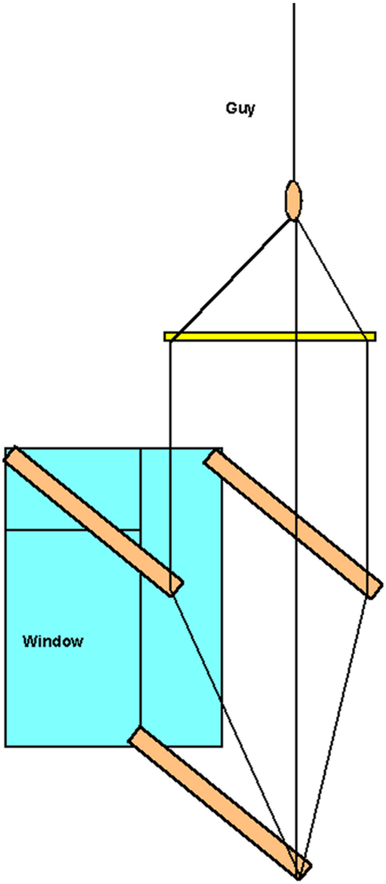
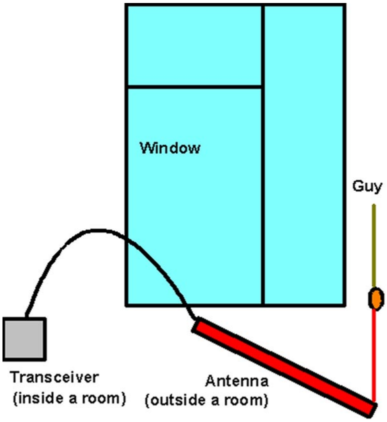


Fig. 3.19 Elongated whip



Some of the disadvantages of external substitute asymmetrical antennas are:

• Buildings are strong absorbers of electromagnetic energy fields.

• Buildings detune antennas. It is necessary to retune, or readjust, the electrical length of the antenna system because of the coupling influence on the antenna from closely spaced building walls. Such coupling and stray capacity lowers the antenna's resonate frequency. Changes in the distance between the wall and the antenna require retuning. An adjustable loading-coil inductor (also called an antenna lengthening coil) can usually help.

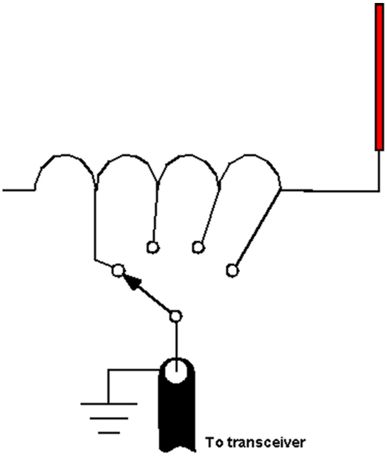
• Cautions must be observed. High RF voltages can exist on the antenna and the matching coil that can create a danger of a lesion or RF burn to a human (or other species), plus creating a threat of starting a building fire.

The antenna factor is small and generally does not exceed a 10% shortening of the external substitute asymmetrical antennas. But even with such antennas, it is still possible to successfully work on the air for a long time.

Universal antenna

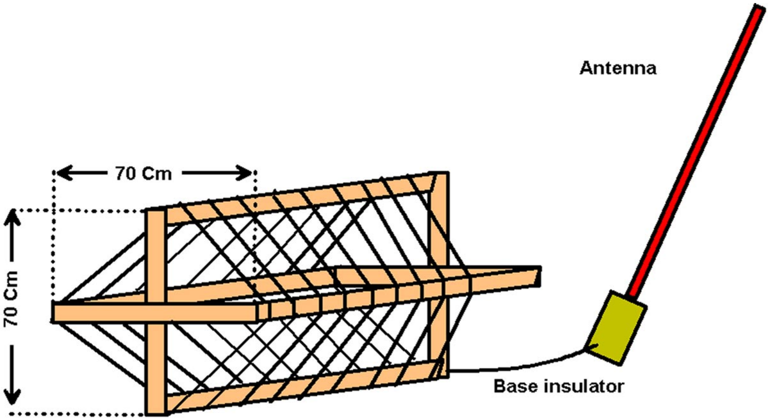
One of the simplest and most universal of antennas that can work on all amateur bands is the vertical antenna with a loading coil (**Fig. 3.21**). The active radiating rod, pole, or pipe element of the antenna with the help of a loading coil can be tuned to resonance on all amateur bands, thus its electrical length will depend on the band being used. The electrical length will be λ/4 on low HF amateur band of frequencies, then 3/4λ, 5/4λ, and 9/4λ on the upper HF amateur bands.

Fig. 3.21 A simple universal antenna



An active radiating element of the antenna can be made from things like ski poles or other suitable pipes of copper or aluminum. Also, military active radiating rod, pole, or pipe elements of a suitable length can be used. An antenna can be constructed as shown in **Fig. 3.22**. It is an aluminum active radiating pole having a length of 1.5 to 3 meters firmly mounted on an insulator on the wall of a building placed 45 degrees from vertical and in a plane perpendicular to the wall. A common base support insulator having small fittings for slanted installation can be used, or be made independently by the radio amateur depending on available materials.

Fig. 3.22 View of universal antenna



The loading coil is the most complicated and critical part of the construction. It is simple to make on a square crossed form of wooden rods. The loading coil may be placed on a window at an outer side of a room, or possibly be placed behind a window. In this case, the coil has to be designed to meet the increased voltage requirements to prevent high-voltage arcs and breakdowns from occurring.

The diagonal width of the coil form can be from 60 to 100 cm. The length of the coil form, depending on a length of the window to be used, can be from 100 to 200-cm long. The longer the coil form, the greater will be the antenna efficiency of operation of this system. Wire is to be wound uniformly over the coil form. The coil consists of 22 or 45 meters of un-insulated 1 to 3-mm diameter bare copper or aluminum wire.

In **Table 3.1** the physical and electrical lengths of a loading coil and pole antenna system are reduced for the wire's length by a loading coil by 45 meters and at a wire's length of a loading-coil by 22-meters.

Table 3.1 Value of lengths of a universal antenna

	Antenna System Lengths			
	----- 45 Meters -----		----- 22 Meters -----	
Band(m)	Electrical Length(λ)	Physical Length(m)	Electrical Length(λ)	Physical Length(m)
160	1/4	43	0.14	All
80	1/4	20	1/4	20
40	3/4	30	1/4	10
30	1.25	37	0.75	22.5
20	1.25	25	0.75	15
17	2.25	38.25	1.25	21.25
15	2.25	33.75	1.25	18.7
12	2.75	33	1.75	21
11	2.75	30.25	1.75	19.25
10	3.25	32.5	1.75	17.5
6	4.25	25.5	2.75	16.5

In the first case, the antenna will effectively work on the 160-meter band. In the second case the efficiency of its operation on this band is expected to be low. The lengths of antennas are elected so that the unused end of the loading coil does not have a large amount of high-frequency voltage on it.

When used on the upper HF bands the antenna's length can get smaller and the antenna's efficiency can become higher, as pointed out in **Table 3.1**. But the large high-frequency voltage on the unused end of a coil can be greater and burn a coil form or damage the switch. On the side of the radiating element (i.e., on the antenna end of a coil), the high-frequency voltage will be essentially smaller than on the other end where it will not be reduced in such cases.

After installation of the active element and the coil at a fixed operating location, then arrange the coaxial cable to connect between the antenna system and the transceiver. Hook the coaxial cable braid to a fixed earth ground. If an earth ground is not available, then connection can be made to any artificially made ground, or to the building heating system's steam or water pipes. (Even better, cold water pipes are preferred because they have a greater probability of being in closer direct contact to the earth's surface. Because of possible fire hazards in the event of even a slight vapor leak, natural gas or other fuel pipes should not be used as a substitute RF ground.)

If the loading coil is installed indoors, setting-up of the antenna system will be easier than for a version that uses a loading coil outside. Prior to starting the setup, use calculated resonance lengths of antenna wire for different frequency bands from **Table 3.1**, and for each calculated section, identify each checkpoint with a masking tape TAB arranged in a neat appropriate order. The resonance length of an antenna is calculated as the length of the radiating pole plus the length of a wire to the loading-coil.

The antenna system can be setup with the help of a flexible conductor about one meter long going from the center conductor of the coaxial cable. The end of the conductor should have a rigid “alligator” clip on it. Now place an RF antenna resistance bridge meter connected directly to the end of a coaxial cable that goes to the antenna. Next, tune to resonance by gradually moving the “alligator” clip from the checkpoint of an appropriate band to the side of the active radiating pole or unused end of the antenna

Having tuned it on an appropriate range, move the checkpoint to a position that results in the antenna being in resonance. Thus, in the future, when making a transition from one band to another band, simply clamp the “alligator” clip on the appropriate checkpoint for that band.

It is necessary to pay attention that the setup of an antenna at resonance depends on several factors such as the length of the coaxial feed line, the position of the cable relative to the antenna, condition of the antenna system’s ground, etc. Therefore, once having spent the time to accurately setup the antenna in advance, further changes to these parameters are not likely to be necessary later.

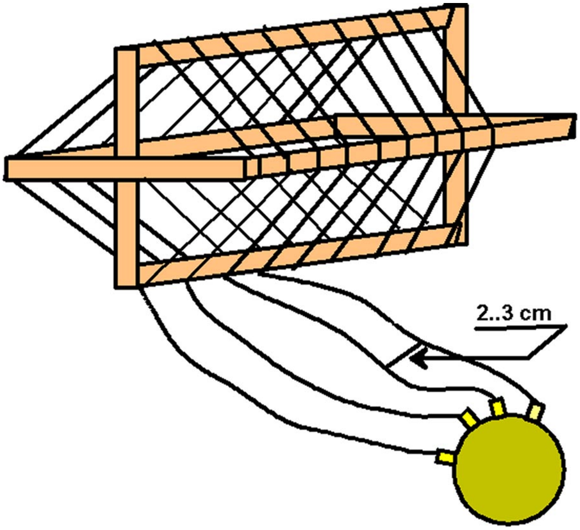
When the loading coil settings have to be made from the other side (the outside) of the window, setting up an antenna system is much more complicated. In this case the coil should be positioned where it can be easily viewed from the operating position in the room in order to see if the coil is arcing or is being subjected to the effects of adverse weather conditions, such as rain, or ice and snow. A suitable standard coil form can be made using pieces of PVC water pipes or tubes.

To switch the antenna system to another band of operation in an installation where the coil is on the outside of the window, it is necessary to use a selector switch to select the desired tap on the antenna loading coil. The switch can be installed inside the room under a windowsill.

Mount the switch in a fixed convenient location and arrange the switch positions for the connectors leading to the coil taps in a logical order according to increasing inductance to simplify operation. Then connect and solder the leads to the switch, while temporarily using “alligator clips” on the other end of the leads connecting to the taps on the coil from each band.

To reduce the danger of RF voltage breakdown, the conductor spacing to the taps should be at least 2 to 3 cm as shown in **Fig. 3.23**. Do not short out the unused portion of the loading coil with a shorting switch.

Fig. 3.23 Hook-up to loading-coil taps



First step for tuning: If you have finished building this antenna system outside, it is now time to start setting it up. Instruments can be helpful here. Connect an antenna analyzer or an antenna RF resistance bridge meter to the end of the coaxial cable feedline. At first, start by tuning the antenna system to the upper frequency range of an antenna and gradually progress to the lower operating frequencies. Adjustments are interactive, so after making a final adjustment of the antenna system on the lowest frequency band, go back and set it up once again on the upper frequency band, updating the positions of the alligator clips on the antenna loading coil.

After that, wind Scotch tape around it and to fill it with a silicone encapsulate, or automobile-type quick hardening epoxy designed for exposure under harsh environmental conditions. When the epoxy hardens, paint it with some protective colored paint, otherwise, the ultraviolet rays of the sun will gradually destroy the epoxy. The temporary “alligator clips” should be replaced with standard screw terminals or, if the loading coil is made with copper wire taps, it is probably better to solder them for better efficiency.

The input impedance of this antenna was within the limits of 50 to 70 ohms on the frequencies within the 6 and 20-meter bands, 40 ohms on the 30-meter band, 15-ohms on the 40-meter band, and less than 20-ohms on the 80 and 160-meter bands. In spite of this antenna’s low impedance on the lower frequencies, it works rather effectively.

On the frequencies within the 6 to 30-meter bands, the instantaneous bandwidth of this antenna does not limit operations, but on the 40 through 160-meter bands it does limit operations.

If the antenna loading coil is installed indoors where it is easy to access and permit compensating adjustments to be made on the coil, then the antenna can be resonated and successfully operated through out all of these amateur bands.

However, if the coil were located outside or in some other location that does not permit easy access to the loading coil, it would then be necessary to select the coil tap positions that would allow the antenna to tune to the most desired action areas of these bands. Or, if this is too limiting, a coil having more taps combined with a selector switch having more positions, will allow more operating flexibility.

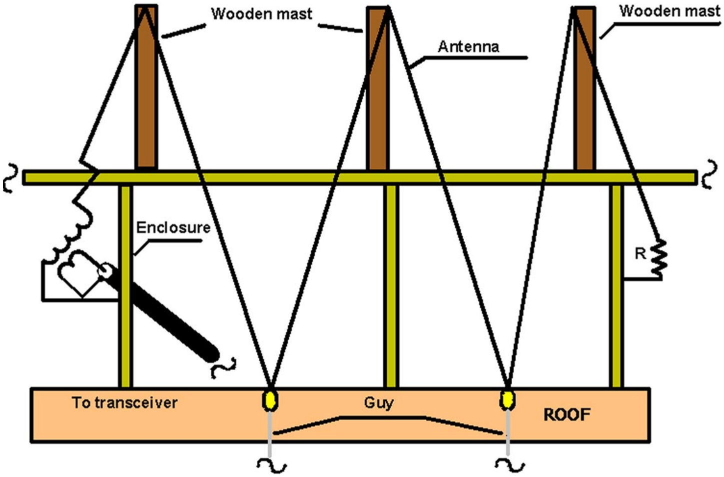
Using a tuner with the antenna will allow compensation for some of the reactivity of an antenna present on the low-frequency bands.

A capacitive load (sometimes called a “top hat”) attached to the end of an antenna, can increase the instantaneous bandwidth and make the antenna more stable and less likely to be detuned by variations of stray capacity introduced by people or other nearby objects.

The Bent Beverage Antenna

For a Beverage antenna to work effectively, it is necessary that the length of its wire be as straight and long as possible. But this cannot always be done because of a lack of space on the roof or in other desired antenna installation sites. During the installation of a Beverage antenna when there is not enough space for a full-size radio amateur antenna on a roof of a building, or in other restricted locations, a bent “Z” antenna, as shown in **Fig. 3.24**, will work quite acceptably.

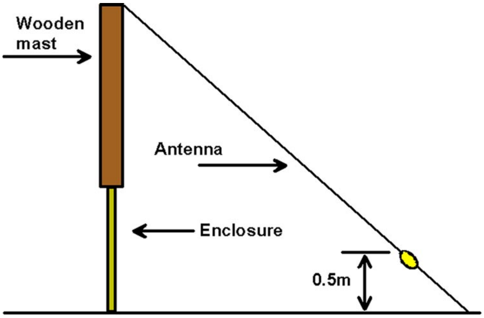
Fig. 3.24 Bent Beverage antenna



Where wooden posts support a metal roof at a height of 1.5 to 3.5 meters, an antenna wire can be centered and stretched between these posts, then extended by guy wires from the roof.

During an antenna installation on a roof, the wires can be sloped from the posts and roof, as shown in **Fig. 3.25**. It will be best, if space permits such an installation, to use numerous wires fanned out from a common connection feed point at the top of the post or roof down to nearby trees or stakes.

Fig. 3.25 Sloped installation of the bent Beverage antenna

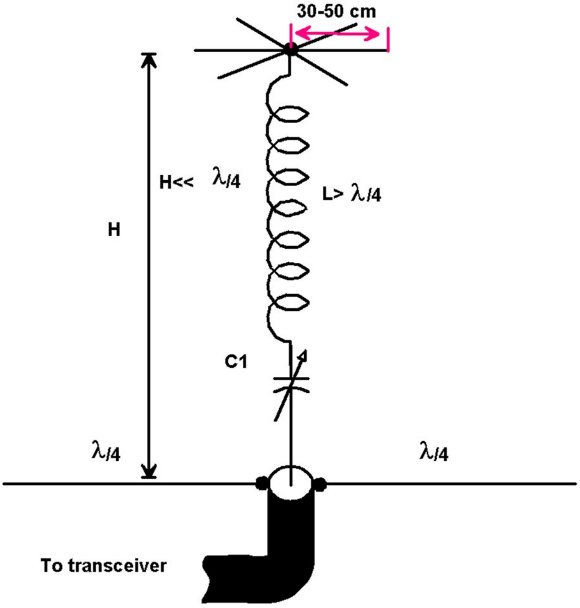


The terminating load resistor network and the feed line for an antenna can be made in the usual way. The Z-configuration Beverage antenna, at the expense of the major front lobe, has considerably more radiation in its side and back lobe patterns, plus radiating at higher elevation angles, as contrasted to a linear Beverage antenna. Despite this, such an antenna can be quite useful under limited operating circumstances, and especially when it is not possible to install any other type of antennas. It can be a good substitute antenna, where directivity is not a priority.

Vertical truncated twisted antennas

Among radio amateurs, truncated or shortened antennas are widely known. The schematic of such an antenna is shown in **Fig. 3.26**. The antenna consists of a wire, having a length only slightly longer than λ/4, which is uniformly wound on a plastic tube. By cutting a part of the coil thus, forming a series capacitor to "shorten" the electrical length of the antenna and adjusting capacitor C1, the antenna can be tuned to resonance. This similar procedure allows matching an antenna to a coaxial cable having a characteristic impedance of 50 or 75 ohms. The capacitive load on the end of an antenna extends its instantaneous bandwidth and allows the antenna to work over all the frequencies of the amateur band to which it is tuned.

Fig. 3.26 Truncated twisted antenna



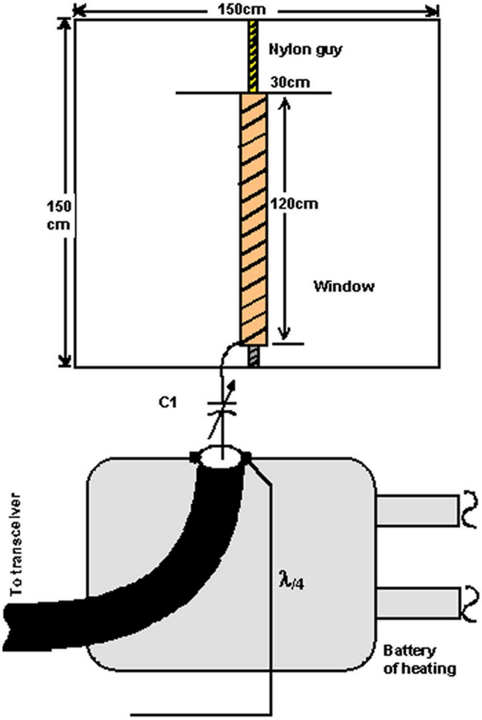
Three truncated antennas for the 10, 15, and 20-meter bands were made and tried for experimental purposes. The antennas were wound on flexible 28-mm outer diameter PVC plastic pipe, the type normally used for water lines. Different diameter pipes or tubes can be used. The antennas were mounted on the outside of a 140 by 150-cm non-metallic window frame and tested.

The installation of the antenna is shown in **Fig. 3.27**. The antenna was suspended in the center of the window. The braid/shield of a coaxial cable was connected to a heating radiator pipe as a “grounding pipe”. A λ/4 counterpoise wire, in the from a cable shield, was mounted on the baseboard of a wall. The antenna wire and counterpoise wire were made from stranded flexible copper wire. The antenna wire was wound on a plastic tube and was supported with Scotch tape. For rigidity, a non-metallic rod was inserted into the plastic tube. The windings on the antenna’s loading coil were spaced apart with the help of a nylon cord. A capacitive load was made using 2-mm diameter rigid copper wire.

The variable capacitor C1 was attached to a printed circuit board plate and mounted under a windowsill. The capacitor C1 had spacing between the plates of 0.5 mm. When operating on the 20-meter band a fixed 68-pF capacitor was connected in parallel to C1. The antenna was matched with a coaxial cable having a characteristic impedance of 50 ohms. The SWR was no worse than 1.5:1 in the center of all the amateur bands. At the edges of these bands, the SWR increased up to 2:1.

When testing these antennas while they were installed in a window opening located on the sixth floor of a nine story metal reinforced concrete building, they were compared to a λ/4 vertical antenna mounted on the roof of the same building (in a direction of radiation that was not shielded or blocked by the building). They were down from the reference antenna by 3 “S”-units on the 20-meter band and down 1 to 2 “S”-units on the 10 and 15-meter bands.

Fig. 3.27 Installation of a vertical twisted antenna

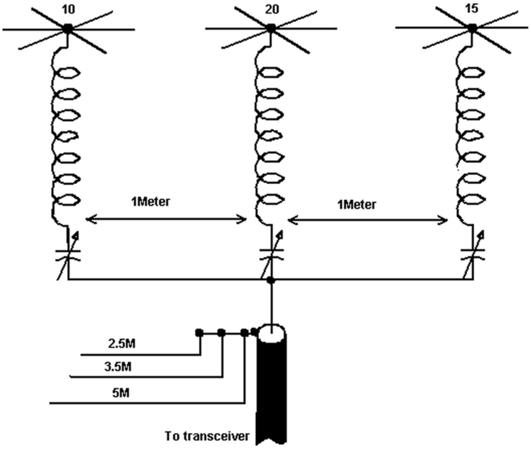


The antenna hardly radiates at all in the direction shielded, blocked, or enclosed by the building. Strong interference to different types of nearby equipment is likely to occur when transmitting with this antenna. Driving the antenna with 50 watts allows working Western Europe, a distance of 300 to 2300-km from the Russian city of Belgorod.

A three-band antenna experiment was conducted using three twisted truncated antennas. They were installed on a balcony according to **Fig. 3.28**. The shield of the cable was connected to the metal protective metalwork on the outside balcony. A single quarter-wave counterpoise wire was used for each band. The variable antenna tuning capacitors were located in a box made from printed circuit boards soldered together. It was positioned in a protected place on the balcony.

The SWR was not worse than 1.7:1 on the 10 and 15-meter bands and 2:1 on the 20-meter band. Using this antenna in the Russian city of Belgorod with a transceiver having 50 watts of output power, easily yielded QSOs with Western Europe at distances of 2300 km and to partially opened areas of Russia in both northern and southern directions at distances of 600 km to the north and 300 km to the south. This once again proves that for the radio amateur there are no completely impossible conditions when it comes to installing a transmitting antenna.

Fig. 3.28 Three-band twisted antenna



However, by using these shortened twisted compact antennas, it is not possible to work effectively in competitions, or to have the extra “punch” to work “DX pile ups”, but they certainly do make it quite possible to successfully operate on the air daily in the course of informal routine radio amateur matters.

Experiments were conducted with truncated twisted window antennas built for the 40 and 80-meter bands. The length of the antenna was 1.2 meters, and the capacity of C1 was 250 pF. The antenna’s SWR on the 40-meter band was not worse than 2:1 within 60 kHz. On the 80-meter band this SWR was reached within 80 kHz. A coaxial cable having a characteristic impedance of 50-ohms was used to feed the antenna.

When testing truncated twisted antennas, compared with an antenna such as a long wire having a length of 41-meters, they lost at least 10 dB on 40-meters and 15 dB on 80-meters. However, official reports obtained by me often were within the limits of “S”- 8 to “S”- 9. A truncated antenna on the low-frequency amateur bands with a 10-meter length of shield made from a thick coaxial cable connected via an "artificial ground" device (for instance, an ***MFJ-931***), was operated successfully through the matching device.

Twisted half-wave antenna

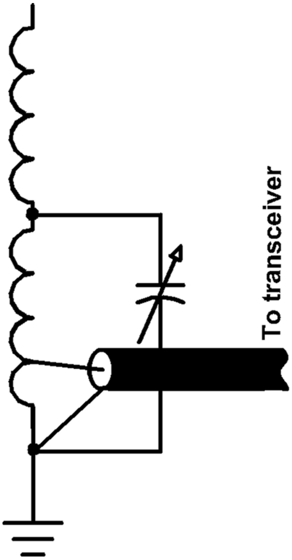
I have conducted experiments using twisted truncated λ/2 antennas, which are theoretically more effective than λ/4 antennas. Antenna matching with the coaxial cable circuit shown in **Fig. 3.29** was used.

Testing was done on the 14 MHz amateur band comparing twisted antennas having electrical lengths of λ/2 with those having electrical lengths of λ/4. All antennas were mounted on 1.2-meter physical length forms.

These tests verified that twisted antennas having an electrical length of λ/2 worked more effectively than twisted antennas having an electrical length of λ/4. λ/2 antennas do not require a ground. Connecting a counterpoise to a λ/2 twisted antenna only had a very slight shift on the resonant frequency of the antenna, but it had a distinct shift on the resonant frequency of a λ/4 antenna.

Twisted vertical antennas having electrical lengths of λ/2 and λ/4 are conveniently used in the 6 through 30-meter bands where the physical to electrical length ratio is high. Such antennas can be located on a balcony, on a roof and in some other cases, where installation of antennas is restricted.

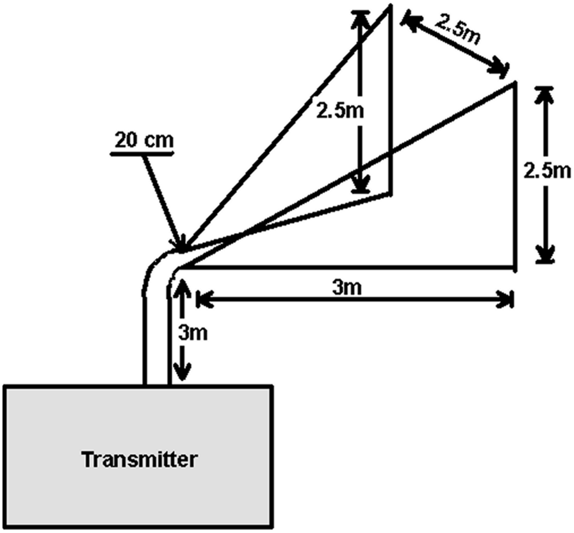
Fig. 3.29 λ/2 twisted antenna



Super broadband antenna

At a station having been involved in electronic warfare activities for some 70 years, I saw an antenna operating over a frequency range from 20 to 200 MHz. This station's antenna is shown in **Fig. 3.30**.

Fig. 3.30 Super broadband antenna

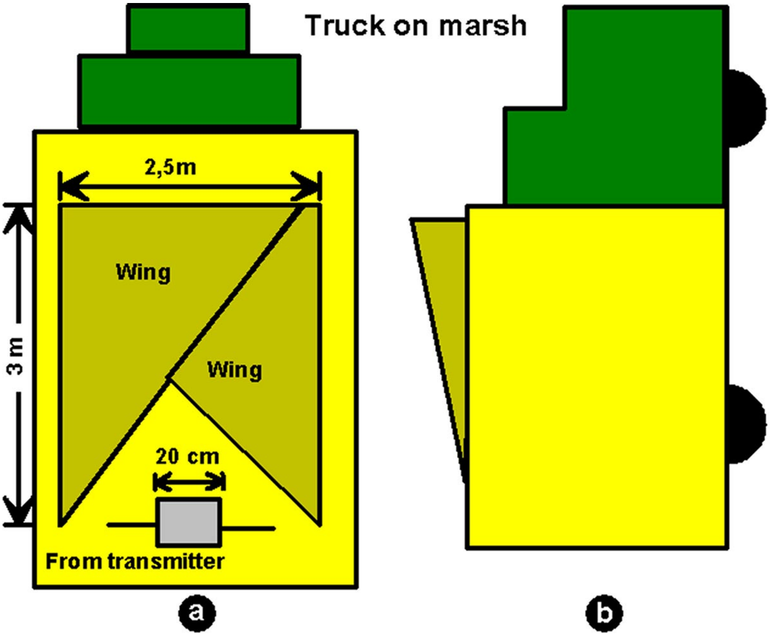


This antenna's principle of operation is similar to that of horn antennas used on UHF and consists of two collapsible "wings" installed on a roof of the automobile. "Wings" are made from rigid metal, on which a copper grid with 3x3-cm openings, is stretched. The sides of the grid openings were carefully soldered. The grid was then coated with anti-corrosion material. The 2.5-meter long open-link antenna feed line was made to have a characteristic impedance of 450-ohms. The line was placed in a protective plastic case.

According to characteristics, this antenna has a SWR no more than 3:1 on all bands. The antenna radiates in only one direction, with the maximum directional radiation pattern being pointed like a horn as an extension of the antenna's aperture. The antenna's directional gain constitutes less than 0.5 dB on 20 MHz and not less 10 dB on 200 MHz. The width of the directional radiation pattern diagram is 90 degrees at 20 MHz and narrows down to 30 degrees at 200 MHz.

In **Fig. 3.31** this antenna is shown in a folded position while being transported on a moving vehicle.

Fig. 3.31 Antenna in a folded position

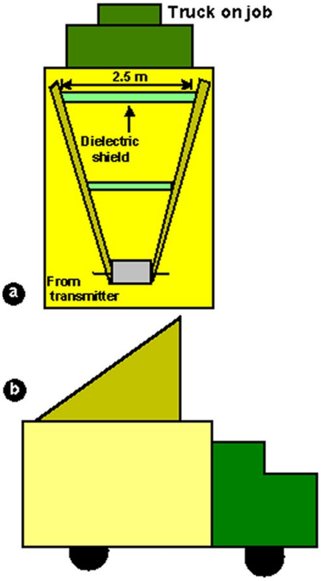


In **Fig. 3.32** the antenna is shown in an open operating position.

This antenna can be used nicely for radio amateur operations. Its continuous frequency coverage includes all of the 15, 12, 11, 10, 6, and 2-meter bands. Its sole inconvenience requires it to use an open feed line having a characteristic impedance of 450 ohms. This excludes it being used with a matching device and a transceiver having an output impedance of 50 ohms.

This antenna can be placed in a loft or attic of a building or be installed on a roof. This antenna's principle of operation is similar to that of horn antennas used on VHF and UHF. The emitted signal polarization of this antenna, when positioned as shown, is mainly vertical, but polarization on the lower frequencies is essentially horizontal.

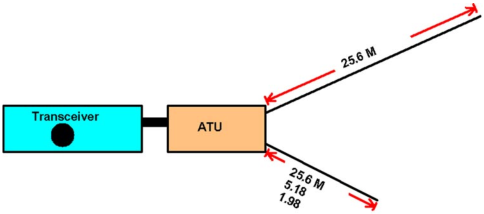
Fig. 3.32 Antenna in an operating position



W3EDP Antenna

W3EDP used this antenna for the first time. His friend W3AWH described it in the March 1936 issue of QST. In those years, using a transmitter power of 15 watts, W3EDP worked Europe on 7, 14, and 28 MHz with this antenna. The antenna circuit is shown in **Fig. 3.33**. The antenna's wire has a length equal 25.6 meters. The length of counterpoise can be equal to the length of the antenna when operating on frequencies of 3.5 through 28 MHz. When operating on frequencies of 7 to 28 MHz, a counterpoise wire with a length of 5.18-meters is recommend. When operating on frequencies of 14 to 28 MHz, the counterpoise can be a length of 1.98 meters. When operating only on 28-MHz it is possible to do without a counterpoise.

Fig. 3.33 W3EDP Antenna



If mounting space is limited, it does not have to be done in a straight line. It may be configured on an angle, bent, or curved. The antenna can be installed vertically as well as horizontally and slanted.

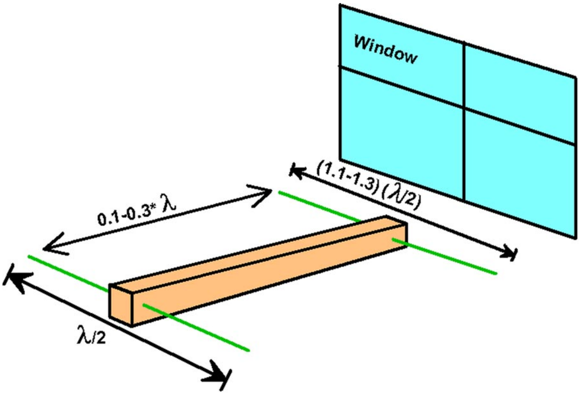
When feeding this antenna, it is necessary to use a regular matching device or a vacuum tube power amplifier. This antenna can connect directly to a matching device or to a vacuum tube power amplifier without using a transmission line.

Despite its simplicity, tests with this antenna have shown it to be very effective in operation. It was easily matched on 3.5, 7, 14, and 28 MHz in addition to 10, 18, 24, and 27 MHz.

A disadvantage this antenna has, when using large power, is that it is possible to get an RF burn from a “hot contact” from the microphone when transmitting on high frequencies. At the same time, the simplicity of the antenna (as well as being the simplest of all constructions in 30 years) certainly justifies its usage, both as a simple country (versus urban) antenna and as a reserve “emergency” substitute antenna. Copper wire having a diameter of 0.8 to 2 mm can be used to build this antenna.

Dipole wall antenna

When compared to the commonly used whip-wall antennas, the dipole wall and room antennas are used rather seldom. This can be explained by the fact that when a dipole antenna is close to foreign objects, these objects easily detune the dipole antenna, distort the dipole’s radiation pattern, and disturb its electrical symmetry to the extent that it negates its many advantages. But, if it is intended to work only in the higher frequencies, then it is feasible to use a dipole antenna with a reflector element (Fig. 3.34) that can help isolate it from these “wall” effects.

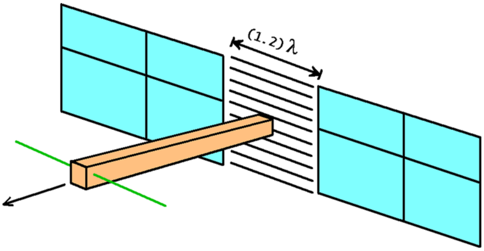


The stripped version of a Yagi antenna is the usual classical $\lambda/2$ active dipole (with two $\lambda/4$ shoulders or wings), placed at a distance of (0.1-0.3)λ from a wall of a building. A parasitic reflector element having a length 10 to 15% longer than the dipole is mounted on the wall. (Antenna elements having these sizes are really easy to make for the 10 and 15-meter bands.)

The reflector element in the given construction (bigger is better) serves well to shield or protect the active dipole from the influence of the wall (and protection from objects behind the wall) on this antenna with quite good results. The maximum radiation exists in the plane containing the dipole and the reflector element and is perpendicular to the plane of the wall.

This type of antenna may be installed on any type of building, including brick or concrete, though metal objects in a building such as heating system pipes, water pipes, rebar in the concrete, or metal window frames, windowsills, etc., can detune a reflector element somewhat. Another version of this antenna that can provide more directional gain by using several reflector elements separated by 1.2λ (see **Fig. 3.35**) is also included in this book.

Fig. 3.35 Dipole wall Yagi with several reflectors



It is usually difficult to install antennas on the wall of a building in a safe manner. This particular antenna is desirable in that it does not require a complicated setup, as its input impedance can be adjusted from 15 up to 70 ohms simply by changing the space (within limits of 0.1 to 0.3λ) between the reflector element and the driven dipole radiator. This allows enough simple flexibility to match an antenna to the feed line.

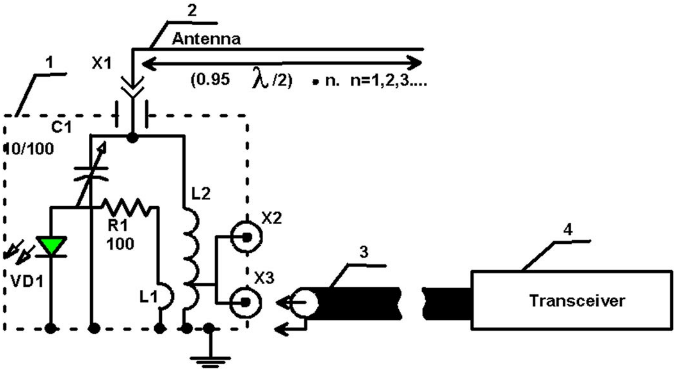
Even if the cable is hooked up directly to the driven element and when the distance between the radiator and the reflector element is 0.2λ to 0.3λ, the SWR and antenna factor appear adequate enough to use effectively.

Effective country antenna

When on vacation in the summertime many radio amateurs operate from rural country areas, forests, national and state parks, and go fishing, camping, hiking, and take an active part in field day campaigns. There is always the question of selecting the right antenna for the trip. So, it is best to build something reasonable, inexpensive, easy to use, plus convenient to transport and setup when camping. The transmitting power used for such operations should be small, yet still sufficient to provide desired communications. It should be simple to tune and rugged enough to avoid being easily broken during field operations.

In most cases, low power operation is carried on in the 14, 18, 21, 25, 27, 28-MHz frequency bands. On these bands, low power operation is especially good this year (2001) and will continue to be good during the coming years - years that are an active part of the Sunspot cycle. An antenna that can operate effectively on these frequencies is presented in **Fig. 3.36**.

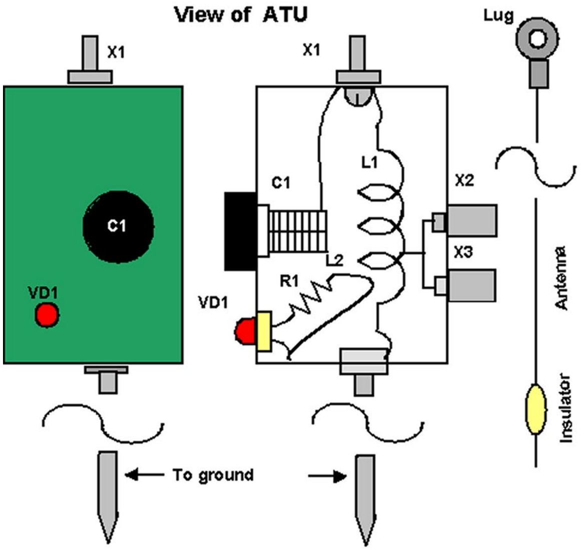
Fig. 3.36 Country antenna system



The "Country antenna system" (**Fig. 3.36**) consists of:

Item 1. a matching device
Item 2. a stranded 1-mm diameter copper wire antenna λ/2 at the operating frequency (taking into account a truncation shortening factor of 0.95)
Item 3. a coaxial cable feed line
Item 4. a transceiver. The matching device is constructed in a box and uses an 80x60x60-mm printed circuit board (**Fig. 3.37**).

Fig. 3.37 ATU matching device



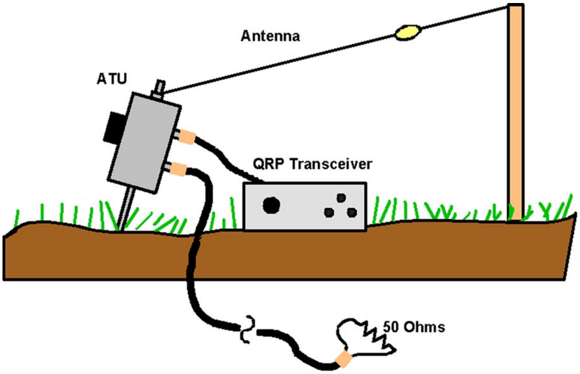
The terminal screw X1 consists of a screw M4 having a length of 20 mm. The antenna uses a lug to connect to X1. The ground rod is made from a rust resistant 4-mm diameter wire 20 cm long. It is connected to the lower cover of the matching network by means of a screw connection. The grounding rod provides some security by having the equipment grounded to it in case lightning strikes near the antenna. Also, it will improve performance of the antenna system by having the matching unit grounded directly to “earth ground”. The upper end of the antenna should be raised as high as possible. The efficiency of the antenna system depends greatly on this.

The light-emitting diode (LED) VD1 serves as an RF tuning meter to indicate (only while transmitting) when the matching device is resonant. A maximum “peak” glow corresponds to the maximum power going into the antenna.

The smoothness (linearity) of its glow during setup of an antenna is determined by selection of a nominal value resistor R1 and the spacing distance between coupling coil L2 and coil L1.

At initial setup of the antenna system at a field location selected for the location of the antenna and ATU matching unit, first connect the antenna (item 2) to X1 of the ATU. Install the coaxial cable (item 3) to the ATU (socket X3) and lead to the place of operation planned for QRP gear. The other end of the coaxial cable should be loaded with a resistor of nominal value equal to the characteristic impedance of the coaxial cable of 50 or 75 ohms. Connect the QRP transceiver (item 4) with a short piece of coaxial cable to connector X2 on the ATU as shown on figure 3.38. Preliminary antenna system adjustments may be made using the ATU's capacitor C1 while watching the receiver's signal strength "S" meter. Next, switch the transceiver to the transmit mode and finish tuning the antenna system by tuning the matching device for a maxim glow on the light emitting diode. Disconnect the transceiver from the short piece of co-axial cable, but keep the coaxial cable connected to connector X2 on the matching unit. Now, the transceiver is installed (instead of the dummy load) and the QRP station ready for operation!

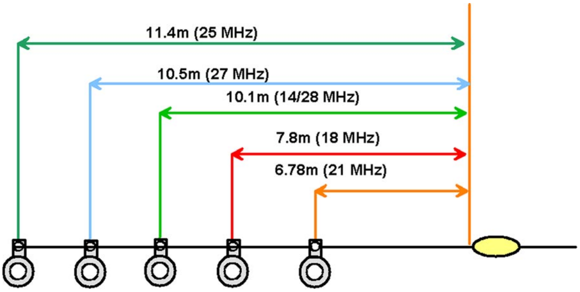
Fig. 3.38 Set-up of a country antenna



Remember the cable connections between the transceiver and ATU play a role in the antenna “ground system” which has an affect on the impedance when tuning. Also, the system can be tuned using a regular transceiver instead of the actual QRP equipment. Now the matching device can be tuned for maximum glow of the LED. An assistant is necessary for this purpose, or the transceiver should be able to withstand operation into a mismatched load while the matching device is being tuned.

The ATU coil, L1 consists of 11 turns of 2 mm diameter wire. The coil is air wound. One end is soldered to the bottom of the matching unit and the other end is

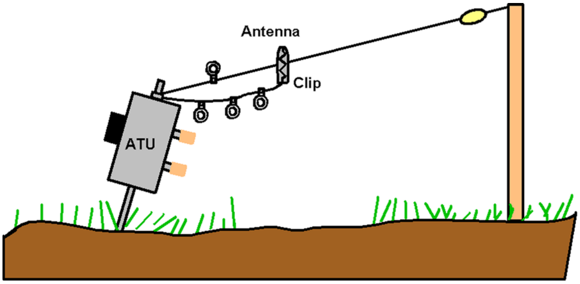
Fig. 3.39 Elements of a multi-range country antenna



soldered to the screw terminal XI. A tap is made on the third turn up from the cold end of L1 to provide good matching to either a 50 or 75-ohm cable. Coil L2 contains one turn of 1-mm wire. The matching device works over a frequency range from 14 to 30 MHz. It is not advisable to change from one band to another by swapping one antenna element resonant on one band for another element that is resonant on another band. It is much more convenient to change taps on a coil and change the resonant frequency of the same antenna element, as shown in **Fig. 3.39**.

When making a transition to another frequency band, the resonance lug on the antenna is connected (or staked) onto screw terminal X1. The excess antenna wire can simply be attached by clipping tightly onto the main antenna element, as shown in **Fig. 3.40**.

Fig. 3.40 Strengthening an antenna element when changing the frequency band of operation



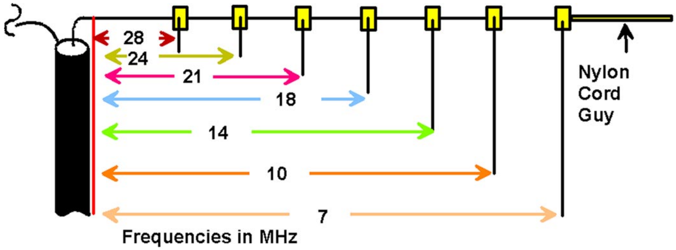
When making the antenna's elements and coils for a matching unit, they should be carefully made according to the description in this book. So, in this case, usually any additional tuning for antenna length will not be required.

The antenna works very effectively having the upper end of the antenna at heights of four or more meters (which is a quite realistic height during an outing of any kind in the country). In my observations concerning efficiency, I found that this antenna's efficiency is similar to other antennas, such as a "Delta", with their upper parts placed at the same height as this single-wire and with the base placed at a height of about 1-meter above the ground.

Simple country antenna

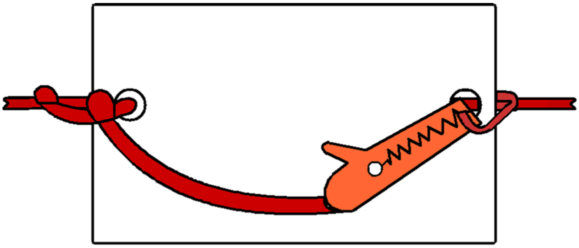
When operating from a campsite in a forest, the installation of an antenna may be restricted and it may be impossible to use a separate antenna for each band. So, it may be necessary to be satisfied using a type of "substitute antenna" for operating on several bands. A very simple antenna can be made according to **Fig. 3.41**.

Fig. 3.41 Simple country antenna



This antenna is a sectional dipole antenna. For operation on any appropriate amateur band, the additive combination of wire sections required to provide a total antenna length to resonate at a given frequency are selected with the help of "alligator clip leads" to jumper across selected insulators in the manner shown in **Fig. 3.42**. Or in other words, "dissect" the antenna enough to leave the desired combination of active element lengths needed to operate on the desired frequency.

Fig. 3.42 Construction of a country antenna



When setting up this antenna, it is necessary to make provisions to have quick access to the switching sections of the antenna. If the center of an antenna is suspended from a tree as shown in **Fig. 3.43**, it can probably be done using a nylon cord to enable it to be quickly raised or lowered. The height of the center of the antenna should be at least five meters. At heights less than this, the antenna is even less efficient. If exact wire lengths are used, the antenna will not require tuning. It is better to use a 75-ohm feed line to feed the antenna, even though it will work with a 50-ohm line. A broadband balancing device will usually improve the operation of the antenna. For an antenna made using wire having a diameter of 1 to 2 mm, the lengths of various sections used to allow operation on different bands of frequencies is reduced from that shown in **Table 3.2**.

Fig. 3.43 A simple country antenna installation

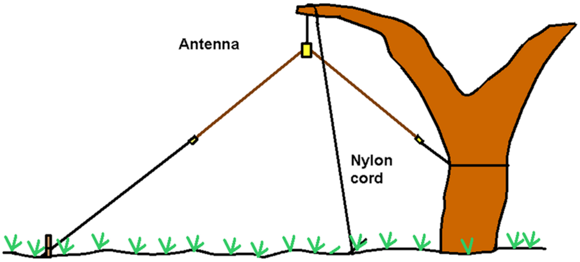


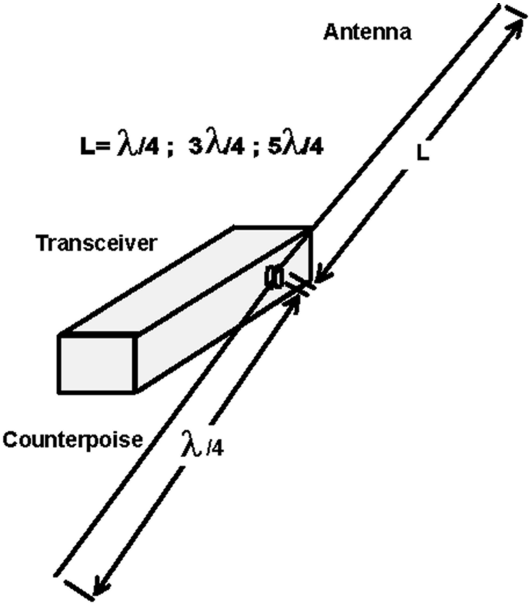
Table. 3.2 the dimensions of a simple country antenna

Band(m)	Length of Sectionals(cm)
10	252
12	294
15	336
17	398
20	506
30	734
40	1050

The insulators used between sections of the antenna can be made by homebrew from printed circuit board, or the standard egg-type insulators will suffice. The length of the flexible wire having an “alligator” clip was not taken into account in the length of the previous section, as it is attached to the previous antenna element. However, this length is taken into account when determining the length of the additional sections of wire.

Direct fed country antenna

Fig. 3.44 Country antenna connected directly to the transceiver



One of the simplest country antennas is the long-wire antenna connected directly to the output connector of a transceiver, as shown in **Fig. 3.44**. The length of an antenna for the 160 and 80-meter amateur bands can be made equal to λ/4. For the 17 through 40-meter amateur bands, it can be made equal to 3λ/4 and for the 6 through 15-meter amateur bands it can be made equal to 5λ/4. For effective work, the antenna required though one counterpoise is a length equal to λ/4 or equal to the antenna length. The counterpoise is connected straight to the antenna socket, as shown in **Fig. 3.44**.

Despite its simplicity, this antenna works effectively and will be sufficiently matched with an output stage of the transceiver having an output impedance of 50 to 75 ohms. The antenna may be made from a copper wire having a diameter of 0.5 to 2 mm, or as a last resort, from aluminum wire. The antenna should be suspended as far as possible above the ground and be spaced as far as possible from metal or any other conducting objects.

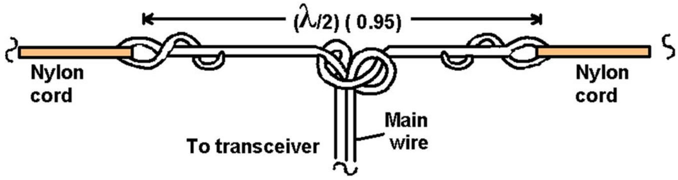
It is desirable that one end of the antenna be mounted higher than the other end of the antenna wire. If this is not possible when operating on the 160 and 80-meter amateur radio bands then it may be desirable to suspend the middle of an antenna to the maximum height needed.

Inexpensive country antenna

The simple country antenna can be made for experimental QRP operation using a network power cord. For practical considerations, the characteristic impedance of network power cords was measured and found to be within the limits of 36 to 60 ohms. The impedance is lower for a cord with thick core wires and high for a cord with thin core wires.

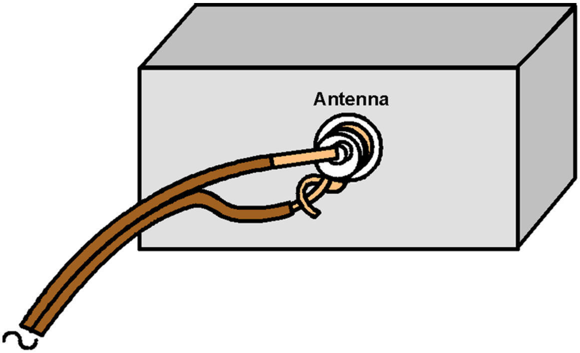
When making the antenna, the network power cord is cut to an electrical length equal to a quarter of a wavelength at the operating frequency and it is knotted as shown in **Fig. 3.45**. This type of antenna construction allows one to avoid using a center insulator. The end leads of an antenna are knotted to a nylon cord serving to support the antenna between trees. This antenna can be made useful for high-frequency operation on the 10, 12, 15, 17, and 20-meter bands. If a thicker network cord is used, then it is possible to make such an antenna for operation on the 30, 40, and 80-meter bands.

Fig. 3.45 Country antenna made from a network cord



On the end of a network cord used as a HF transmission line, the connector is not hooked. On one end of the cord, one conductor is built up and enlarged with solder to a diameter that could be firmly inserted into the transceiver's female coax antenna connector. The other conductor, of this same end is connected to the transceiver's chassis "ground" at the transceiver's antenna connector as shown in Fig. 3.46. Using such a hook-up for connecting this transmission line to the transceiver simplifies the construction of this antenna even more and reduces the cost.

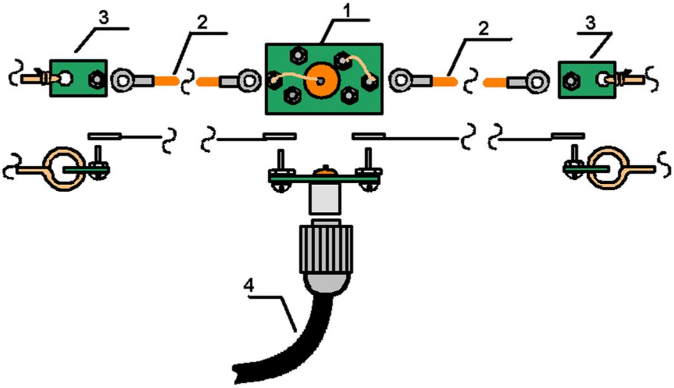
Fig. 3.46 The antenna connection to the transceiver



Antenna for QRP expedition

This easily folded simple dipole antenna for use on QRP expeditions can be made according to **Fig. 3.47**.

Fig. 3.47 A simple folding antenna for QRP expedition



On a plate made from a printed circuit board (Item 1), the antenna connector hardens on which output clip-leads are fastened to connective screws for use as terminals. The connector contacts should be soldered to reduce the chances of contact failures. Then, they should be enclosed with quick-setting automobile-type epoxy to provide protection from the weather.

The antenna consists of an appropriate pair (or set) of two λ/4 active radiating wire elements which are required to form a dipole antenna (Item 2). It is suggested that one have additional pairs (or sets) of λ/4 elements available as back-ups for other frequencies. These can be stored in a carrying package to permit swapping out to operate on other bands scheduled for the QRP expedition. They can be easily connected to the central insulator (Item 1) and to the end insulators (Item 3), with the help of their solder lugs. These insulators are made from printed circuit board material. On one end of the insulator is the screw for an antenna fitting. Attached on the other end is a guy wire made of nylon cord. A coaxial cable (Item 4), with coax connectors on its ends, is used to connect between the antenna's central insulator and the transceiver.

The coaxial cable should have a length of 10 to15 meters to provide some freedom of arranging the antenna at an installation site of the transceiver situated in a concrete building.

This demountable antenna is easily made and can be used on several selected bands of frequencies, and it uses an optimum approach for field operations.

Obscured by clouds

PART 2

Antennas
for
Special Bands
or
Frequencies

PART 2: Antennas for Special Bands or Frequencies

In this part of this book only the antennas pertaining to three particular frequency ranges are discussed: 136 kHz and 27 MHz. But, certainly antennas of other ranges have the particular features that can be applied to urban conditions. The effective antennas for 136-kHz are rather complicated for placing not only in urban conditions, but also outside of the city. Even outside of the city, it is hard to find a suitable place for an effective shortened vertical 136-kHz antenna. Therefore, in this part of the book the theoretical operational analysis of antennas for long-wave communications is given which will allow the radio amateur to learn a "how to" approach the construction of these antennas in view of all possible conditions. Practical instructions are provided for 136-kHz antennas as designed and tested by me from actual experience.

This includes a digest of different design versions of antennas for the 27-MHz CB band that were checked and tested by me at different times since 1991, when I first began work on this range. (This band was closed to Russia prior to 1991.) Shown are various instructions that allow installation of a CB-antenna under practically any urban condition.

The tree on a stone

CHAPTER 4: ANTENNAS FOR 136 KHZ

Russia permitted radio amateurs to use the frequency section 135.7 to 137.8-kHz, in a long-wave region of the electro-magnetic frequency spectrum at the end of 1998. Shortly before that, this section was authorized for radio amateur operation in many countries of Western Europe. In the USA, 160 to 200-kHz has been used for a long time for unlicensed extremely low power radio links. Probably, in due course of time, radio amateurs in Russia and Western Europe will be authorized to work in this range of frequencies, also.

The activity of radio amateurs in Russia and in Western Europe on 136-kHz is small primarily because of the absence of equipment and antennas. The antennas on long waves define an overall performance of a channel link, and consequently the radio sets. Effective approaches used to build antennas on the HF bands is inapplicable to antennas at 136-kHz.

Any antenna for 136-kHz operations constructed in amateur conditions will require personal set-up. Any long-wave band antenna will have small band pass because the loading coil inductors have high Q (quality-factor). Tuning will, by necessity, be extremely sharp at this frequency. Any change of season, weather, and even changes of the time of day, will result in it being very unstable. Any 136-kHz antenna will require frequent manual adjustments. Basic construction and methods of adjusting such antennas will be covered herein.

Features of 136-kHz antennas

One of the features of long-wave radio propagation is that electromagnetic waves having horizontal polarization undergo strong absorption in both the surface of the ground and in stratums of the ionosphere, owing to how they are spread in short distances. Radio waves having vertical polarization and extending orthogonal to the surface of ground, or at a small elevation angle, are spread along the Earth with small losses for long-distances, which are defined only by transmitted power. Depending on power it is possible to overlap any distance on a terrestrial globe. The old LORAN-C system of global radio navigation used a section of a long-wave region 90 to 110-kHz and ensured determination of coordinates at most surface locations on the earth. Presently, determination of coordinates uses the satellite system called GPS. GPS receivers having the dimensions of a small soapbox, enable even an individual man to quickly find his location within a few meters of anywhere on earth without any effort.

The elementary antenna radiating vertically polarized waves is a vertical tower. The construction of a full-scale quarter-wave tower for long-wave communication is not feasible, not only for radio amateur purposes but also for professional radio communication purposes. Therefore, shortened truncated vertical antennas with capacitive load “top hats” are used. Small towers, with heights up to 50-meters, achievable for some radio amateurs, will have radiation resistance of no more than 0.1-ohms on the 136 kHz range. To achieve effective performance of an electrically short vertical antenna without being tuned to resonance by some sort of antenna matching system is not a viable option. The antenna system is usually setup with the help of a loading-coil inductor. The ohmic resistance of such a coil at 136-kHz is usually larger than 10-ohms, thus considerably diminishing the common antenna efficiency. Operating such a vertical antenna requires an effective grounding or counterpoise system. However, the resistance losses in a counterpoise system are high, and if not properly constructed they can degrade an antenna factor even more. Mihail Shuleykin, in 1924, commenting on experimental data, presented this formula for determination of losses in an earth system:

$$R_n = A\,\lambda / \lambda_0,$$

Where:

R_n - resistance of losses,

A - efficiency depending on quality of grounding,

λ - working wavelength,

λ_0 - the self-resonant wavelength of the antenna (The antenna’s own natural self resonant wavelength is the wavelength on which antenna has a natural free self resonance determined only by its mechanical size, and independent of any adjusting circuits or compensation being applied to it.) However, it is possible to measure the self-resonance frequency of an antenna system using the usual high-frequency bridge.

Any one attempting to build a long wave vertical antenna for radio amateur purposes would find out that even with an antenna height of 40 meters and with a top loading capacitive hat, the antenna would have a natural self resonant frequency of less than a 100-meter wavelength.

There is the capability of theoretically defining the efficiency of the radio amateur system. With the determination of the wavelength for 136 kHz being 2200 meters and by assigning a ground quality factor of A=1 (The quality factor of A=1 is like having a mirror for radio waves which is virtually impossible to ever achieve under radio amateur conditions), plus an amateur long-wave tower 40 meters high with the self resonant wavelength of the tower at 100 meters, we get:

$$R_n = \frac{2200}{100} = 22 \text{ ohмs}$$

In reality, factor A will lay within the limits of 6 to 10 when using 10 to 30 counterpoise wires with lengths no less than the length of the vertical part of an antenna and located under it. It is understandable, when the losses in a ground system are combined with the active losses of a loading coil, then the antenna factor of vertical antennas of a long-wave range will be rather small.

It is possible for radio amateurs to use fractional wavelength magnet loop transmitting antennas for operation on 136-kHz. To work effectively, the perimeter of such a magnetic loop antenna should have a length of at least of 220 meters. For the antenna to operate more efficiently by using vertical polarized waves it is necessary that the loop be mounted vertically. Also, it is necessary to use effective matching networks to match this loop to a transmitter.

For a radio amateur to install and to match such a huge vertical magnet loop-transmitting antenna is not a simple matter. If one made the loop using wires having a diameter of 2 to 4 mm, the antenna efficiency factor will be too small because of a large ohmic resistance drop. To reduce the ohmic loss, an efficient transmitting loop requires the use of low loss copper pipes having a diameter of at least 100 mm.

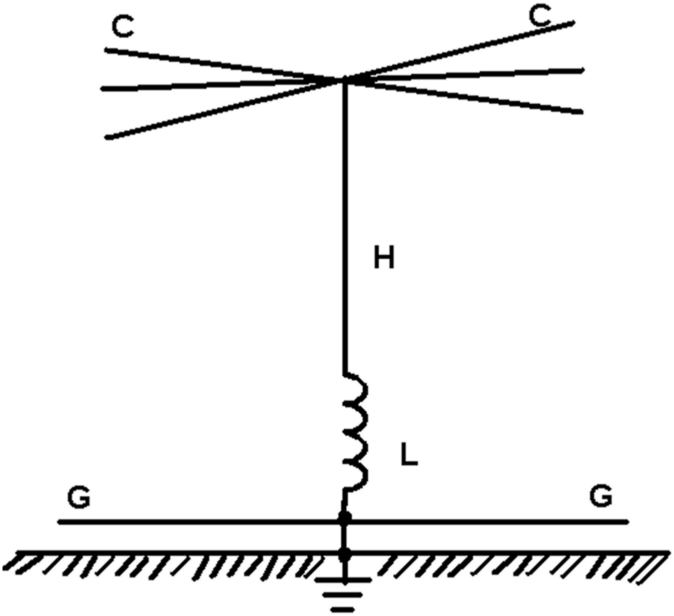
For radio amateurs, it is possible to attempt to use vertical freestanding full-scale loops having lengths from 80 to 160 meters, tuned for operation on 136-kHz. Theoretically, the antenna efficiency factors for loops can be even better than for short vertical long-wave antennas. For long wave reception, multi-turn tuned loop antennas are often used. Because of their directional properties, the selection of stations at a given direction is possible. Thus, it is desirable that the antennas be capable of being rotated at least 90 degrees. This complicates its construction.

Optionally, using an electro-statically shielded receiving magnetic loop for long-wave reception results in a better signal-to-noise ratio, plus providing the directional feature. We shall consider each type of an antenna separately.

Vertical broadcast antennas for long wave

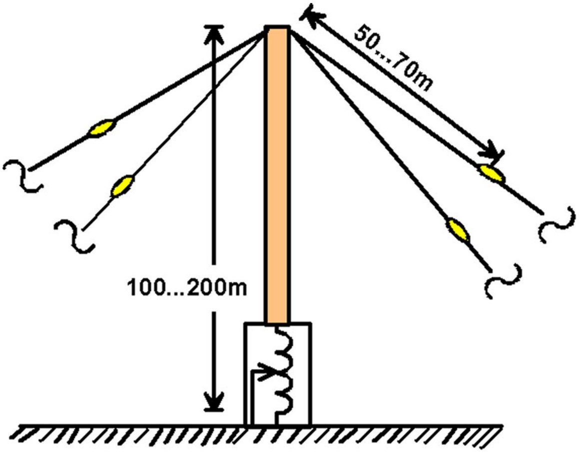
Mention was made earlier about the construction of a vertical antenna for 136-kHz (**Fig. 4.1**). It is based on using a system of capacitive loading C to shorten the height, and tuning it to resonance on an operating frequency in the long-wave region with the help of a loading coil L, plus using a counterpoise ground system G.

Fig. 4.1 Construction of a short vertical antenna for 136-kHz



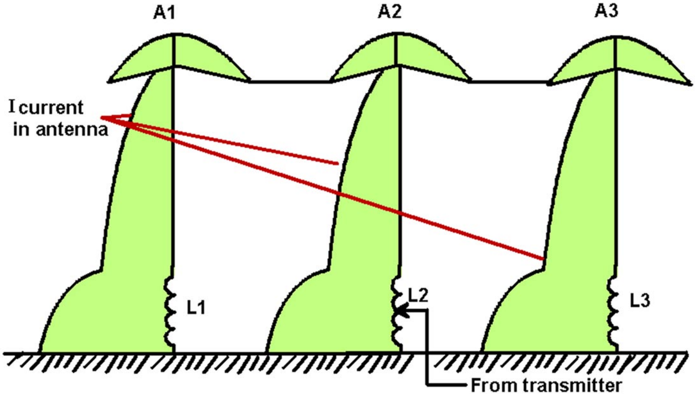
To increase the antenna efficiency factor of a 136-kHz antenna system, the self-resonant frequency of an antenna is lowered by using capacitive load C. It is necessary that it have as low a resonance frequency as possible. Increasing a length C and increasing the number of wire of a capacitive load can reach it. In practice long wave antennas use masts having a height of 100 to 200-meters and a capacitive load system made of from about hundred conductors (**Fig. 4.2**). The large long wave broadcasting antenna loading coils can occupy whole rooms. They are made from silver-plated copper tubes or polished copper pipes having a diameter of 40 to 100-mm to increase their quality-factor.

Fig. 4.2 A vertical antenna for a long wave broadcasting station



The ground system of long wave antennas can be made with the help of a metal grid positioned under the antenna, or it can consist of a lot of (more than 200) counterpoise wires having a length 1.5 times the height of a vertical part of the antenna mast. The counterpoise wires are located under the capacitive load of the antenna. The counterpoise wires are usually place at a small height (10 to 50-cm) above ground. To increase the antenna factor of an antenna system, connect three antennas in parallel as shown in **Fig. 4.3.** The antenna A2, with the help of a loading coil L2, is tuned to resonance on the frequency of operation in a long-wave region. It is the shunt fed grounded antenna. The supplementary antennas A1 and A3 are the grounded antennas of the upper feeding and will be fed through a jumper from anti-node of voltage of antenna A2. The antennas A1 and A3 with the help of coils L1 and L3 are tuned to resonance on appropriate long-wave frequencies. By appropriate selection of the distances between antennas A1, A2, A3 and selection of the individual frequencies for setting-up antennas A1 and A3, it is possible to change the maximum azimuth lobe of the antenna system's directivity diagram toward antenna A1, or toward antenna A3, thus achieving directional broadcasting antenna arrays.

Fig.4.3 Three-tower directional broadcast antenna array



For long wave low-power transmitters, which are operationally used as aircraft radio-beacons or used for local low-power radio broadcasting stations, apply these simplified antennas constructions. To secure a pi chart of directedness the T-antenna exhibited in **Fig. 4.4** is used. The capacitive load of this antenna contains from three up to ten conductors. From each of these conductors, a separate wire leads to thecommon antenna loading coil. To achieve the most directivity in a fixed azimuth direction, the L-antenna (**Fig. 4.5**) is used. The maximum radiation pattern lobe is toward the antenna appearing as a capacitive load. The system of counterpoise wires of these antennas is positioned under a capacitive load with a point of a divergence of beams positioned in geometrical center of a T-antenna (**Fig. 4.4b**). For a L-antenna the counterpoise wires are placed in the direction of radiation of the antenna (**Fig. 4.5b**).

Fig. 4.4 T-antenna

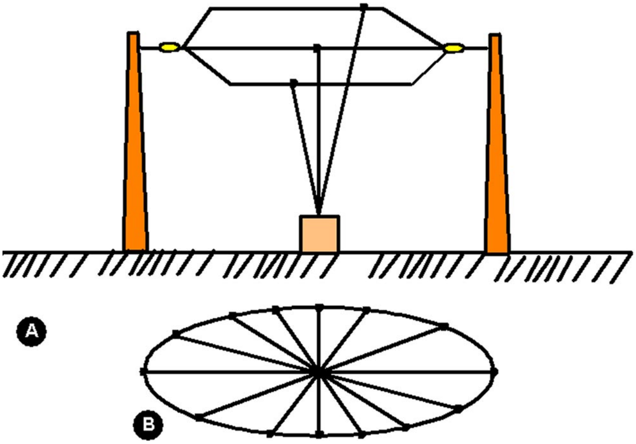
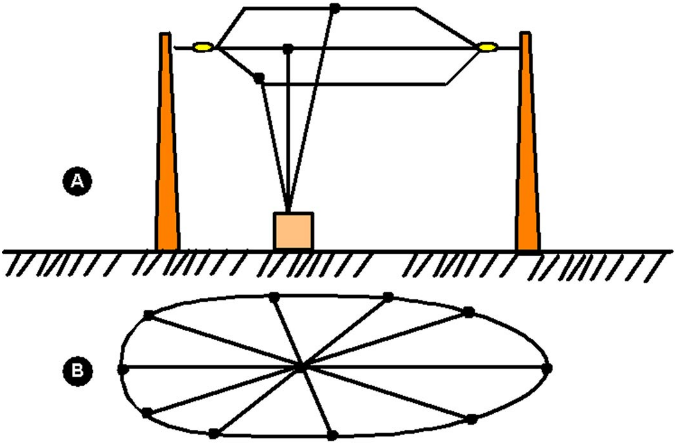


Fig. 4.5 L-antenna



The antenna fields of long-wave radio stations need larger terrain and require larger construction expenditures.

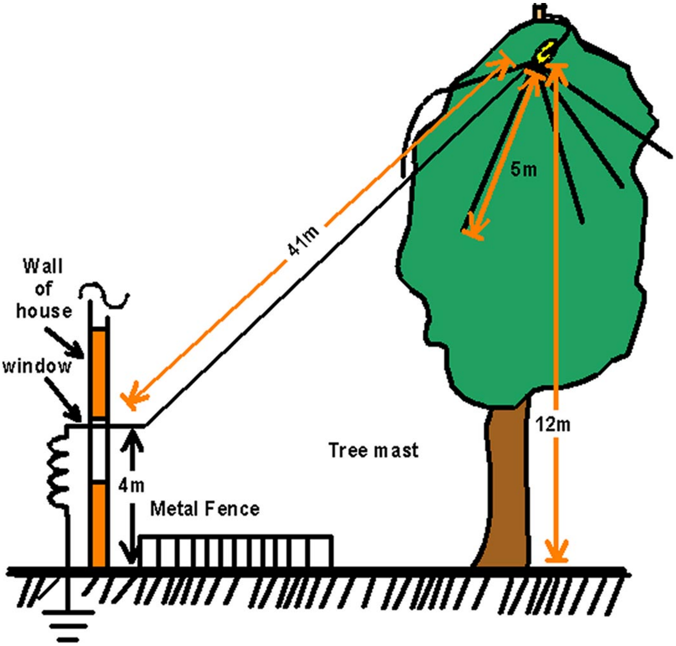
Radio amateur antennas for 136-kHz

As was exhibited above, antennas for the long-wave band can provide acceptable operation only if truncated vertical antennas are used. The radio amateur wanting to operate on this interesting range should initially decide whether an existing HF antenna will be used and then matching it to 136-kHz, or else build a separate antenna for 136-kHz. The latter is most desirable and will provide a maximum overall performance. For an effective work of a long-wave antenna, the self-resonant frequency of the antenna system must be as low as possible. For this purpose the vertical part of an antenna should be positioned at the greatest possible height. The capacitive end loading of the main radiator should be made from not less then 3 conductors. It is desirable that each conductor used in the capacitive load have its own wire connecting to the antenna loading coil as shown in **Fig. 4.4** and **Fig. 4.5**. This carries over to lowering the ohmic losses in the vertical part of the antenna. Certainly, in a realistic situation, construction of such an antenna in a city is not always possible.

I experimented on 136-kHz using a long-wave antenna having a length of 41 meters with the upper end at the height of about 12 meters above the ground level.

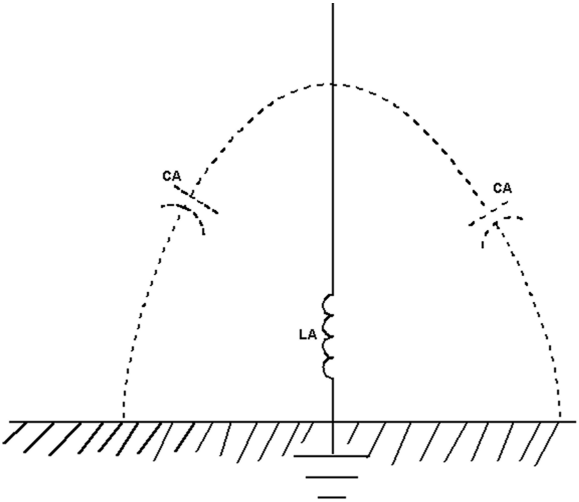
It was supported on a tree. The capacitive load was made of five conductors, each 5-meters long. Coaxial cables having a diameter of 12 mm were used with shield/ braiding connected to the long wave to build the capacity “umbrella”. The end leads of the cable were protected by a coating of regular tar (of the type used as coating to preserve timber). The capacitive load was evenly distributed on the tree. The black coaxial cable was well masked between a dark branch and the fulcrum of a tree, so it was practically imperceptible from the side. Unfortunately, I failed to make a solder connection of the braid/shield of the coaxial cable with the antenna radiator, which I have subsequently bitterly regretted. Instead of soldering, the wire on the end of the long-wave antenna was carefully striped and the shields of coaxial cables were fastened and then pressure gripped together. The junction was wrapped with Scotch tape (**Fig. 4.6**).

Fig. 4.6 Practical construction of a 136-kHz antenna



The scheme of this 136-kHz antenna is exhibited on **Fig. 4.7**. The antenna consists of a circuit LA, which is physically made as a loading coil, and capacitor CA, which consists of a capacitive load. Capacity of this capacitor to a great extent depends on quality of grounding of the antenna.

Fig. 4.7 The schematic of a 136-kHz antenna



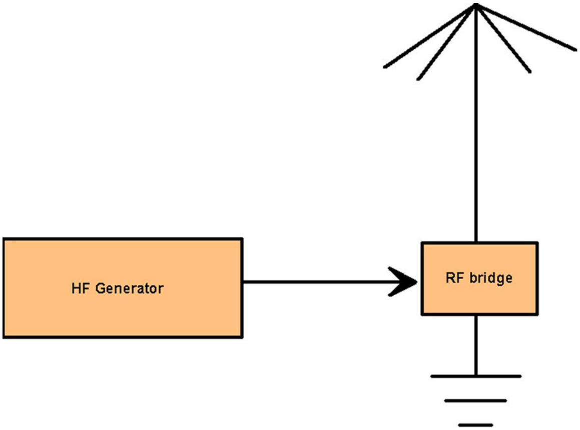
The resonant frequency of circuit LA/CA should equal 136-kHz. For a capacitive load to vary the parameters, the variations of the physical dimensions require sufficient space, which often is hampered in reality. Thus, to tune the system to resonance, this is usually done with the help of loading coil LA.

For a qualitative determination of the antenna efficiency factor for operation of the antenna on 136-kHz, it is necessary to define the self-resonance frequency of the antenna. It can be defined with the help of the high-frequency bridge and oscillator producing signals in the long-wave range. The method of measurement is exhibited in **Fig. 4.8**. The resonance frequency of my antenna was defined by hooking up the HF bridge of the antenna and its earth ground system in the manner shown in **Fig. 4.8**.

For my antenna, the resonance wavelength of the antenna appeared to equal 190 meters. With ideal grounding the resistance of the losses in the antenna system can be defined according to the above formula; and it numerically equals:

$$R_{losses} = \frac{2200}{190} = 11.6 \text{ ohмs}$$

Fig. 4.8. Determination of theself-resonance frequency of an antenna



To initially determine the maximum necessary loading coil inductance, it is necessary to find the capacity of the real antenna system that includes the counterpoise wires. To determine the capacity of the antenna's comparative counterpoise, an RLC meter (a meter that measures: R for resistance, L for inductance, and C for capacitance) model ELC-131D was used. Use such equipment rather cautiously since this equipment can be damaged from a voltage discharge such as from an electro-static potential being accumulated by the antenna system, or by high-frequency voltage received from a powerful nearby local radio station,

When using an RLC meter to make measurements, it is necessary to do it in calm weather when there are neither thunderstorms nor precipitation that can electrify an antenna and damage the meter. It is desirable to conduct measurements when the powerful local broadcasting transmitters are turned off and communications centers are not working. To eliminate high-frequency interference from bridge input circuits, a 1000 to 4000-pF capacitor is connected and turned on to bridge to the RLC meter. The measurement of capacity is made on the difference between the observations of the equipment with the antenna system being first connected, then without it.

The capacity, measured by the RLC meter, appeared to equal 190 pF for a substitute “ground” system using the pipes of the hot water heating radiator system. The value of this capacity did not satisfy me. I have concluded, from reading reference literature that it is possible to achieve large values of capacity with an antenna’s “ground” system. Physically, the greater the capacity of the antenna above ground, then the greater will be the antenna current flowing between the antenna and ground, and the better the antenna efficiency factor will be. To increase capacity between an antenna and ground, the reference literature recommends using counterpoise wires under the antenna to make “ground” from a common point in a parallel with grounded metal rods. Unfortunately, under my antenna there was an asphalt road, and there was no possibility of putting counterpoise wires on it or under it. But it was helpful to me that the people living in the first floors of the houses had converted the yards around their houses into flower gardens. Each section was carefully fenced. The fences used metal posts sitting in the ground, and they were fitted with aluminum and iron wire fences. All of these manmade “circuits” of wire fences were interlaced among themselves, plus providing the advantage that each fence was making some electrical contact to the earth.

In addition, these kitchen gardens were watered daily; so during a dry summer, the ground provides qualitative crude but good conductivity for me. It was only necessary for me to connect to this “circuit”, and a perfect grounding for the antenna was provided! After measurement of capacity of the antenna together with this ground circuit the equipment showed a value of capacity between antenna and ground of 260 pF. Using this capacity, the loading coil was calculated. I used the following formula to determine inductance:

$$\mathrm{L} = \frac{2{,}533 \cdot 10^{7}}{F^{2} \cdot C},$$

Where:
L - in milliHenry,
C - in picoFarads,
F - in kiloHertzs.

The calculated value of inductance was 5.26-mH. This value required readjusting during setup, therefore it was necessary to provide a method of tuning.

I decided to make the loading coil into two separate coils. One of them was made using a plastic bucket as a form. Both were meade with a slide control for adjusting inductance in small increments and with three taps for broader step tuning. The other coil was made using a three-liter glass bottle as a form with coil taps provided for rough steps to tune the antenna to resonance (**Fig. 4 9**).

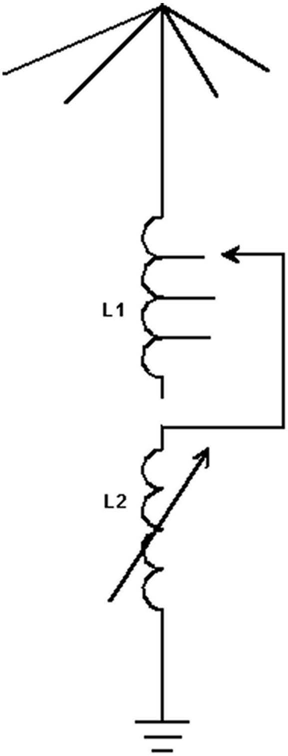
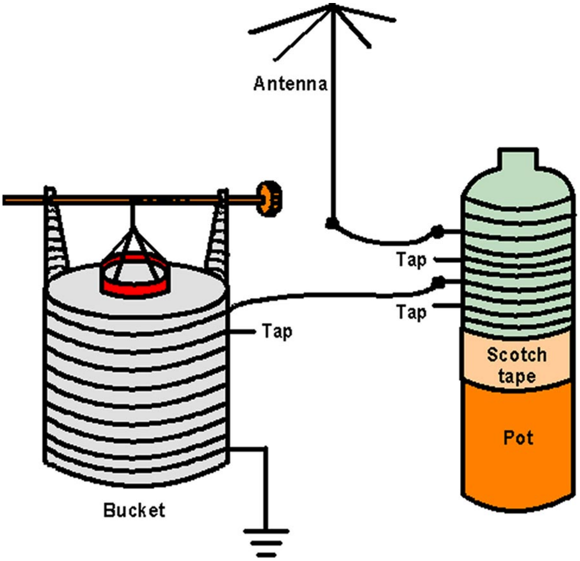


Fig. 4.9 Schematic of a 136-kHz antenna using loading coils

I introduced some tuning variation of the inductance with the help of a short-circuited 5-cm wide copper foil coil which, with the help of a 10-mm diameter screw, smoothly lowered the shorted coil partially into the bucket coil form (**Fig. 4.10**) to provide vernier control. It is also certainly possible to make a variable inductor coil as a variometer, but in my opinion, construction of a variometer is too complicated to be build by most radio amateurs.

Fig. 4.10 A practical contruction of loading coils



The loading coil was connected in series with the antenna. During transmission time, this coil will be subjected to high voltage – tens of kilovolts. The coils were insulated from the desktop in which the system of loading coils were installed. The small coil was insulated with the help of additional three-liter bottles to which the coil was attached by adhesive tape as shown in **Fig. 4.10**.

The coil inductor, formed on a three-liter 16-cm diameter glass bottle, used 120 turns of 1.0-mm diameter copper wire spooled onto a length of 16 cm resulted in a total inductance of 1.4-mH. Throughout the coil, a tap was made every 10-turns. Epoxy lacquer was used to coat the coils after the turns were held in place at three places by a 3-cm wide tape, which was placed from the upper edge of the coil to its lower edge.

When building the basic loading coil, I used a 25-cm diameter plastic bucket over which was spooled 180 turns of 1.0-mm diameter wire with a length of 29-cm. The inductance of the coil was 4.8-mH. Increasing mutual coupling between the short-circuited coil and the basic loading coil decreased the inductance of the basic coil to 4.5-mH. In the top of this coil, 3 of the top, 10-turn taps were made available for possible tuning the coil to resonance.

The pure resistance of two active sequential coils, measured with the help of the bridge on a direct current (not RF) mode, was 4.5-Ohms. ***The transmitting antenna for 136 kHz was ready!***

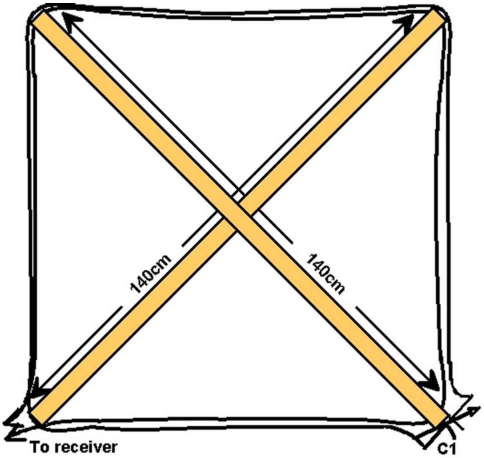
Now, a separate receiving antenna was necessary.

Receiving antenna for 136-kHz

The magnetic receiving antenna for 136-kHz was made on a remote spider with the dimensions shown in **Fig. 4.11.**

The antenna contained 140-meters of 6-mm diameter coaxial cable with the braid/shield and center conductor connected together. Building an antenna from cheap thick flexible insulated wire is also an option. The antenna was tuned to resonance with the help of a

Fig. 4.11 A practical construction method of a magnet antenna for 136-kHz



large triple variable capacitor from an old vacuum tube receiver. It had a built-in vernier capacitor that allowed smooth adjustments. The coupling coil contained 10-meter length of the same coaxial cable from which the antenna was made. The coil was supported with the help of Scotch tape. The antenna was positioned on the window that allowed for reception tests from the southeast to westerly directions. The house blocked the north side and reception from that direction was out of the question. The antenna was precisely tuned and the directivity was clearly verified by reception of lightning discharges from known directions of thunderstorms and from some impulse serial signals of unknown origin.

Experiments with transmitting antenna

Having assembled the antenna system according to **Fig. 4.9**, I immediately connected it and a system of counterpoise wires to the high-frequency bridge. Then the antenna system was tuned to resonance on 136-kHz. An input impedance value of 120 ohms was determined. If the resistance of the coil (4.5-ohms) is subtracted from it, we obtain the resistance of the counterpoise wire system of 115 ohms. This final result is rather approximate because the coil's resistance is actually larger due to the skin effect at a frequency of 136-kHz. It is presumed also that the coil capacitor system (capacity of the antenna) is precisely tuned to resonance on 136-kHz, meaning that the reactances of the coil and capacitor, which are opposite in sign (±), cancel each other. This is very important, as the reactance of a loading coil having an inductance 6-mH at the frequency 136-kHz produces 5.12-kilo ohms. Any detuning of the antenna from the frequency of measurement sharply changes its input impedance. This is very visible on the HF bridge.

As mentioned above, the ideal ground impedance for such an antenna is 11.6 ohms. I have measured real ground impedance equal to 115 Ohms. So, the ground losses for my antenna is more than 100 Ohms! Thus, it makes no sense to worry about the efficiency factor for such an antenna.

Obviously an antenna efficiency factor of such an antenna will be rather small (possibly near 0.01%), but under my actual conditions, I could not improve on its parameters. Neither variation of height or the installation of a more effective ground system helped and thus, it was necessary for me to be contented with it.

I decided to use a low frequency oscillator to transmit through a rebuilt audio amplifier from an old audio recorder. The measured output power on a 4-ohm load was 15 watts at 136-kHz. Unfortunately, it was not known what impedance the amplifier source had at this frequency. The 4-Ohm load resistance was selected because it was assumed to be the impedance of this amplifier. As for matching the amplifier to the antenna, I used a coupling coil (**Fig. 4.12**), which was wound onto the bottom of coil L2. The selection of the number of turns onto this coil for matching the impedance of the amplifier with a loading coil is important and critical.

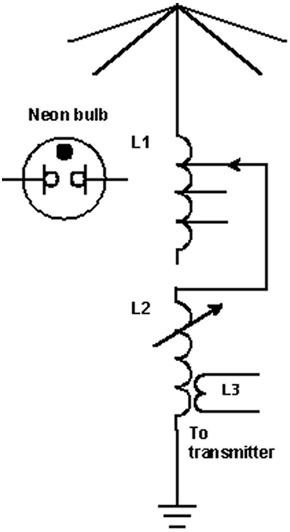


Fig. 4.12 matching an antenna system to a power amplifier

I sequentially changed the number of turns on coil L3 while tuning the antenna to resonance as I measured the HF voltage on coil L3. This was observed on an oscilloscope while also inspecting the wave-shape of the output signal.

Setting up the antenna to resonance is rather critical. To initially setup the antenna for resonance, I made an RF voltage indicator. For this, I used a neon bulb, held by adhesive tape near the center of coil L1 from the inside of the bottle on which it was wound. For a qualitative measurement of antenna current, I also used a homemade small-sized HF-voltmeter, connected in series with the wire going from coil to ground (see **Fig. 4.13**) It was switched to a 20-centimeter length of the wire. The maximum antenna current was obtained when the amount of turns on the coupling coil L3 was equal to 40.

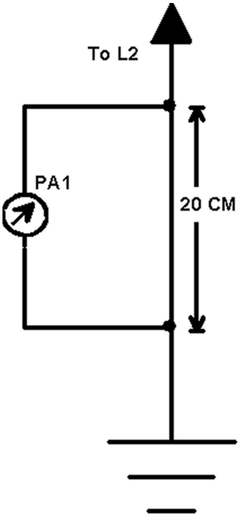


Fig. 4.13 Hook-up of equipment to set-up the antenna

On the end of coil L2, and especially at L1, when 15 watts of power is being delivered to the antenna at resonance there is tens of kilovolts present. The wires leading to a vertical part of the antenna through a window frame, was made from a 12-mm diameter coaxial cable with the exterior braid/shield removed.

While using a long screwdriver, in an attempt to reattach an unplugged neon bulb of the RF voltage indicator from the inside wall of bottle/coil L1, there was suddenly an arc between turns of the coil. This occurred on the outside of the bottle causing a sting from the screwdriver on the inside of the bottle and which burned a hole through the glass bottle. As I removed the screwdriver, the arc then jumped onto adjacent turns of the coil. The proximity of the screwdriver to the upper turns of the coil and to the antenna connector was accompanied by the familiar sparking noise of voltage discharging between the antenna and the screwdriver. It was necessary to remove the turns damaged by the arc, after the power was turned off.

Setting up the antenna system is not hard and the initial resonance of the antenna system is easily determined. If the antenna system is tuned lower than 136-kHz, then reducing the inductance of coil L1 can tune the antenna into resonance with the help of a smooth variation of inductance L2. If the antenna system is tuned above 136-kHz, then increase the inductance of L1.

With the transmitter turned off, variation of L1's inductance should only be made by soldering to coil taps on the end nearest to L2. Using "alligator clip leads" should be avoided because they result in sparking at the place of contact and make the correct set up of the antenna to resonance impossible.

High voltage in the order of tens of kilovolts may be present on the end of coil L1 when the antenna system is at peak resonance. Therefore, tuning the circuit to resonance using variable capacitors connected in parallel to coils L1 and L2 is impossible. However, it is possible to switch taps on the coils to vary their inductance, which in turn varies the resonance of the antenna system.

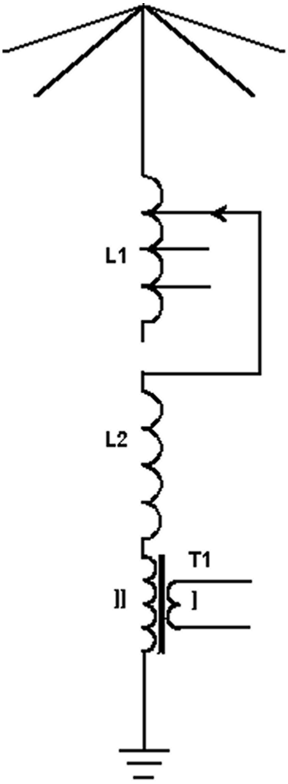
In my experiments, switching coil taps on L2 did not cause significant variation of the antenna current, so subsequently, I only used coil L1 for set up switching.

To link with the antenna I tested transformer coupling, as shown in **Fig. 4.14**. A ferrite cup having a permeability of 600 was removed from a color TV set's deflection yoke and used for the transformer core. The optimum number of coil turns was obtained by experimenting with the antenna system. In this case it appeared to be equal to15. The number of coil turns of the coil hooked up to the audio amplifier equals 25. The coil windings were made of 1-mm diameter stranded copper wire having plastic insulation.

The antenna current with transformer feeding was found to be less than 30% of the antenna current with exterior coupling coil feeding, but the audio transistor did not overheat.

Different bulky ferrite rings, having permeability from 600 up to 2000, were tested for cores in the antenna transformer. But, the best results were only obtained when using the ferrite core taken from the color TV set's deflection system. Subsequently, I returned to feeding the antenna through the coupling coil because it provided the greatest amount of radiator current.

Fig. 4.14 The coupling transformer



During all experiments I listened to 136 kHz in hopes of hearing someone to communicate with. Sometimes it even seemed that I heard someone calling CQ and I attempted to respond using the antenna. Upon interrogating neighboring radio amateurs I was told that nobody worked on 136 kHz. Alas, arranging a QSO with nearby radio amateurs was not possible!

I attempted to receive my own signals on the "Ishim" receiver taken out at my alternative location. At 20 km from the antenna the signals were clearly received. Another monitoring point was at 35-km distance from the transmitting antenna, but it only indicated a weak signal. Thus, it is assumed that a link with an ionosphere reflection when using 15 watts of power is rather problematic and that a direct ground wave link is possible only at close distance.

A way for increasing power and, therefore, extending the communication distance was solved by using my friend's homemade 100-watt stereo audio amplifier. The 136-kHz power delivered by combining the two channels of this amplifier measured 180 watts on a 4-ohm load.

In the afternoon when I hooked up this modified amplifier to the antenna, I could not tune it to resonance in any way. It would unexpectedly detune as I approached resonance. That night I found an explanation for this phenomenon. It appears that on a surface of one of the insulators of the long wave antenna, a corona discharge would develop at a certain power level and I could see the sparks in the dark. It was necessary to use a daisy chain of four insulators in series. When substituting insulators, I noticed with concern that the twigs of a tree near the antenna had turned black and that its smaller twigs had dried up from the burns. ***Caution should be observed!***

When observing the antenna system in the darkness of night during a high-power test, it was possible to see small-sized discharges running on twists of wires that were a part of the front garden metal fence I was using as a part of the earth grounding system.

After some days of operation, it was observed that the insulation of the coaxial cables, which served as the capacitive load of the antenna, was beginning to melt and fuse. It had been placed across some twigs on a tree. At night, the discharges originating on one or the other conductor were visible. One night while transmitting, there was a powerful discharge at the junction connecting the antenna with the shield/braiding of the coaxial cable end capacitor. The antenna was disabled! After that, I could not use it on 136-kHz. I re-measured the capacity between the antenna and the counterpoise with the RLC-meter and it was found to vary chaotically!

Fortunately, the low frequency amplifier was not damaged during all the experiments and was returned to its owner in good condition none the worse for wear.

The guidelines for constructing 136-kHz antennas

As a result of my experiences I am able to provide some useful guidelines for achieving greater efficiency in building 136-kHz antennas.

1. All junctions of a vertical part of an antenna with a capacitive load should be carefully soldered.
2. It is necessary to prevent any contact of a capacitive load and vertical part with trees or any other foreign objects.
3. It is necessary to use insulators in series in supporting antenna elements.
4. It is necessary to provide a correct antenna “lead in” through a window frame. The conductor should be contained within thick high voltage insulation. For example, a thick coaxial cable from which the shield/braiding has been removed satisfies this requirement.

5. Safety and caution have very high priorities when setting up and operating the antenna’s inductance coils because they are at a very high voltage levels when transmitting. Man and domestic animals must exercise extreme caution to guard against random access to these coils. (For some unknown reason both are strongly attracted to these coils!)
6. A very important role in the successful operation of the overall antenna system is played by the “grounding” system of counterpoise wires. Using the pipes of a

heating system as a “substitute ground system” for the antenna system does not solve the problem. The installation of a complete system of counterpoise wires under the antenna is essential. Elevated insulated counterpoise wires are preferred, but insulated counterpoise wires buried at a very shallow depth (to permit mowing the grass) may be used.

7. A transmitting antenna cannot be used on reception because the receiver’s input has a different input impedance than the transmitter’s output impedance. At the antenna connection to the receiver the resonance frequency of an antenna varies. The setup of an antenna at resonance requires switching coils of loading coils that hamper operation. Optimum version: Use a separate tuned magnet rotatable loop antenna for receiving.

8. It is absolutely essential to strictly adhere to safety precautions when setting up and operating the antenna. The high voltage existing on the coils during transmission times can cause serious skin burns.

A good idea for 136 kHz antenna mast

CHAPTER 5: URBAN CB ANTENNAS

In the various countries there are a variety of approaches to the radio amateur operation on Citizen's Band Radio (CB). In some countries it is forbidden to establish CB communication at distances more than 50 to 200 km, while in others, there is no limitation on the communication distance. In most countries the power permitted for CB is restricted to 5 to 20 watts (in the US the maximum legal input power to the final stage is 5 watts), however many operators illegally use 50 to 1000-watt power amplifiers for CB and run the risk of being caught by law enforcement agents. In some countries registration of CB stations is necessary, but in others it is not. In most places it is forbidden to use homemade equipment for operation on CB. Radio amateurs (Hams) are ambivalent, and even intolerant in their regard toward CBers. Some licensed radio amateurs try to completely ignore them and call them " radio hooligans". Other radio amateurs work CB without considering it anything shameful.

I have permission to operate on CB. I have conducted many DX QSOs on this range, using homemade equipment, retired (surplus) military equipment, and a "Promed –72" (a modern small-sized transceiver). The 27 MHz CB range serves as a forerunner of propagation on the 10-meter amateur band, and often, the CB-range "rattles", while the propagation on 10-meters is only starting. I debugged many antennas on CB. CB is a common phenomenon in most of the world, and I think that in those countries where long-distance communications on CB is officially forbidden that it will be permitted in the future. You see, in essence, CB is the most accessible mode of communication to the citizen for private usage. It is possible (in some, but not all, countries) on CB to conduct long-distance communications and do interesting experiments with antennas and homebrew equipment.

For this reason, antennas for CB, which are described herein, will be useful for radio amateurs in those countries where long-distance CB is not forbidden. The installation of effective CB antennas in urban locations represents known problems, which will be identified in this book. For the majority of antennas, described in other chapters of this book, information is also included for 27-MHz CB antenna construction.

In this chapter CB antennas for city use are discussed. All of these antennas were assembled and tested by me at different times. It is possible to use the antennas described here under city, suburban and country conditions.

The construction of substitute and invisible dipole, vertical and magnetic antennas specially calculated for operation on CB are described. Unfortunately, not only hams but also even the holders of CB - radio sets often have the need to conceal the antennas.

From the antenna types described here various versions of construction are presented for fixed operations of a CB radio set.

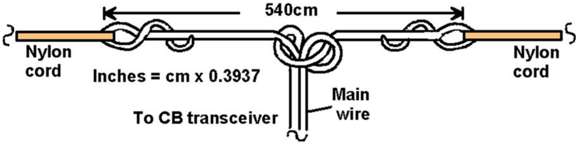
Inexpensive CB – Antenna for the Beginner

For the beginner with a brand new CB radio set, the installation of an indoor antenna can present a problem. This is because of the lack of proper components in the "junk box" such as antenna insulators, connectors or cable. Since coaxial cable can cost anywhere from 50 cents USD to as much as $1.50 more per foot, the installation of an antenna can be an expensive matter, especially if the antenna is a long way from the radio set.

These problems can be solved if the antenna is constructed from wire normally used for power transmission such as the 220-volt power grid wires. The impedance of many of these lines fall within the limits of 40-80 ohms. The large diameter wires are low impedance and the small diameter wires are high impedance. The measurements show a low loss at 27 MHz.

The inexpensive antenna described here is made according to **Fig. 5.1** The power wire was cut to a length of 2.7 meters and then knotted to prevent further unraveling of the wire ends. Then each end of the dipole was tied to a length of nylon cord. The knots at each end of the antenna acted as a capacitive load and increased the bandwidth of the antenna, which eliminated the normal tune up procedures.

Fig. 5.1 Inexpensive CB antenna

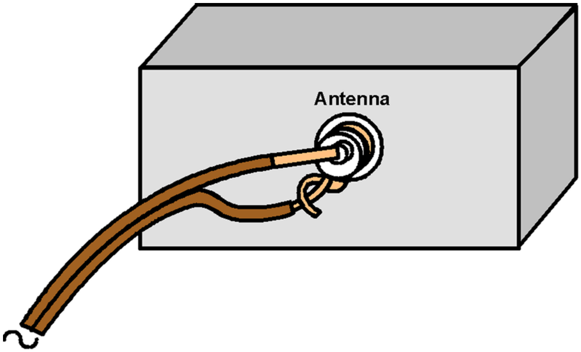


The construction of this inexpensive CB antenna does not require tuning to frequency. The inexpensive power cord (zip cord) costs anywhere from 5 to 25 cents USD per foot and sometimes less, depending on the quality.

The antenna can be installed vertically, horizontally or as a sloping dipole, depending on local conditions. On the ends of the wire that serves as the feed line, a connector is not installed. One end is tinned and formed into a loop that can be fastened to the ground connector of the CB radio. The other end is tinned and built up with solder until large enough to fit snuggly into the coax connector. Then the wire is plugged into the connector for connection to the antenna (**Fig. 5.2**).

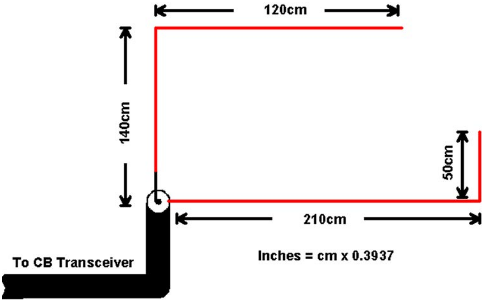
Urban Window CB Antenna

Fig. 5.2 Hooking up CB antenna to the transceiver



In an urban environment, it is not always suitable to install an outside antenna for a CB radio. As an alternative, a substitute antenna may be installed on a room window and allow successful operation. The standard dimensions of a window used in this example are 140x150 cm or 140x210 cm and will allow the installation of the “bent CB dipole” (**Fig. 5.3**).

Fig. 5.3 Bent CB dipole



The antenna is constructed from plastic insulated stranded wire. The initial length of each element is 270 cm. During tune up of the antenna, the element lengths were shortened to compensate for the capacitive loading affects on the antenna by the window frame, heating radiator and radiator pipes in the walls. Measuring the antenna input impedance with a HF bridge, in this example, gave an impedance of 55 ohms and the passband of the antenna was 600 kHz.

The antenna was installed in the room’s interior with the antenna wire being placed on a wooden frame. After painting the frame and the antenna, the antenna becomes almost invisible in the room, thus the classification as an “ invisible antenna”. This helps minimize the chance of an argument between a neighbor and a CB radio operator who could be blamed for interference, whether true or not.

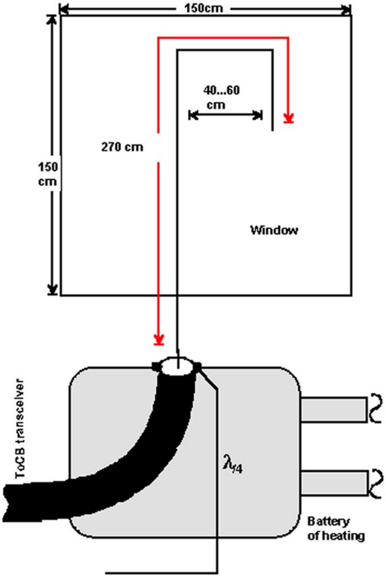
To boost antenna’s efficiency, it is recommended that it be built on the glass and not on the frame. It should be separated from the window frame border by a spacing of 15 to 30 cm. In this case the detuning influence of the room heating radiators and other components will be less, but the antenna becomes more noticeable and the input impedance increases to about 60 ohms.

Since the antenna contains both horizontal and vertical elements which this allows it to radiate with both vertical and horizontal polarization. The antenna can work well with other antennas using vertical, horizontal or any combination of polarization. This allows the antenna to be used for DX contacts and QSOs particularly when it is installed on the upper level of a multi-story structure.

A drawback of this antenna is that it causes bad interference to local electronic equipment, such as TV sets, stereo equipment and other similar items. This is particularly true when a powerful amplifier is used. Despite this drawback, this design provides a useful method for building and operating an invisible window antenna for the amateur radio 12 and 10-meter bands.

Window Vertical CB Antenna

Fig. 5.4 Window CB antenna



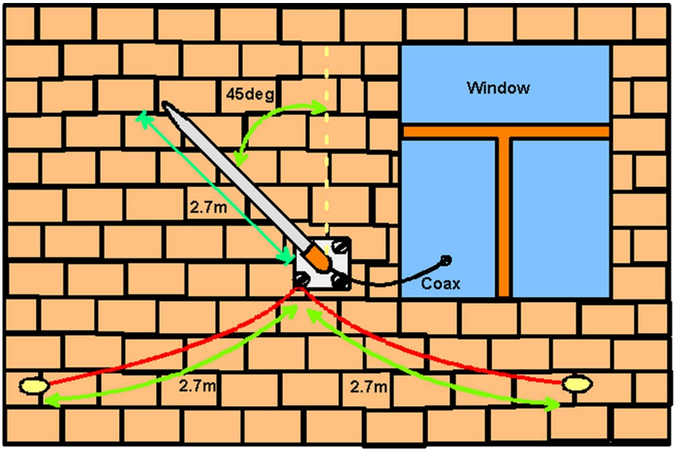
A window-type CB-antenna may be installed on just about any window. This type of antenna is much more effective than the short “rubber duck” CB radio set antennas. Using a window-mounted antenna, one may conduct local and DX QSOs. The antenna may be installed in all types of buildings whether constructed of wooden frame or masonry with steel reinforcement.

The vertical antenna construction is shown in **Fig. 5.4**. The antenna is made of stranded, flexible copper wire mounted on the exterior of the window frame. The initial length of the antenna is 2.7 meters. The coaxial cable braid is connected to the room-heating radiator usually located below the window and, in this case, serves as the ground for the antenna. For transmitting, one 2.7-meter long resonant counterpoise is added. This single counterpoise is soldered to the coax braid where it is connected to the radiator. It is then placed along the wall baseboard. An RF bridge was used to measure the input impedance to the antenna and was found to be 40 ohms. This is close enough to a 50-ohm coax to not cause SWR problems and it will be well-matched to the 50-ohm output of the final stage of the CB transceiver.

Urban CB Antenna

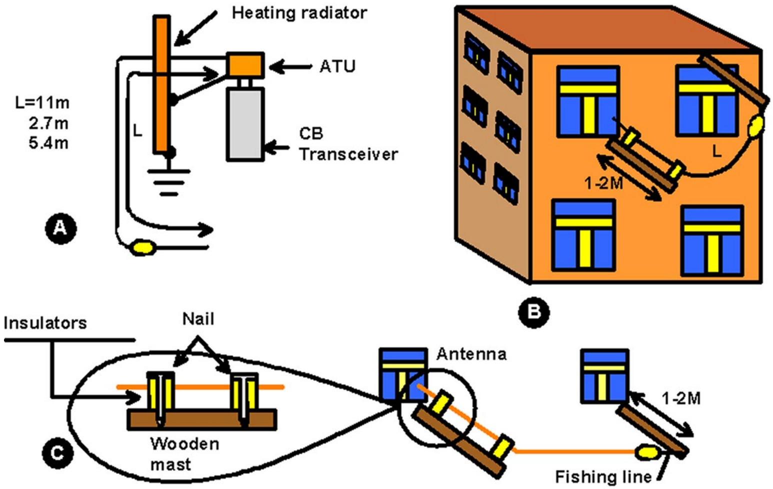
CB operators with stations in multi-story houses under restricted circumstances for installing and using antennas, may elect to install a wall-mounted vertical CB antenna or a simple single-wire CB antenna. The whip wall-mounted antenna (**Fig. 5.5**) is simple to install. It can be firmly mounted at 45-degrees to a wall or on a balcony under a corner at a 45-degree angle to a wall of the house. Two counter-poise wires are required for the antenna. The antenna is fed through a coaxial cable with a characteristic impedance of 50 to 75-ohms. For the support insulator of the antenna's radiating element it is convenient to use thick plastic or fiberglass of the kind used in PC boards. The vertical radiator can be made of either aluminum or copper tubing.

Fig. 5.5 Whip wall-mounted CB antenna



The simplest wire CB antenna is merely draped outside of the window and is shown in **Fig. 5.6a**. Another mast-mounted version is shown in **Fig. 5.6b** having a length of length 2.7 m is connected directly to the antenna socket of the CB transceiver. A more complicated two-window version of installation is shown in **Fig. 5.6c**. For an antenna with a length of 5.4 or 11 m, it is necessary to use a simple matching device due to the high input impedance of these antennas. But these antennas with a length of 5.4 or 11 m will work more effectively than the 2.7-meter antenna. For the mini-masts, wood may be used, however the ends must have insulators made of ceramic, plastic or PC board for insulating the antenna.

Fig. 5.6 Open wall-mounted CB antenna



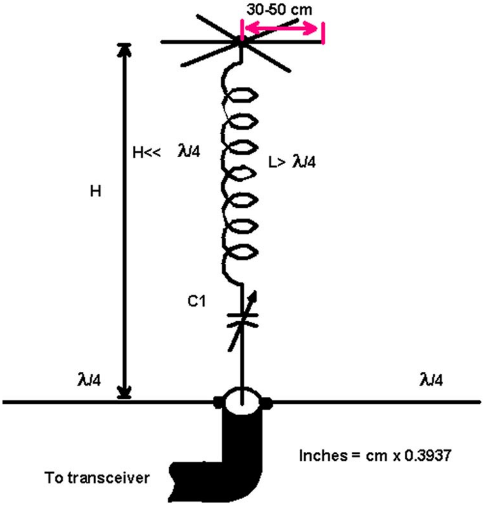
In the transmission mode, losses are caused by metal windowsills, steel rebar and other metallic structures found in concrete buildings that absorb the RF energy.

Twisted Antenna for the CB

When it is impossible to install an antenna out in the open, the radio amateur should consider an indoor antenna, which will work fine in a brick house or wood frame building. This type of antenna will not work well in a concrete building with metal re-enforcing material because of the detuning affect. In these situations, it is better to use a window installation when using this type of antenna. One of the most simple and effective antennas is the “continuously loaded” vertical antenna as shown in **Fig. 5.7**.

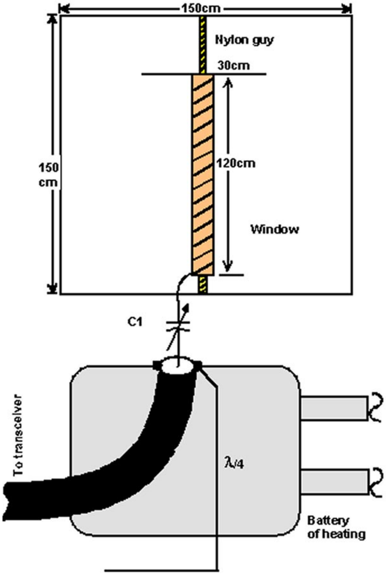
This type of antenna is made from copper wire with a diameter of 1 mm (#18 AWG – American Wire Gauge), 275 cm long. It is close wound on a PVC pipe section with a diameter of 28 mm, (approx. 1.25 in) although larger and smaller diameters may be used. To increase the bandwidth, a capacitive hat is used and made up of 3 to 6 conductors, each 30 to 40 cm long. The electrical length of the antenna is slightly longer than needed and is tuned to resonance by capacitor C1. This eliminates the time and labor intensive tuning of the antenna by cutting off small pieces of wire at the top in order to resonate the antenna. C1 also allows the matching of the antenna to both 50 and 70-ohm antennas. Remember that shortened antennas require a good solid RF ground.

Fig. 5.7 Twisted vertical CB antenna



The method of installation is shown in **Fig. 5.8**. The antenna is wound on PVC as mentioned before and, for rigidity, a rod of either plastic or fiberglass is inserted in the pipe. The windings on the pipe are held in place by Scotch tape. The antenna is suspended in the window by nylon cord and the windings are made of #12 stranded wire (2 mm dia.). The variable capacitor C1 is located on the windowsill and mounted on a plate made from PC board. The coax braid and one counterpoise wire (2.7 meters long) are mounted on the baseboard of the wall. Both the braid and counterpoise wires are connected to the room's heating radiator for grounding. Measurement of the input impedance indicates that the antenna may be matched to either 70 or 50-ohm cables by using C1. The reactive component of the complex resistance was within the limits of 10 to 20 ohms

Fig. 5.8 Installing a CB antenna



By using a gamma match, the coaxial cable matching to the antenna may be improved. The

Fig. 5.9 Gamma-matching whip CB antenna

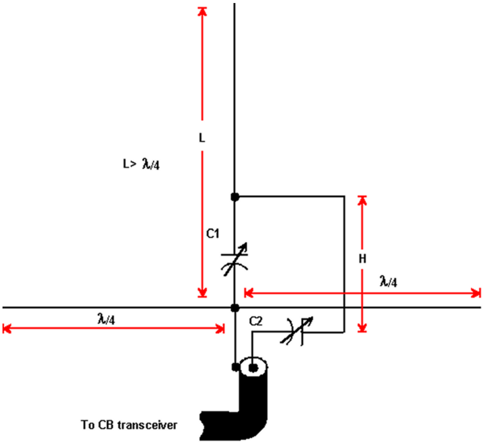
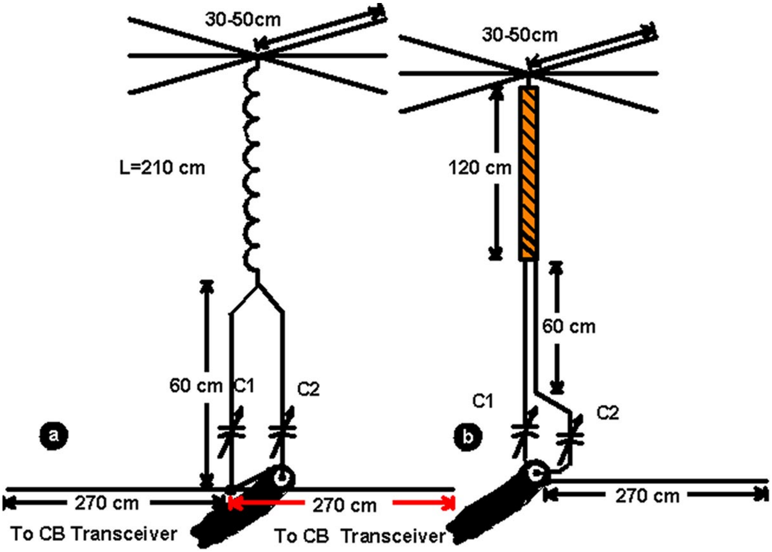


diagram of the gamma matching used to match the whip to the cable is seen in **Fig. 5.9**. By tuning variable capacitor C1 the whip can be tuned to resonance. Then with C2, and varying of the tap and height "H", the antenna may be matched to the coaxial cable.

The construction of the antenna gamma matching used for the CB antenna is shown in **Fig. 5.10**. The gamma match lines are made of a 60 cm length of twinlead telephone wire ("noodles" as they are called). This part of the antenna is not twisted and leads through the window to the matching capacitors. The rest of the wire is wound on a tube and fixed in place by Scotch tape. The wire length wound on the tube is 210 cm. The antenna is first tuned to resonance by C1 with C2 at minimum mesh. Then C2 is tuned for minimum

Fig. 5.10 Construction of a gamma matching CB antenna



SWR and C1 is tuned for resonance. This procedure is repeated until the minimum SWR is reached at the desired frequency.

With a resistance bridge, the radio amateur may tune up the antenna more precisely. Once the complex resistance and impedance is defined, the use of a stub line can be used to cancel out either inductive or capacitive reactance. By using the stub line as shown in Figure 5.10, the antenna may be matched with a SWR not worse than 1.5:1 with either a 50 or 75-ohm cable. This antenna has a bandwidth of 800 kHz between 2:1 SWR points. If during tune up, the plates of C1 are approximately meshed one third or less, then trim a small piece of wire off of the antenna. For operation of an antenna with high efficiency the plates of C2 should be more than half meshed or approximately 70 pF. By using these principals it is possible to construct an antenna for the upper amateur HF ranges.

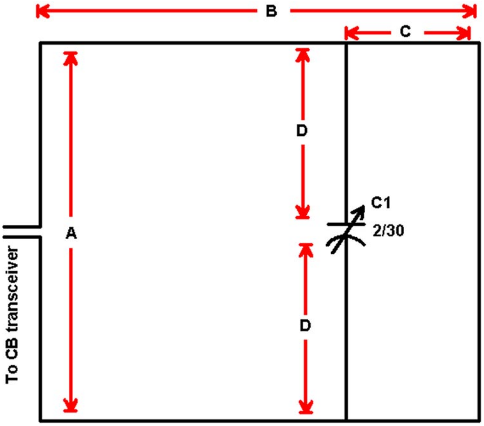
Drawbacks: These antennas do not radiate toward the interior of the building and will cause RFI to nearby electronic equipment within the room of installation.

Frame Window Antenna

An antenna may be made to work effectively within the window frame. It is easy to mount the wire on the perimeter of the window frame. The antenna shown in **Fig. 5.11** represents a shortened frame antenna tuned by the capacitor.

The tuning capacitor for resonating the antenna is placed on the crosspiece dividing the window. Two versions have been tested. The first version was of the dimensions A=140 cm, B=140 cm, C=40 cm and D=70cm. The capacitor is placed in a box made of PC board and the final capacity equaled 3.5pF. The capacitor is not mounted in the electrical center of the antenna, but this does not seem to hinder the normal tuning of the antenna. It is natural to assume, due to the smaller dimensions of the window that the total capacity of the capacitor would be increased.

Fig. 5.11 Frame window antenna



The second version of this antenna have dimensions of A=140 cm, B=210 cm and C=40 cm. In this case the tuning capacitor is not necessary. Conductor D, which in this case is 60-cm long with a 1mm diameter, did the tuning to resonance. It was mounted on the interior of the window. It should be noted that for operation of this antenna there is no difference whether installed on the inside or outside of the window. These parameters define the ease and convenience of the installation. Distance C can be modified according to variations of the window frame construction.

When the antenna is mounted on lower floors of a multi-story structure, attempt to locate in a space least affected by the shielding affect of nearby buildings and objects. For optimizing the efficiency, the antenna should be fed in one of its lower corner.

In practice, feeding the antenna in this manner versus feeding the antenna in the center of the vertical side will lower the overall performance of the antenna. This is because the metal windowsill and the heating radiator will absorb the RF power. In this type of installation the nearby objects will have a much greater influence on the antenna efficiency due to the absorption of the radiated energy from the antenna. If the room is at the corner of the building, it may be better to install two antennas with one on each corner window. This will allow more reliable operation in two directions.

The tune up of this antenna is not complicated and may be done in several ways. The simplest method is to use a field strength meter, but a more precise tune up is achieved with the aid of an SWR bridge or HF bridge. Tuning the antenna with an FSM is difficult when using a commercial CB radio with SWR protection. Using a bridge that matches the impedance of the CB, it is easier to fine-tune the antenna to resonance. It also allows the determination of the actual radiation resistance and other characteristics of the antenna.

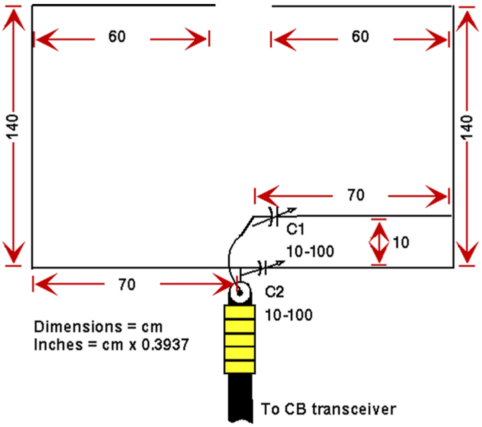
The input impedance of the first version of the frame antenna was about 35 ohms and the second one had an input resistance of about 55 ohms. There was a small amount of reactivity present in both antennas.

Comparing the frame antenna (**Fig. 5.11**) with other shortened antennas, (**Figs. 5.3, 5.4** and **5.7**) the frame antenna had an advantage. The frame antenna made long-range DX contacts but caused more TVI and RFI. The version of the antenna with the tuning capacitor can be matched well over the frequency ranges from 21 to 30 MHz, thus allowing it to operate over the upper amateur ranges as well as CB. If more than 10 watts of power is used, the antenna capacitor will have a high RF voltage and therefore it must be placed in some sort of insulating box to prevent it from being touched accidentally. The window frame antenna is not noticeable in the room and so it can be classified as an invisible type of antenna.

Invisible Dipole Antenna

A very essential factor in local and DX communications is the antenna. Since installing an outside effective antenna is not always an option, often one must be content to use a substitute antenna. Simple and effective invisible substitute CB dipole antennas can be built in the opening of the window as shown in **Fig. 5.12**. This particular antenna was built in a window with dimensions of 140x150 cm.

Fig. 5.12 Invisible substitute dipole CB antenna



The antenna is a dipole, with the elements cut a little longer than 1/2-wave total length. On 27 MHz the antenna is tuned by capacitor C1. The matching to the coax is done by C2. This construction allows the use of a fixed-length antenna without outside influence affecting the antenna such as the added capacity of the windowsill and the heating radiator that absorb the RF field. The use of the gamma match for feeding the antenna allows the usage of any cable with a characteristic impedance of 50 or 70 ohms and any CB radio with the same output impedances. The antenna is made of flexible copper stranded wire of 1-mm diameter with white plastic insulation. Of course you must use the color of insulation that will closely match the frame or use paint for concealment. The antenna was installed on the frame of the window and it becomes hardly noticeable inside the room.

The C1 and C2 are air-dielectric capacitors and mounted inside a box made from PC board material mounted under the windowsill. It is desirable to feed the antenna with a balanced feed system and for this purpose; five ferrite toroid forms are placed on the cable at the connector and secured in place with Scotch tape.

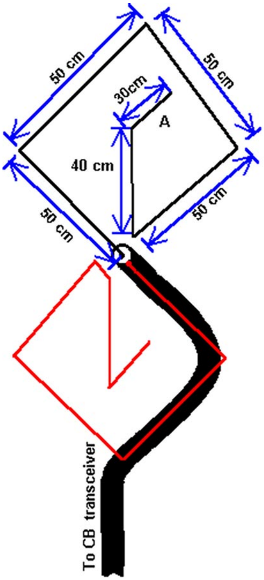
The antenna radiates both vertical and horizontal signals and will work for both local and DX contacts. By varying the length of the antenna and the gamma-matching element, the antenna can be moved to the 15 and 12-meter bands. Again, operation can cause interference to other electronic equipment in the room near the antenna's location. The antenna radiates outward from the room, with very little signal radiated into the room because o the shielding affect. Optimum installation is on the windows of any upper floor levels.

"Television" CB Antenna

Often there is a question for the CB radio owner as to what kind of outside antenna to use. However, the standard CB antenna stands out from the rest of the TV antennas and can cause problems with the neighbors worried about interference. Even though the exact cause of the interference may not be known, the CB owner will get the blame none-the-less. A good way to avoid this neighborhood problem is to use an antenna that looks like a TV antenna **(Fig. 5.13).**

The disguised CB antenna resembles the ***Kharchenco*** TV antenna and is widely used for TV reception. The antenna can be made from a rigid aluminum or copper wire. By shortening part "A" the antenna is tuned to resonance. Operating characteristics are that of a bent vertical dipole cut to the CB frequencies. The input impedance is close to 65 ohms with a reactive component of 20 ohms. The antenna can be fed with 50 or 70-ohm coaxial cable. The antenna radiates both horizontal and vertical polarization. This combination allows communication with local portable stations inside the cities as well as with DX stations. It is desirable that the antenna be mounted as high as possible such as the rooftop. It can be installed as a sloper or horizontally.

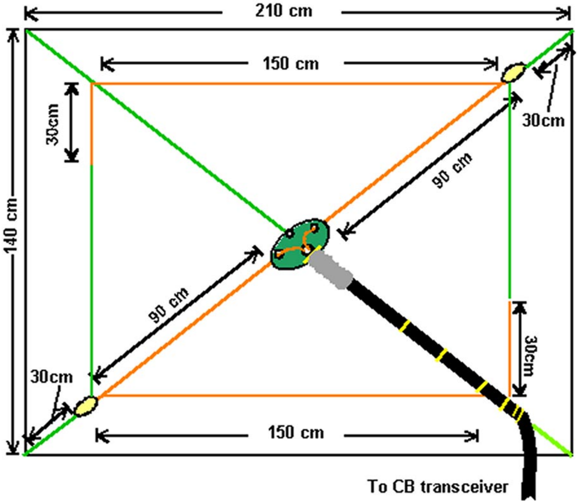
Fig. 5.13 TV CB antenna



Z – Antenna for CB

Often an expensive vertical or dipole antenna for operation on CB frequencies cannot be easily installed. This is particularly the case when the radio is in a concrete building. The installation of the window antenna is not always effective due to the re-enforcing steel rebar and metal frame of the building. In this case, the Z antenna is the best choice. The influence of the surrounding metal framework is

Fig. 5.14 Dipole Z antenna



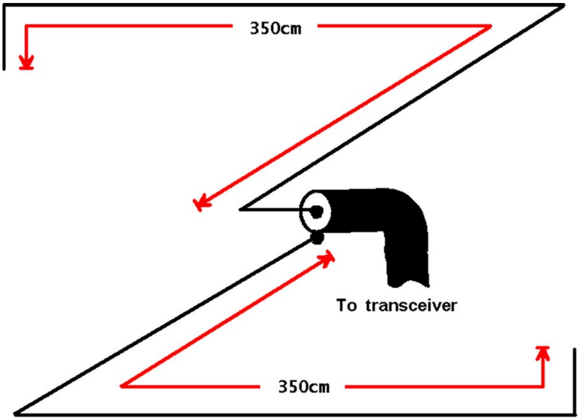
minimized. This type of antenna was installed in such a building and tested in a window measuring 140x210 cm

Fig. 5.14 shows the construction of the antenna using the corners. On one corner a 90-cm diagonal portion of the dipole is stretched and mounted across the window. From the lower opposite corner, a diagonal piece of nylon cord is stretched. The coax cable runs parallel to the cord for 150 cm, taped in place. The other element of the dipole is attached to the lower end of the cord. The total length of the dipole elements is then 270 cm.

The tuning of the antenna includes the gradual shortening of the elements to get minimum SWR on the CB frequencies. The antenna was made from stranded flexible wire with plastic insulation. The center insulator and the diagonal insulators are made from PC board pieces. The insulators are tied to a nylon cord. End insulators are not used and the dipole ends are held in place with a nylon cord. To ensure a balanced feed, ferrite toroids were put on the coax and secured with Scotch tape.

The input impedance of this antenna was determined to be 45 ohms according to a HF-bridge. Therefore, a CB transmitter with a 50-ohm output will work with this antenna. The free space impedance of the antenna is 75 ohms but the proximity of the heating radiators and the metal windowsill lowers the impedance to 45 ohms.

Fig. 5.15 Z antenna for 15 meter range



The antenna was mounted outside the windows so as to not hinder the opening of the window. The Z antenna radiates both vertical and horizontally polarized signal and allows both long range DX contacts and short range QSOs.

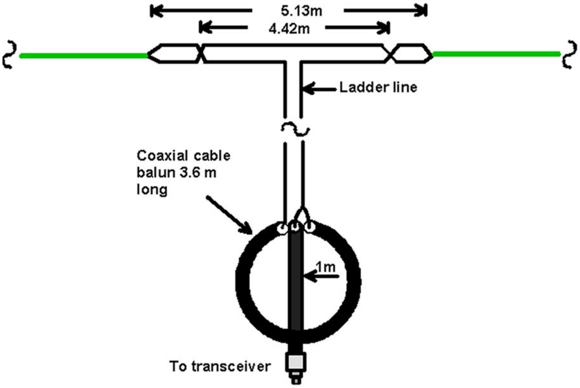
An antenna for 15, 12, or 10 meters can be built using this method. A 15-meter antenna is shown in **Fig. 5.15**.

Simple Bent CB Dipole

The bent dipole for the CB band can be made from a two-conductor telephone line and known otherwise as “noodles”. The line is cheap, strong and this will do quite well for the construction of a CB antenna and its feed line. A drawback with the “noodles” wire is that the ultraviolet radiation from the sun destroys the insulation over time (2-3 years depending on location) and it will split. Then the wire corrodes and becomes unfit for use and gives the antenna a limited life before it becomes necessary to replace.

The bent dipole built from the “noodles” wire is shown in **Fig. 5.16**. A single piece of line is used to make the antenna. The feed line, also made from the “noodles” wire, is connected in the middle of the antenna. This line has a velocity factor equal to 0.8. For the antenna resonance tuning its overall length must be equal to 5.13 m. But because the line with a hard dielectric velocity factor equal to 0.8, it will have resonance length in the 27 MHz range equal to 4.42 m. Therefore, overall antenna length is 5.13 m, but a “noodles” line length is equal to 4.42m. For the air dielectric line antenna length and feed line length, they must be equal to each other.

Fig. 5.16 Bent CB dipole



This makes the antenna a folded dipole with approximately 300-ohm impedance. The antenna is matched to the feed line with a half wave coaxial stub using 75-ohm cable 3.6 meters long attached to a cable 1.76 meters long connecting to the CB radio set. The characteristic impedance of 75 ohms was chosen for optimum antenna matching for a CB radio with either 50 or 75-ohm output impedance.

The SWR on a 50-ohm line is 1.6:1 over the frequency range of 26.5 to 27.5 MHz. It increases to 2.5:1 at 26 and 28 MHz

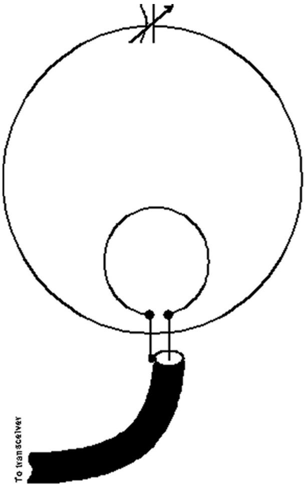
The length of the coaxial cable is shown for the most commonly used cable with polyethylene insulation and a velocity factor of 0.66. The matching circuits can be made with 50-ohm cable provided the cable from the matching transformer to the transmitter is limited to a length of 0.8-1 m. The SWR will increase a little, but not enough to affect operation.

The antenna can be mounted vertically, or horizontally or as a sloping dipole. The length of the feed line from the antenna to the CB Transceiver is not critical and can be any length. It is desirable to have the feed line perpendicular to the antenna if the feed line is 5 meters or longer. The antenna was tested with the CB "Promed 72" and it worked well on reception and transmission for local and DX.

Magnetic Loop Antenna for CB

The magnetic loop has a radiation pattern shaped like a "figure 8" where the maximum signal strength is in the plane of the loop. The loop antenna is in essence a tuned circuit from which there is radiation. In the near field of the antenna the magnetic loop radiates an RF magnetic field. The electric field is contained in the tuning capacitor and this is not radiated very well, if at all. The transmitting loop is coupled and matched to the feed line by using a gamma match or inductive coupling loop. The diagram of the magnetic loop CB antenna with inductive coupling is shown in **Fig. 5.17.**

Fig. 5.17 Schematic of a magnetic loop CB antenna

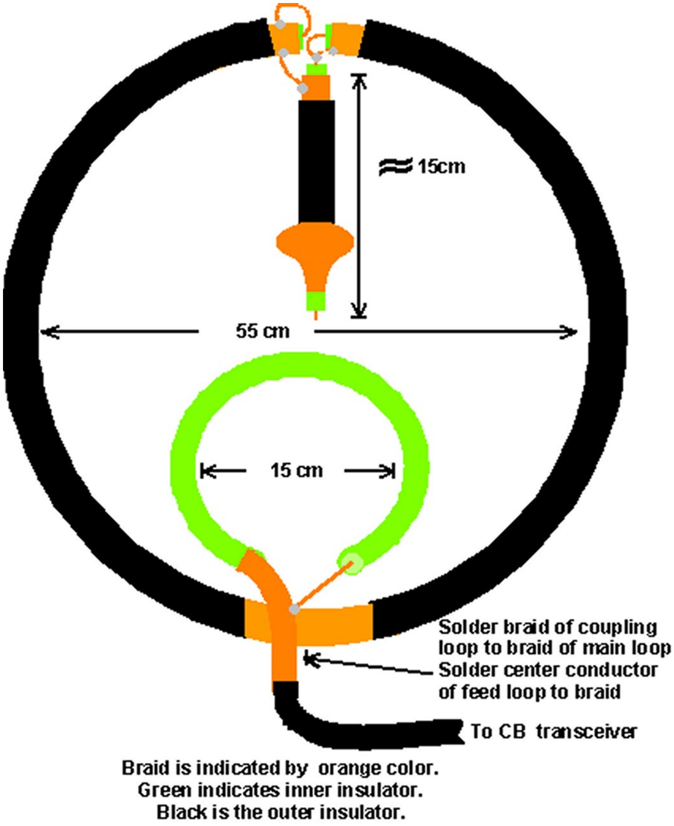


The link-coupling loop has a diameter 5 times smaller than the main loop. The diameter of the wire in the loop is 2-5 times smaller than the conductor used in the loop. This coupling loop must be precisely opposite the tuning capacitor. Theoretically the link loop cannot be electrically connected to the main loop, but in practice this is done on occasion. In this example, the location of the loop in relation to the center of the main loop is not so critical in matching to the coax cable.

To build a magnetic loop it is best to use polished copper tubing for maximum efficiency. However, the use of the outside braid of large diameter coaxial cable will give good results. If cable is used, it should have a 9-20 mm diameter absent of any damage or corrosion to the braid.

The construction of the loop antenna is shown in **Fig. 5.18** and is made from a loop of coaxial cable with a 55 cm diameter. The center conductor of the coaxial section that forms the tuning capacitor is soldered to one side of the braid of the loop and the braid of this section is soldered to the other side of the loop. The section of coax used for the tuning capacitor is 20 cm long. This is used to tune the

Fig. 5.18 Construction of the magnetic loop CB antenna



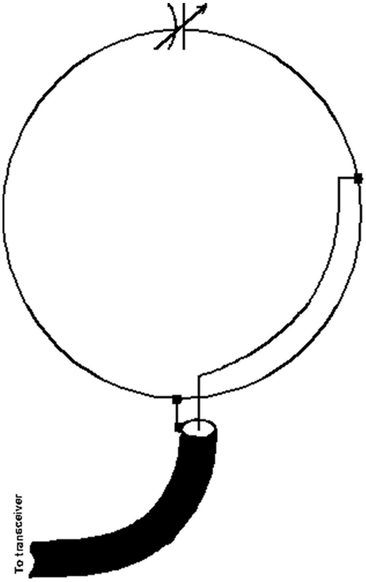
loop to resonance. The junction of the connections to the loop is covered with Scotch tape or other suitable insulating material.

The initial tuning of the antenna is done by gradual trimming of the cable capacitor. When the antenna frequency is close to resonance, the braid can be moved (slide) up the cable in order to fine-tune the antenna. When the antenna is resonant the braid is taped in place. The passband of the magnetic loop is less than 500 kHz.

The feed loop is made from the same 50-ohm coaxial cable. This connected to the CB radio. In some articles about the magnetic loop it is recommended that the braid be left on the coupling link. However, the antenna will be matched better and the antenna efficiency will be higher if the braid is removed from the cable.

If lower SWR is desired, start the feed loop diameter at 20 cm and then gradually reduce it for the lowest SWR at the CB transceiver. In my version, I was able to get the SWR down to 1:1.2 using a 15-cm diameter. Any further reduction only made the SWR worse.

Fig. 5.19 Schematic of gamma matching



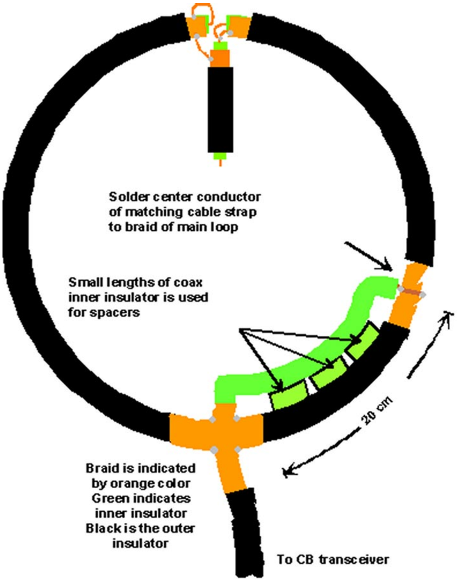
The gamma match method is a more effective method of matching to the cable. The diagram of the gamma match is shown in **Fig. 5.19** and construction of gamma matching to the CB magnetic loop antenna is shown in **Fig. 5.20**.

The insulation is removed at the measured distance of 20 cm from a point exactly in the middle of the loop opposite the opening where the capacitor is located. This must be accurately measured. At this point the center conductor of a length of coax must be soldered. The braid must be removed from this length of coax so that only the center insulator remains with the center conductor in place. Between this center conductor and the loop several sections of the outer insulation is placed. Then the entire assembly is wrapped with Scotch tape for security and rigidity.

Testing this antenna revealed an increase of 0.5 to 1 S-unit above the loop fed antenna. The SWR and passband for both antennas was similar. The use of 50-ohm coax for an antenna made from coaxial cable with a 12-mm diameter resulted in an optimum length of 20 cm for the correct match.

The antenna may be installed on a balcony, in the opening of the window, or even on the roof of the house. Which location is used depends on the options available to the radio amateur. If one wants to work in a fixed direction, simply aiming the antenna in the desired direction can do this.

Fig. 5.20 Construction of the gamma match



Simple CB Antennas

Usually in the privacy of a home there are fewer problems with the installation of a CB radio antenna. It may be a simple CB dipole antenna (**Fig. 5.21**) or a simple vertical CB antenna (**Fig. 5.22**).

The dipole works most effectively at a height of not less than 2.5 meters above ground and it has the “figure 8” radiation pattern. The antenna is made from copper or aluminum wire with a diameter of 1-4 mm. There is no need to use thicker wire because it is too heavy and hard to solder. The center insulator can be made from PC board after the foil is cut in the middle to isolate the antenna elements. The coaxial cable should be protected from the elements with epoxy or similar material. Paraffin will work if you live in the northern colder latitudes. Heat will melt the paraffin in the warmer regions of the world.

Fig. 5.21 Simple CB dipole

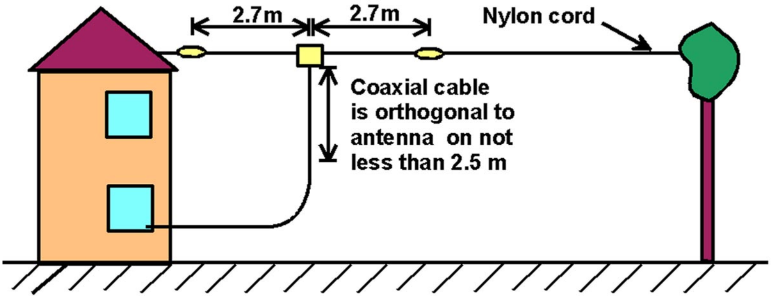
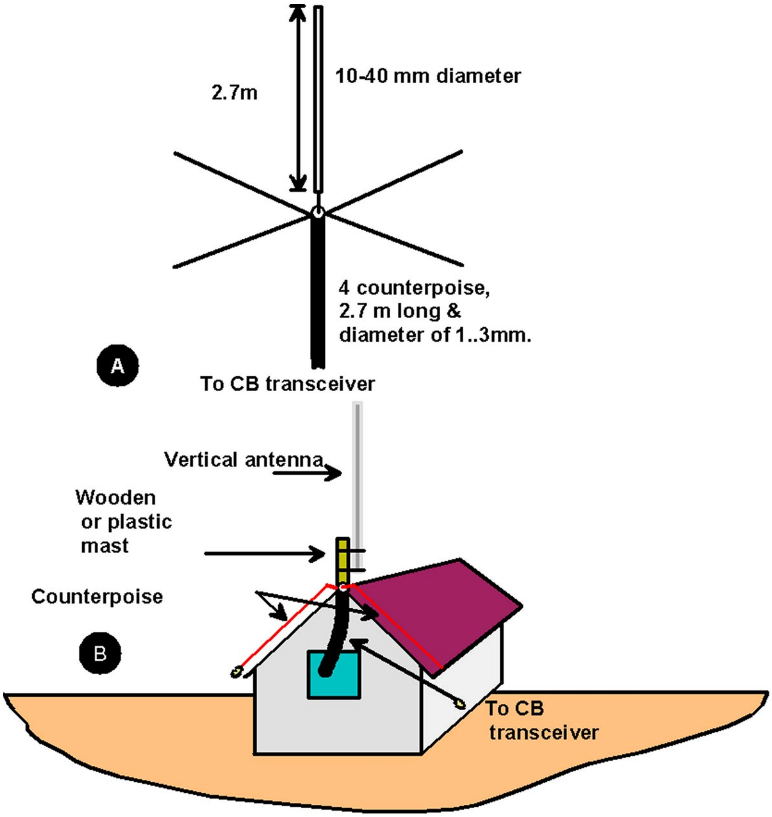


Fig. 5.22 Simple vertical CB antenna

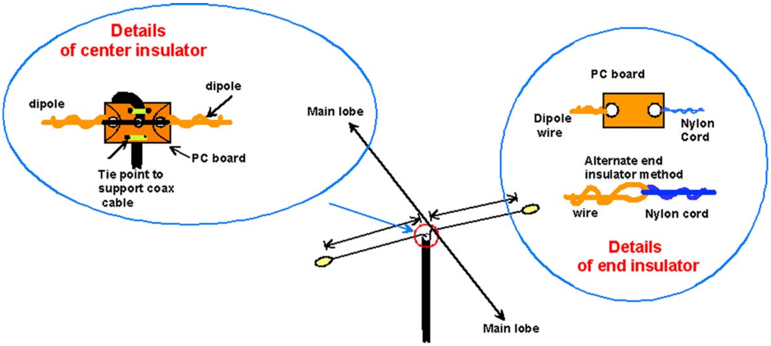


End insulators may be made from thick PC board if desired. Otherwise, the ends of the antenna may be merely tied to either nylon cord or fishing line as insulation.

It is desirable for the coaxial cable to be at a 90º angle to the antenna for at least 2.5 meters where it extends from the antenna. Optionally the dipole antenna may be placed under any corner near the ground surface.

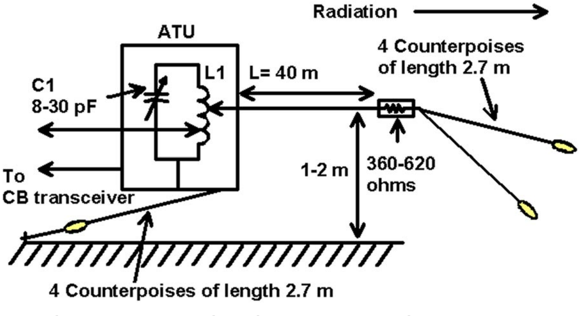
To mount a vertical antenna, it is better to use a plastic insulator or a wooden mast that has been boiled in paraffin. An even better method is to use a special support insulator that is commercially made for the purpose of supporting the vertical antenna. It is also a good idea to use guy wires to stabilize the top of the antenna against the winds. The vertical radiator can be made from aluminum or copper tube with a diameter of 10-40 mm. Counterpoise wires can be made of wires 1-2 mm in diameter. The pattern will be a circular one in the horizontal plane. These dipole and vertical antennas may be installed on the roofs of urban multi-story buildings.

Fig.5.23 Strengthening the coaxial cable to the self-made insulator



Beverage Antenna for the CB

Fig. 5.24 Beverage CB antenna



If you want to call home from a place of fishing or hunting it is suitable to use a Beverage-type CB antenna (**Fig. 5.24**).

The “Beverage” antenna has a length of not less than 40 meters and an example is shown in **Fig. 5.24**. It may be made from 0.5-1 mm diameter wire. The antenna wire does not require support at a low height (1-2 m) above ground. It is desirable to place three or four counterpoises 2.7 meters long at both ends. In **Fig. 5.25**, the load construction uses a 320 to 640-ohm non-inductive resistor of the proper wattage. **Fig. 5.26** shows the construction of the antenna that can be used for portable operation and **Fig. 5.27** shows the construction of the antenna that can be used for stationary operation.

Fig. 25 Load of Beverage CB Antenna

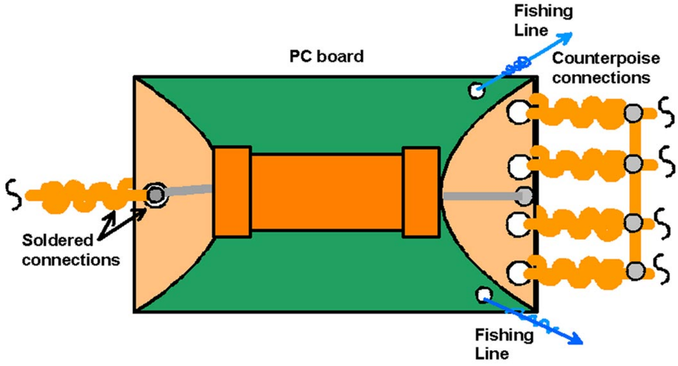


Fig. 26 Field Beverage CB Antenna

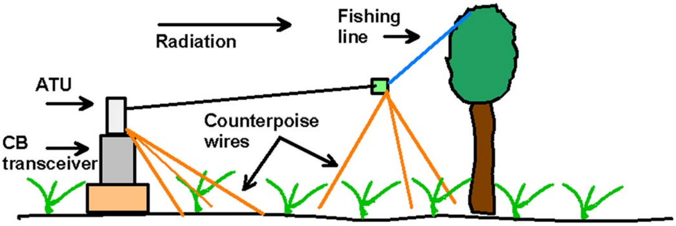
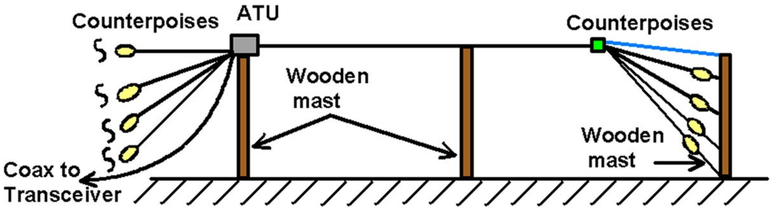


Fig. 27 Urban Beverage CB Antenna



The Beverage antenna requires a matching device for the antenna to work properly. The matching device must be installed on the Beverage antenna and fed through coaxial cable of any characteristic impedance from the CB radio. The matching device circuit is shown in **Fig.5.28**.

The matching circuit is a parallel circuit with the coil wound on a form 22 mm in diameter and 40 mm long. The coil L1 consists of 10 turns of 2-mm diameter wire (or #12 AWG - American Wire Gauge). The antenna connects to the coil between turn 6 and 8 and the coaxial cable connects to either the second or third turn. These connections are from the “cold” or ground end. An air variable capacitor C1 is used to tune the circuit. The matching circuit shown here was built in a box made from PC board material, as shown in **Fig.5.29**.

The matching device may be located on or near the CB radio, or it may be connected to the radio using a short piece of coaxial cable.

The antenna may be mounted on the roof of a multi-story structure. In this case it is also desirable to use a similar matching network at the transceiver. This will take care of any impedance discrepancy that might occur between the antenna matching unit and the transceiver.

Fig. 5.28 ATU for Beverage CB antenna

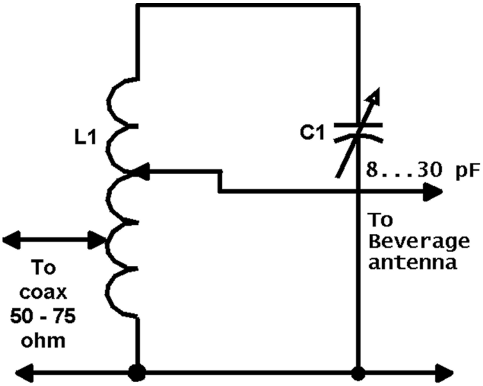
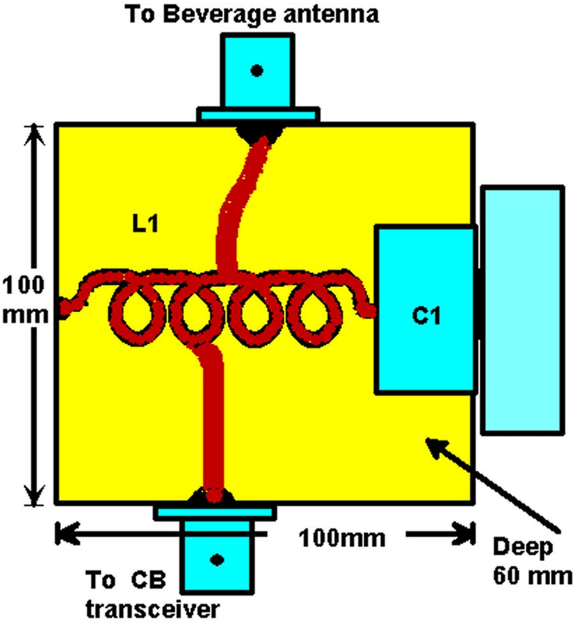


Fig. 5.29 ATU box



PART 3

Special Antennas

PART 3: Special Antennas

In this part about special purpose antennas, the alternative types of antennas for use in urban conditions are described. The basic construction of these antennas is based on special purpose antennas used in earlier years for espionage and also used by Special Services of various countries engaged in these clandestine activities.

As with data concerning spreading and underground antennas, such information was previously classified and therefore unavailable to the general public and the radio amateur community throughout the world. Now that the information has been declassified, the radio amateurs can experiment with these antennas and see for themselves how the antennas performed for the intelligence agencies and militaries during the years of WWII and afterwards. These antennas are almost totally imperceptible and do not require tuning or any other setup procedures.

The chapter describing antennas made from coaxial cable will explain the use of old coaxial cable deemed as salvage and can be purchased at “flea” markets and other commercial sources that use this same type of coaxial cable. Often the radio amateur will have accumulated over the years an abundance of cable that consists of many different cable lengths. This collection of old coaxial pigtails from the junk box may be used for making antennas.

The widespread need and use of television antennas will allow the radio amateur to install an antenna for the dual purpose as a television antenna and as an antenna for radio amateur use. While this may not be a very efficient method of operation, this method will allow operation where there may be no alternative antenna options available. This type of disguised antenna will help to minimize complaints from the neighbors and allow the radio amateur to operate.

In the chapter describing combined antennas, we will discuss antennas that will provide operation on two or more amateur bands with high efficiency. It will be useful for radio amateurs who live in the city and are having difficulty installing an antenna for each amateur band. The combined antennas described apply to the 10 and 6-meter bands. Propagation in these two bands varies greatly with 10 meters having the better propagation at times. 6-meter propagation is very sporadic and for the most part it is poor. But when conditions for these two bands are good, it is possible to work DX stations using these simple antennas that are described.

CHAPTER 6: UNDERGROUND & SPREADING ANTENNAS

Underground and “spreading” antennas are normally not used by radio amateurs. Usually there is enough area in which it is possible to put up an antenna of choice. However, with cities getting larger, and architectural demands to keep the exterior of houses and communities attractive, placing the antenna underground may be one of the only solutions.

Earlier, here in the USSR, underground and as well as other concealed types of antennas were used on military classified signal operation centers. Now with development of satellite communication systems, these unusual antenna systems are used less often. Information about underground and concealed antennas were not available to the general public and were held only in unclassified documents. Such was the case not only in the USSR, but also other countries. Therefore, how these types of antennas were installed and used was considered highly confidential in earlier times. Now, this data has been declassified and the items of information about underground and concealed antennas has become accessible to the radio amateur.

During the early 1990s, while on a trip from Moscow to a remote area of Russia, I passed a huge field fenced with barbed wire. I asked my fellow traveler what he thought the facility might be and he replied that it was a communications site. However, I noticed there weren’t any antennas visible. My companion remarked that they were installed under ground! So, for the first time I had seen an underground communications center. Later, I met the people who served on the center. The manner of constructing the particular antennas used on these centers especially interested me, but no one was allowed to tell me anything at the time. While I was allowed inside the center buildings, I was not permitted to see the equipment in any detail. Nevertheless, even from my limited view, I could draw certain conclusions about the layout and construction. The following chapter is my concept of the “spreading” and underground antennas used.

History of Underground and Spreading Antennas

During the First World War, an antenna farm of field radio set masts having a significant altitude 15-30 meters (49-98 feet) represented an easy target for artillery and thus, concealment was an absolute necessity. But, even when the masts were broken, spreading by the ground antennas allowed on to conduct a link. It was found that spreading the antennas on the surface of the ground enabled communications to be maintained, with the signals propagated in the same direction of the antenna wire leading from the transmitter. Thus, it was essential for the antenna wire to be pointed in the direction of the receiver's location. The "spreading" antenna is defined as an antenna lying on the top of the ground which follows and blends with the irregularities of the earth's surface and vegetation coverage.

Also, at the same time of building submarine fleets, a need to communicate with those submarines was apparent. Radio communication on submarines used an antenna consisting of wires installed at a very low height of about 1-2 meters (3.2-6.4 feet) above the body of the submarine. Submarines submerged could send messages by radio communication using their regular short, low-height antennas. Articles are available now on this subject of submarines communication, but they are hard to find.

The development of the spreading ground surface antennas found its beginning in 1923 with the origin of the "Beverage" antenna, followed later by the "Rhombic" antenna. But, it took almost 50 years for the low-profile antenna used on the submarine to evolve to the more efficient DDRR type of antenna.

In some books and magazines about the spies of the Third Reich operating in England, there are references about these underground antennas. In all cases it is possible with confidence to say in Germany, during the Second World War, underground and spreading antennas were developed extensively and widely used. Undoubtedly, the information about these types of antennas fell into the hands of the USA and USSR allowing these countries, over considerable time to advance in this area through more engineering efforts. The historical records will never list the names of those persons, both scientific and military, who first developed and used these underground and spreading antennas. Later, underground (horizontal and vertical) and spreaded horizontal antennas were developed and widely used for classified underground military bases.

Spreading antennas were used for espionage over a 50-year period. To help conceal the spy antenna, they were commonly placed behind a city so as not to be easily seen and to defy directional finding equipment. Usually the antenna was nothing more than an insulated wire lying on the ground and having special feeding. This is where they were maintained for operation with the purposes of concealment and to hamper the ability to determine their bearing with directional finding equipment.

The theory for both underground vertical and underground horizontal antennas was rather detailed. For a while, information was readily available in the public libraries about the use of the stationary underground antenna for espionage, however, the publications have since been removed. Design of an antenna used for the purposes of spying and reconnaissance units has remained classified for the past half century.

Let's examine the theoretical operation of these types antennas.

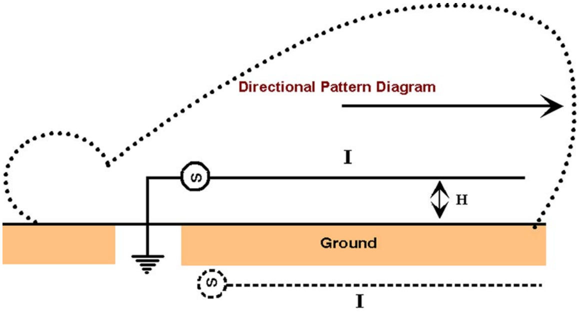
Operation of a Low-Height Horizontal Antenna

Both vertical and horizontal underground antennas exist and have been used. In my opinion it is improbable that radio amateurs will use vertical underground antennas. Instead, the use of the horizontal underground antenna is more probable.

As is known from the theory of antennas, a horizontal antenna mounted close to the ground during excitation establishes in the ground a mirror image. The currents flowing in an antenna and the image are mutually cancelled at low altitudes foiling the antenna's ability to radiate waves horizontally polarized. Now it can be said about an antenna installed at a low height of one meter or less, a spreading antenna will poorly radiate horizontally polarized signals **(Fig. 6.1).**

It is known that vertically polarized waves are not absorbed in the soil to such a degree as waves horizontally polarized. Therefore, with the underground antenna, there is little radiation of vertically polarized waves present. It is necessary to pay attention to the fact that in the more conductive soil under an antenna, the antenna will be less effective and the radiation will be less.

Fig. 6.1 A Spreading Antenna



The installation of an antenna above a poorly conducting surface, the currents excited in the mirror image antenna will be smaller. In other words, if the antenna is located in a sandy soil, the apparent height will be greater than if it were in moist soil. Thus, theoretically, the antenna height, "?" of such an antenna at the ground level is in reality more than the "real" height, depending on the type of soil. In practice it means that the horizontal antenna above the surface can radiate electromagnetic waves, not only with vertical, but also horizontally polarized.

At the contact on ground of a vertically polarized wave there is an inclination of the wave-front, i.e., the vector electrical component will be tilted with respect to ground, therefore the reception of vertically polarized waves is made possible. The antenna also receives horizontally polarized waves in a plane perpendicular to the elements of an antenna, but is much weaker, than the vertically polarized wave, sky or ground. The sky waves incident on an antenna from an ionosphere, are already tilted due to reflection from the ionosphere, therefore the antenna also receives sky-waves. Sometimes such antennas are used specifically as low-noise receiving antennas, owing to their ability to reject the usual types of atmospheric and man-made interference.The so-called “barkhan” (dune) antenna is another version of interest for the radio amateur application. The antennas were tried by the military on barkhan of sand deserts in Central Asia. It was found by spreading one of these antennas on barkhan, and appropriate selection of physical length and frequency, coupled with the dimensions and shape of the barkhan, a type of dielectric lens is achieved causing an overall improvement in the performance of the spreading antenna.

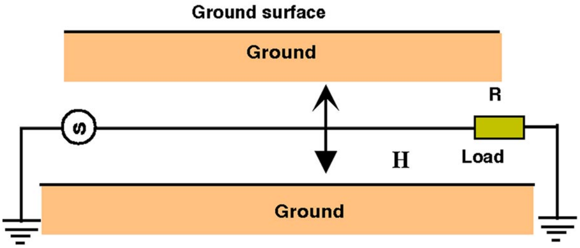
The directive pattern of an antenna is exhibited in **Fig.6.1**. The maximum direction of the antenna is in line with the element of the antenna. Depending on the construction of an antenna, it can be calculated for operation mainly with ground wave signals and for operation mainly with sky-wave signals. For the radio amateur with restricted operating environments, the construction and use of an underground antenna is a viable alternative. However, for the radio amateur information on the construction of such antennas has been hard to find. Now, this book provides some of the most accessible literature on this subject.

Input impedance of spreading antenna

Determination of input impedance of an antenna both theoretically and practically [1] can be difficult. Therefore, we shall confine our discussion to only items of information necessary for the radio amateur to put into practice applicable to the construction of the underground antenna.

As is known from antenna theory, the low-height horizontal antenna has low input impedance. But this applies only to resonant antennas. All low-height and almost all horizontal underground antennas are non-resonant, therefore another approach is necessary and the underground antenna becomes an alternative approach to this solution. So, the wire covered in plastic or aerial isolation by thickness H, is installed into ideally conducting soil **(Fig. 6.2)**.

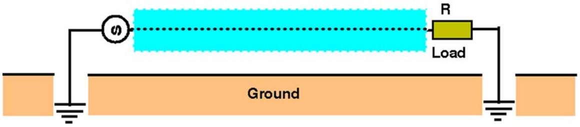
Fig. 6.2 An Underground Antenna



In this case, the antenna of this type shall be considered as feedlines being buried in ideally conducting soil with the velocity factor depending on the property of the dielectric. The center portion of the line is the antenna while the grounding to the soil takes place on the ends. If the resistance of a load is matched with characteristic impedance of a transmission line, all power into the antenna is absorbed and radiation does not take place. In reality the underground antenna lies in or on the soil in which there are losses of high-frequency power along the wire of which the antenna is constructed. There are losses within an antenna as well as its radiation.

Thus, it appears a good choice of material for making underground and spreading antennas is coaxial cable with the braid removed, or wire with thick plastic insulation, lying on the surface or immediately below. Depending on the conductance and the dielectric property of real soil, the characteristic impedance of this type of forming transmission line and, therefore impedance forming its antenna, will be 100-500 ohms on frequencies from 2-30 MHz. Despite the variation of values of characteristic impedance forming transmission line, usually it is possible to define and to match a spreading antenna if it is aperiodic with load resistance **(Fig. 6.3).**

Fig. 6.3 Construction of the Spreading Antenna



Length of the Spreading Antenna

The first Beverage antenna (father of underground and spreading antenna) had a length of almost 10 miles. So, how does length affect the overall performance of a spreading antenna? As the theoretical analysis is analyzed more thoroughly, the data can be compared to the completed results discussed in the book, Spreading and Underground antennas: The Soviet Wireless [1] publication was previously classified, but is now available (the book was in very small circulation in 1965).

As is known, at propagation in an ideal transmission line there is no radiation loss or fading power. At propagation of a high-frequency current in the spreading antenna there are losses in the antenna — radiation losses, and losses in ground — both thermal and dielectric. One can say about radiation from an antenna, the basic role is determined by the length of the antenna during which the amplitude of a current (or voltage) diminishes by a factor of 10 as contrasted to by this voltage in points of power supply of an antenna. It is understandable that after a tenfold reduction in amplitude of current, that part of an antenna in which the current flows through will radiate poorly. In **Table 6.1** (taken from ref. [1] with some variations) the lengths of a wire are reduced after burying in soil with different parameters during which the amplitude of a current diminishes by a factor of 10.

Table 6.1 Lengths of a wire in which the amplitude of a current diminishes by a factor of 10

	---- PARAMETERS OF SOIL ----		
Length of Radio Wave	**Soggy Soil $\varepsilon=20;$ $\sigma=10^{-1}$ m0m/m**	**Moist Soil $\varepsilon=10;$ $\sigma=10^{-2}$ m0m/m**	**Drain Soil $\varepsilon=6;$ $\sigma=10^{-3}$ m0m/m**
100	2.15	7.1	33
60	1.68	5.93	31
30	1.22	4.76	30.5
15	0.92	4.2	30.5
10	0.79	3.9	30.5
6	0.67	3.9	30.5

----- Length in Meters -----

From **Table 6.1** it is seen, using given soil definitions for the underground antenna, there is no benefit from trying to improve overall performance of an underground antenna by increasing the length. For the radio amateur, the antenna installation (on basic types of soils), the length should be not less than 30 meters for effective operation on HF bands. Increasing the length of an antenna more than 60 meters, without raising it above ground, will accomplish little. If the installation is on dry, sandy soil, or on top of deep snow, the length may be greater than 60 meters.

The Types of Spreading Antennas

The primary choice for the underground and spreading antenna is the aperiodic (broadband) which is a progressive-wave antenna (see **Fig. 6.3**). This commonly loaded on the end with a resistance equal to the characteristic impedance expected for this type of line forming to the underground antenna.

Usage of non-loaded spreading antennas (called quasi-resonance) is possible too. These antennas are not loaded, so the distribution of current and voltage is similar to their distribution normally present in resonant antennas. In contrast to an aperiodic antenna having a large bandwidth, the non-loaded antenna's parameters are rather unstable. The electrical length and input impedance depend on parameters of the soil on or in which the antenna is installed. As is known, these parameters vary over time and are rather unstable. But, sometimes, with stable parameters of soils (desert sands and other such wastelands), it is possible to tune an antenna to resonance and have it remain stable. Considering all of the variables in parameters, it is impossible to recommend the proper length for resonance for any given frequency for an antenna placed in soil. Input impedance and resonance underground is not of prime importance for usage by the radio amateur. Experimentation with the parameters will be necessary to find the optimum configuration for a specific frequency. Again, information for deriving appropriate theoretical information on constructing these antennas can be found in [1].

It is most expedient to use in radio amateur conditions an aperiodic spreading antenna loaded on the end with a load resistor equal to the characteristic impedance expected for this type of line forming the spreading antenna. At a length of an antenna of 30-60 meters installed immediately on a surface of average soil, the antenna's input impedance will be in the range of 300-500 ohms. That allows the construction of a matched load and the feeding of the antenna through known matching circuits commonly used among the radio amateurs. As the amplitude of the current and voltage on the end of the underground (spreading) antenna is reduced greatly, the resistance of a load in the range of 100-150 ohms is then possible for increasing the antenna current and efficiency.

Antenna Efficiency

As shown in reference [1] with a sufficient approximation it is possible to consider that the efficiency of a spreading-underground antenna (and, therefore the gain) on HF ranges constitutes no more than 10 % in comparison to an ideal Beverage antenna of the same length and installed at a height of 2 meters above the same soil, operating on the same frequency. But such antenna efficiency is achievable only with many consistent conditions. In reality, it can lie between the values of 1-10 % depending on quality of installation of the spreading-undeground antenna and the parameters of the ground on which the antenna is installed. Although the efficiency is in the 1-10% range, it is possible to make contacts on radio amateur bands under normal conditions using more than 100 watts powered into the antenna.

The pattern directivity of low-height spreading antennas is almost similar to the above-mentioned Beverage antenna installed above ground at a height of 2 meters, but the vertical angle of radiation of a spreading-undeground antenna will be 10-20 % more than for Beverage antenna. It allows us to assume that using a spreading antenna in a range 80 and 160 meters is possible for local contacts (up to 500 km). On bands higher than 40 meters, both local and long-distance QSOs are possible.

Again, due to variations of conductance and inductance of soil because of rain and other atmospheric conditions, the parameters of such an antenna will vary.

After the tiresome theory let's again return to practical constructions of underground and spreading antennas.

Historical Files About Construction of Underground Antennas

The development of underground and spreading antennas were widely conducted as early as the 1930s. Before the Second World War, early research into the operation of underground antennas was made for the purpose of espionage and invisible (stealth) antennas. These antennas needed be easily installed and set up in order to be useful as well as to provide operation of short-wave bands, specifically of 2-5 or 8-12 MHz, which was commonly used by spies throughout the world for clandestine operation. For that purpose it was revealed that most effective spreading antennas were using a wire of about 1-mm diameter and enclosed by a dielectric (insulator) of approximately 10mm in diameter. In those times it was found an effective length of a spreading antenna for operation in the "espionage" ranges of 2-5 or 8-12 MHz required a length of about 30-45 meters.

During the Second World War and subsequent years thereafter, active research was conducted into underground and spreading antennas for the RF ranges of 9 kHz through 50 MHz. The antennas for stationary underground radio centers were then developed. Easily installed espionage antennas for operation in short-wave bands for clandestine operation also were developed for portable use. The results that were obtained by the various countries working on these antennas were classified by each of the governments at the time. Meanwhile, some parts of the research documents about such activities fell into the public domain allowing us to conclude that the development of these types of antennas were actively used in the USSR and certain other countries.

The authentic documentation of information on usage of underground and spreading antennas during World War II can be found in the military files. Such information is repeatedly described in the Soviet files of documents so-called “Shorony” (underground stealth bunker). These bunkers were employed by the German army in the terrain of Western Ukraine after the Ukrainian nationalist moved over to the German side. I personally met and talked to the people actually involved in the use of these “Shorony” bunkers. Many of the underground HF aerials used were similar to the type described in this chapter. The so-called “Shorony” with these underground antennas were well disguised and practically undetectable even in immediate proximity of them. Only after 20–30 years of erosion by rain or from the rotting of the supporting girders have these “Shorony” bunkers been fully detected. Some time after World War II, many of the military records of the USSR were censored and purged of any mention about such underground antennas of the Wermacht. Books and magazines in which contained any information about such underground antennas were removed and destroyed. Nevertheless, old files about these “Shorony” have been located which enables us to verify that indeed underground antennas played a prominent role for communications during World War II.

It was determined that direction-finding equipment had great difficulty in locating underground and spreading antennas operating on the short-wave bands. Spies operating on the underground antennas from a distance of more than 20 kilometers from direction-finding centers were practically impossible to locate. Because of this difficulty in finding the radio’s location, the underground antenna was excellent for field espionage operation from suburbs of large cities. This was also true for stationary radio operation from places located at remote distances from large cities and direction finding centers. The field strength from underground and spreading antennas is low even when one is near them. The signal radiated even in the immediate proximity sounds like it is coming from a distant station, which is a result of ionospheric reflection. Thus, locating these espionage stations operating underground antennas was almost impossible.

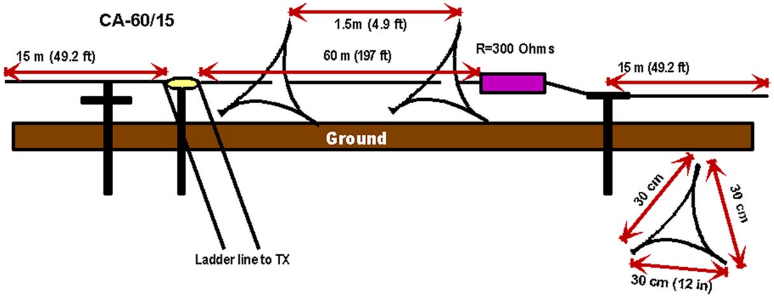
After WWII, usage and the development of underground and spreading antennas went in two separate directions. First, was that of creative antennas for stationary underground radio centers operating in a broad frequency range from 9 kHz up to 50 MHz. A second effort was to establish spreading antennas for army movable links on HF. Because times have changed, work on such espionage underground antennas has been curtailed for lack of that particular need.

However, now let's consider the practical construction of the spreading antennas as used by the USSR army.

Construction of Spreading Antennas Used in the USSR

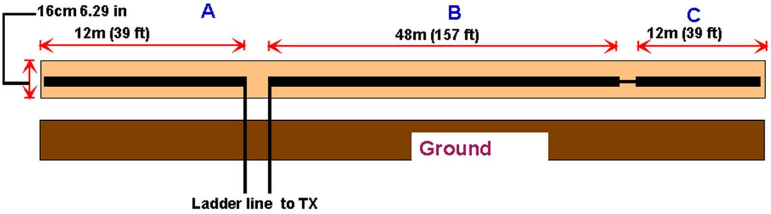
Spreading antennas, and those similar in construction, remain in existence not only in the Soviet Soyuz, but also in other countries. I managed to get some detailed descriptions on antennas of this type which has now been declassified. Let's consider the spreading antenna such as SA - 60/15. This antenna is made of a copper cable with a steel core inside. The cable passes inside plastic triangular insulators, which help keep it isolated from being grounded (**Fig. 6.4**). The cable is located in thick plastic insulation. The insulators are separated from each other by a space of 1.5 m. The two-wire line in plastic insulation from the transmitter is connected to an antenna. The length of this line is 5 m. The load resistance is a nominal 300 ohms and is protected from mechanical damage. The plastic triangles used for supporting an antenna are driven into the ground and therefore, they are made from strong plastic. The counterpoises are fifteen meters long and made of the same copper wire. They are connected electrically to steel pins that are 70 cm long, which are hammered into the ground at the counterpoise installation site. According to engineering parameters, the antenna works in the frequency range from 1 to 50 MHz. The maximum power into the antenna was no more than 5 kW. This antenna was referred to as a "spreading antenna" in 60 meters length with counterpoises in 15 meters length. This particular antenna configuration was used by the USSR Army

Fig. 6.4 Spreading Antenna SA- 60/15



for about 60 years. Later, in 1970 in place of the SA- 60/15 spreading antenna, a new version was introduced as the SA- 60-2M-PK antenna shown in **Fig. 6.5**.

Fig. 6.5 Spreading Antenna SA- 60/15 60-2M-PK



This antenna was made in a plastic body with a diameter of 16 cm. The antenna is constructed of an insulating material that is lightweight and could be floated. It floated on the surface of both fresh and salt water whenever the communications link was to be established. The surface of the plastic was special and it repelled water and dirt. If the antenna was used in a muddy pool it would have to be hung up to dry after each use and the dirt wiped off. The plastic insulation of this antenna was non-flammable and it was made very strong. According to technical parameters, this antenna can withstand being run over by a tank weighting up to 100 tons. It does not fail even with close explosions of bombs and practically direct hits by shells or mines.

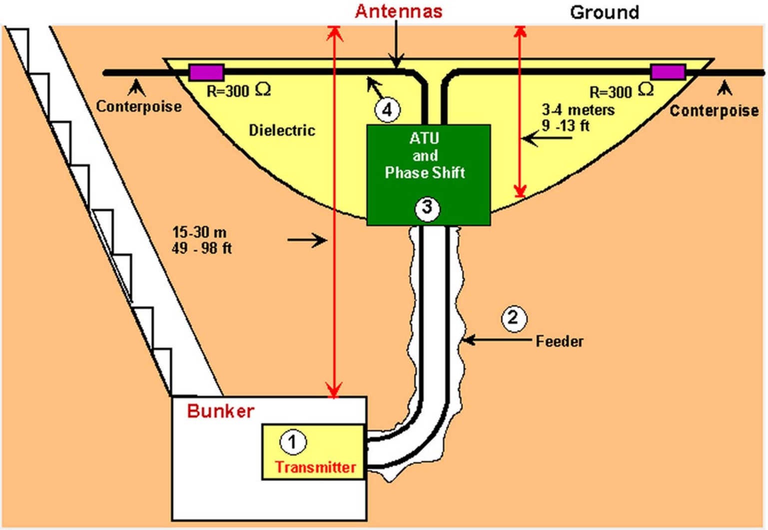
Antenna “B” is made from a cable with a width of 4 mm. The counterpoise “A” is made from a cable, similar to the antenna. Counterpoise “C” is made from a cord having a pure DC resistance of 100 ohms. This counterpoise is part of the load of the antenna that allows the use of an antenna without grounding pins on any type ground: sand, permanent ice, etc. A two-wire line (similar to ladder line) with a length of 5 meters is connected to the antenna. According to technical parameters the antenna works in a frequency band of 1-50 MHz and can stand an input of 5 kW. In the records, the antenna is defined as a “Spreading antenna upgraded with counterpoises”. This antenna can be buried at a small depth.

Spreading antennas were developed in mind for operation in hostile conditions where an exposed taller antenna could be blown away by an explosion. Such durability was necessary because under hostile conditions, it would not be easy to replace an antenna quickly using just natural objects like trees.

Construction of Underground Short-Wave Radio Center

The underground radio centers were established for different purposes. Some were constructed as powerful navigational underground radio centers operating in the range of very low frequencies. These underground radio centers with global coverage operated in a range of very low frequencies, super-long, long and medium waves. Other underground radio centers operating only on short-wave bands were also used.

Fig. 6.6 Construction of an Underground Short Wave Radio Center

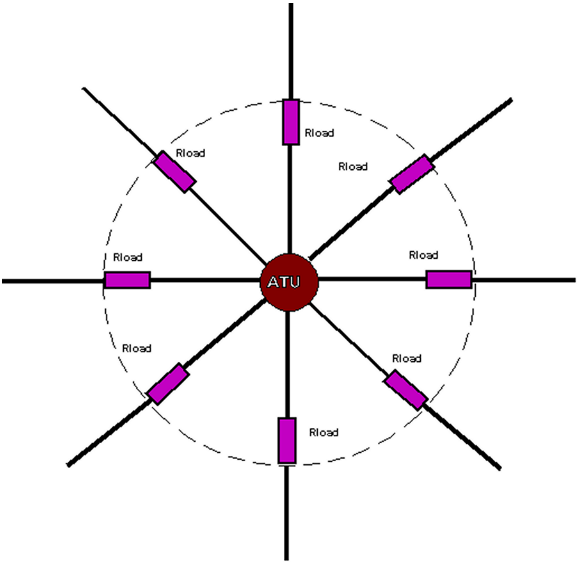


As for use by the radio amateur, the greatest interest would be the operation on short waves. In **Fig. 6.6**, the construction of an underground short wave radio center is illustrated. The underground radio center consists of a hardware hall (1) located at a depth of 15-30 meters under ground (halls = rooms or chambers). The transmitters are connected by feed lines (2) to the hall of matching devices (3). It is at a depth of 2-3 meters from the surface of the ground. The aperiodic loaded antennas are connected to matching devices and the counterpoises are buried close the surface. To increase their efficiency, the antennas are placed in the funnel at a maximum depth of 2-3 meters. The funnel is made of a dielectric and is disguised from above by ground covering. The composition of the dielectric is such that this funnel cannot be detected from the air, seismographic, or other devices (I cannot mention other classified methods, which does allow detection). In the hall of matching devices the antennas may be combined in groups for creation of a desirable directivity diagram.

The material these antennas were made of at these transmitting centers were bi-metallic tubes (copper plated iron) with a diameter of 20 millimeters. For directional control the phasing method was used where some antennas in the group are powered up applying phase shifting rather than moving them.To create the necessary directional patterns, some antennas are fed by a phase-shifted signal. The primary antenna is one single antenna from the group in which high-power is fed from the asymmetrical ATU. But, a lower level is fed to the opposite antenna in the array. Other antennas in the radio center which are not used for creating the directional pattern are also fed low power. The antennas which have low power act as a ground element antenna and the antennas with high-power are referred to as "working antennas".

It is possible to synthesize practically any directivity diagram by an underground antenna system. For example, altering the angle of radiation as well as azimuth directivity. Sometimes, similar short-wave underground radio centers were arranged with extendable masts with VHF antennas installed on them which were used for radio-relay or special link. With the arrival of satellite communications, underground radio centers as links or relays are no longer needed. In **Fig. 6.7** the top view of the antennas of short-wave underground radio center designed for short wave is exhibited. The length of these simple antennas range from 20 to 50 meters in length on various underground short-wave radio centers. The construction of similar underground radio centers was pos-

Fig. 6.7 Top view of the antennas in a short-wave underground radio center



sible on types of soils and therefore, could be placed at any location. Shifting soil or variation of soil content generally made little difference on the characteristics of the HF aerials which enabled keeping the required directivity pattern of the antennas.

Vertical Underground Antennas

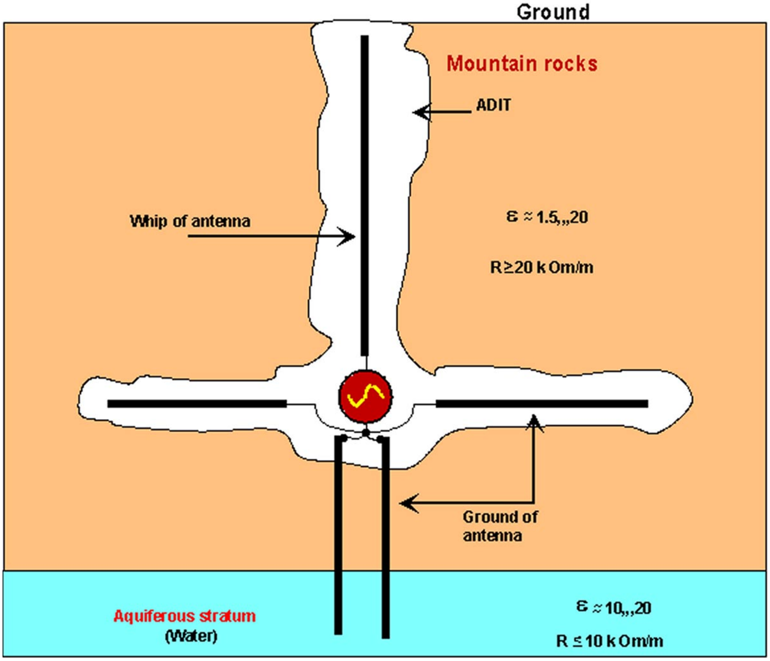
Although the documentation about the design of the short-wave vertical version of underground antennas is rather cryptic, I was able to draw ample conclusions about the operation of such underground short-wave radio centers using these vertical antennas. The vertical underground antennas were placed in tunnels drilled into mountain rocks as shown in **Fig. 6.8**. These mountain rocks were selected to have low losses on short waves. The inductivity **e** of these rocks should be no more than 4, conductance **s** no more than 20 millisiemens per meter. In this case, inclination of vector of electrical polarization of an electromagnetic wave passing through mountain rocks is not very great. It can be said that the resulting signal consists of vertically polarized waves.

The vertical underground antennas are usually constructed asymmetrical. It is nearly impossible to build a symmetrical vertical underground antenna because of different soil effects on the components of the antenna system. The altitude of the antennas depends on how deep of a hole can be drilled in a mountain rock and how close it is to an aquifer stratum, which commonly is used as the “ground” for the underground vertical antenna. The grounding for underground vertical antennas consists of several non-resonant short ground rods and wire counterpoises, which are placed about the antenna base. The vertical radiator of the underground antenna is tuned to resonance with the help of special matching devices when transmitting.

At construction of a vertical underground antenna is shown in **Fig. 6.8.** This configuration is used for a fixed location. By certain arrangements within mountain rocks, there are so-called “frequencies of transparency” whereby the absorption of vertical polarization is minimal. Therefore, the radiation of radio waves with vertical polarization is maximized because the signals “see through” the rocks. These “frequencies of transparency” are commonly used to operate from such underground transmitting centers. Remember that underground and spreading horizontal antennas do not have such frequencies of transparencies and they generally ensure broadband operation.

The underground vertical antenna shown in **Fig. 6.8** is based on information I located in some historical files and records. This configuration was used at one of the classified German underground radio centers during WWII located in the Carpathians (now Western Ukraine). Obviously, the creation of underground centers that use vertically-phased antenna systems is feasible also, but any reliable information about such centers could not be found.

Fig. 6.8 A vertical underground antenna

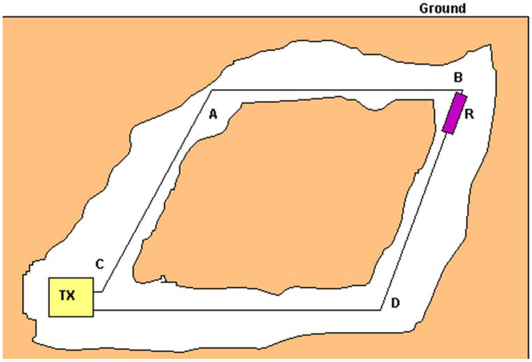


Cave Antennas

A special class of underground antennas is the rhombic vertical underground loaded antenna. Before WWII, these were first tested by the USSR in the Crimea and Georgian caves. The layout of this type of antenna is shown in **Fig. 6.9**.

The part of an antenna AB is placed on the surface of the ground or at a small depth under the surface. The parts AC, BD, CD are placed in a hole either artificial or natural.The first trials of these antennas were conducted on mountain plateaus

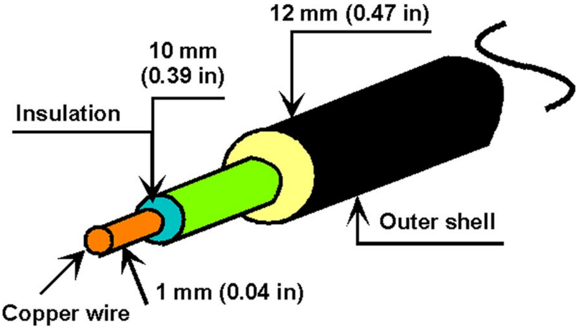
Fig. 6.9 A rhombic vertical underground loaded antenna



(in USSR in the Crimea and Georgian mountain plateaus) where natural caves were located. The rhombic underground vertical antenna, as well as the above ground version is directional toward the termination load. The rhombic terminated antenna is a progressive-wave antenna and there is less influence by the soil on its operation. The soil does not affect it as much as it does to a vertical underground resonant antenna. By switching the load from a point B in a point A, and accordingly switching feed point from point C to point D, the antenna directional characteristic can be changed 180°. In underground transmitting centers such antennas were used with some phasing couplers to allow transmitting in several directions.

In my research of documents, there was mention of the rhombic vertical-type of installation in rocky formations as military hardened radio centers under Sevastopol (this hardened center is now sealed), designed by General Dmitriy Karbyshev (killed in German Mauthausen P.O.W. Camp in 1945). For construction of these antennas, a wire with a diameter of 1 mm in plastic insulation with a diameter of 10 mm was used. It is like a thick coaxial cable with the outer conducting braid removed. It is not known, with any accuracy, when and in what country first used this type of antenna made of coax without the outer braid. Then being convinced of its adequate efficiency, this material became commonly used in construction of these particular underground antennas. In the USSR, for construction of underground antennas, a special "coaxial cable" configured as cable only with a copper center conductor and thick polyethylene insulation was used without an exterior metal braid

Fig. 6.10 A special "coaxial cable" for construction of underground antennas



shield. If a cable like this is ever found, you can be sure it was used for construction of underground antennas. From the regular coaxial cable it is distinguished only by stronger plastic outer insulation above the polyethylene insulation that covers the center wire conductor with absence of the metal braid. The exterior of such cable is shown in **Fig. 6.10**. The outer shell of this cable is very stiff, hard to manage, mechanically strong and serves as the armored covering of the internal plastic insulation.

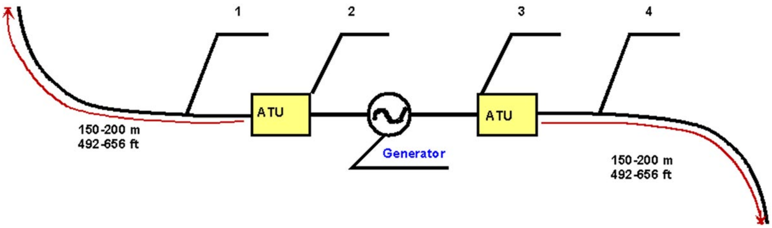
Underground radio centers that used the vertical rhombic terminated antennas are restricted to areas in which the terrain has high resistance and a small dielectric constant. Therefore, it exhibits a low degree of absorption of a high-frequency signal. It can be in the mountain areas with natural caves of rocky formation, abandoned mines, or any other similar places. In my view the use by the radio amateurs of rhombic underground antennas in mountains is improbable, though the modern multi-story buildings and apartments represent a likeness of a rock mountain, and if desired, it is quite possible to install a loaded rhombic antenna inside a building. During installation of such an antenna, it must be kept away from close proximity of RF absorbing objects and the electrical wiring in the building. As the maximum directivity of an antenna of this type is directional toward the termination, the termination can placed in this case not only in the upper corner of an antenna, but also in one of its lower corners, or in the middle of one of its sides.

Underground Radio Centers of Super-Long Wavelengths

The underground long-wave and super-long-wave radio centers are more widespread than short-wave centers. Often, a combination is used such as a long-wave radio center at a short distance from the short-wave radio center. The antennas used on long-wave centers are not commonly used for short wave, though in rare occasions there have been double application. Underground and spreading antennas used for radio communication on super long and long waves have similar features. On short waves the centers commonly use underground and spreading horizontal progressive-wave antennas or vertical underground antennas. For super-long and long waves the operation of spreading progressive-wave antennas are not very useful. The length of spreading antennas in these ranges cannot be more than 150 -250 meters. This is because they become too lossy (that was discussed earlier about the ***Length of Spreading Antennas***). Therefore, for better efficiency, spreading antennas of super-long and long waves use only resonant-type of antennas.

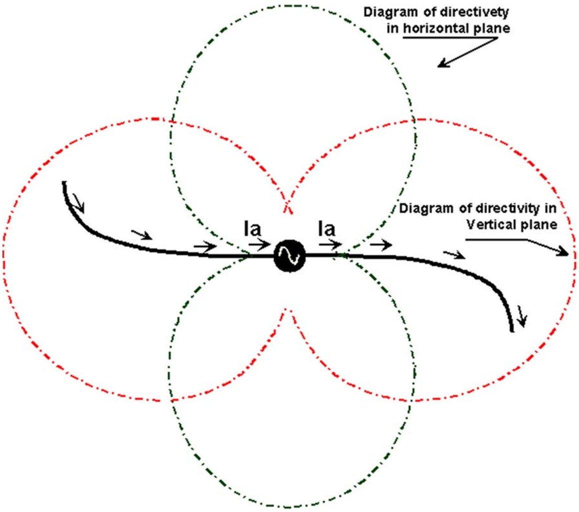
The diagram of a spreading antenna for super-long and long waves is exhibited in **Fig. 6.11.** The antenna consists of bent elements 1 and 4, which with the help of the appropriate matching devices 2 and 3, are tuned to resonance. As shown by **Fig. 6.11**, the elements of the antenna are bent in the shape of a boomerang. Therefore, such antennas in the USSR use the conventional name of “boomerang”.

Fig. 6.11 A spreading antenna for super-long and long waves



The construction of an antenna in the shape of a “boomerang” on super-long wave band has an advantage. First, the area with defined and fixed specifications of the soils is necessary for installation and setup of spreading antennas. At installation of an antenna in the shape of a “boomerang”, the antenna may be installed in a smaller area therefore it is easier to find a place for antenna installation.

Fig. 6.12 A directivity diagram of a spreading antenna for super-long and long waves



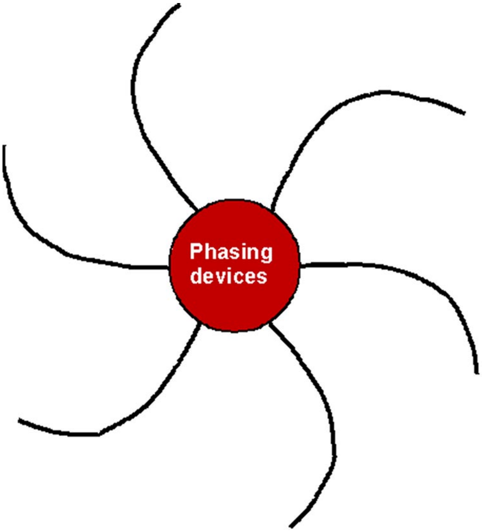
At these underground radio centers, sometimes it is necessary to pump out underground water and freeze the ground under the antennas. In this case it is possible to create soil with low conductance. This considerably reduces loss of high-frequency power into the soil. The construction of underground radio centers in this case is more complicated because of the need for special water pumps and water freezing stations which must be located near the centers.

As seen from **Fig. 6.11**, the spreading antenna of super-long waves represents a symmetrical antenna, which in contrast to the asymmetrical antenna, can be influenced by the soil characteristics. In this case, the antenna's directional characteristic in a vertical plane will be along the conductor of the antenna (**Fig. 6.12**). The directivity diagram in a horizontal plane of the antenna is perpendicular to the element of the antenna (**Fig. 6.12**). But the horizontally polarized radio waves will suffer from severe absorption in soil, and owing to a short electrical length of the antenna on super-long wave frequencies, the horizontal radiation component of the antenna is insignificant.

The electrical polarization is equal to the direction of the current in the antenna system. The propagation of the power along the antenna conductors on the surface is such that the main radiation from the antenna will become the electrical component of the signal.

The input impedance of a spreading antenna for super-long waves is in the very low ohmic ranges which causes engineering difficulties when matching these antennas. The efficiency of such antennas is very low being minus 40 to minus 80 decibels compared to the half-wave radiator. It is necessary to note, that in the super-long wave band, even the stationary vertical antennas have efficiencies in the range of minus 10 to minus 20 decibels.

Fig. 6.13 A spreading antenna called a "spider"



For construction of underground radio centers operating in short-wave bands, a series of antennas such as the "boomerang" will allow directional patterns to be generated by using phasing networks. In **Fig. 6.13** the top view of a spreading antenna system of an underground radio center is illustrated (in the USA, these radio centers are called a "spider"). For the material to build such antennas, you must use a coaxial cable as described above that has no shielding braid. As such antennas cover large areas, and when in operation, the directional pattern can be largely influenced by soil motion due to erosion or other natural conditions. Also weather conditions, such as snow and rain will change the characteristics of soil conductance and, therefore, increase losses in the antenna system. The range of wave and long waves is used for navigating, global radio communication, command and control of the army in emergencies. Thus, these radio centers are in operation worldwide.

Fig. 6.14 Plans for an underground radio center for super-long and long-wave range station

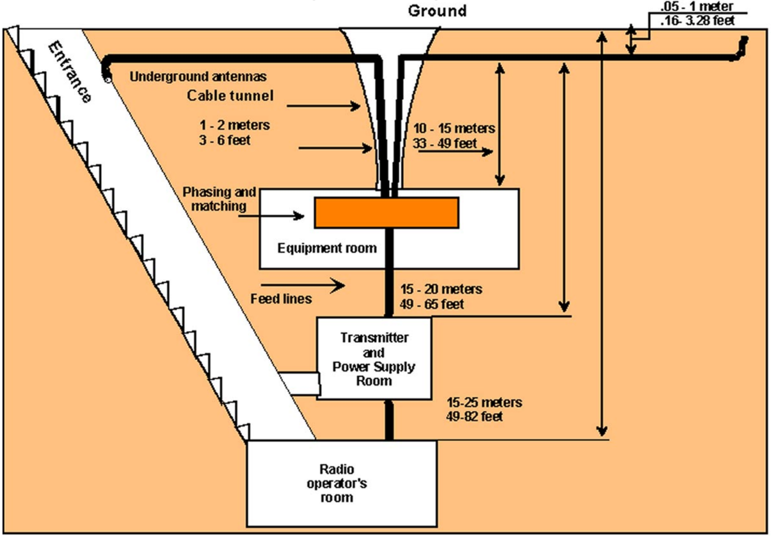


Fig. 6.14 shows the plans for the underground radio center for the super-long and long-wave range. The antennas of the radio center are buried at a shallow depth and 0.5-1 meters is common. In cable tunnels, feed lines for the antennas go to the room where phasing and matching devices are located. There the matching devices match all of the antennas and then the phasing networks generate the required directivity pattern. The hall of phasing and matching devices is at a depth of 10-15 meters depending on the type of soil. Detection of these centers is very difficult. Even using an audio locating device, such as the oil company seismographic “thumpers” that search for hollow spots in the ground, have great difficulty finding the center since the entire installation is buried.

Just below the phasing and matching devices room at a depth of 15-20 meters, the room is situated for the power supply and transmission devices. For operation during normal peacetime the normal electric power grid is used. For operation in emergency situations, diesel or nuclear power stations will be used. At a significant depth underground, the room for the power supply and transmission devices is located. This is so that it cannot be detected by its thermal radiation by satellites and troposphere reconnaissance flight vehicles (SR71). The cooling of this heat-generating equipment represents a serious problem. The water-pump and the refrigerating stations are partly installed in this room, but must extend at some distance from it. They are also at considerable depth to help prevent detection.

The operations' control room and life-support systems are installed below the power supply and transmission room at approximately 15-25 meters underground. As now illustrated from the figures and descriptions, the radio center of long wave resembles the construction layout of a radio center for short wave.

For the radio amateur, spreading and underground antenna for long wave are also of interest. The 136 kHz frequency is a preferred choice making the construction of radio amateur spreading antennas for operation on long-wave band is quite possible. As of now for these purposes, the radio amateur commonly uses vertical capacity loaded antennas, which are complicated for installation and setup. The underground and spreading antennas for operation on long waves are a good alternative to the vertical.

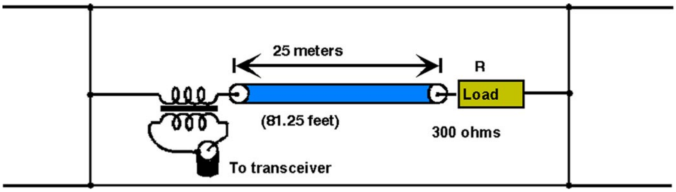
Below we shall consider how, for radio amateur conditions, it is possible to construct an invisible underground antenna.

Some Experiments

I conducted experiments with spreading antenna with a length of 80 meters in field conditions. The spreading antenna was placed on the ground surface and nearby was placed an A/B comparative Beverage antenna. Three quarter-wave counterpoises were used in both cases lying on the ground.

In test operation at the 10-40 meter bands, it was determined that there was no difference in the signal strength between the two antennas, even when the Beverage was raised to a height of 2 meters. Only at 80 and 160 meters did the spreading antenna show a signal weaker than the Beverage.

Fig. 6.15 An experimental spreading antenna



Next, I tried an experimental spreading antenna on the rooftop at home. The schematic of this antenna is exhibited in **Fig. 6.15**.

For this experimental construction of the spreading antenna I used an old coaxial cable with a length of 25 meters with a damaged and rotted outside braid. The outer shell and braiding from the cable was removed and the cable placed directly on the concrete roof which could be considered as an adequate substitute ground. The antenna was located approximately in the middle of the roof of the house. The end of the terminating load of 300 ohms was then connected to the metal portion of the roof which was connected to other metal grounded components.

The antenna was fed through the broadband transformer that had a 1:4 load ratio using a 75-ohm coaxial cable. The end of the transmitter input to the antenna was also grounded in this same manner. With the terminating load of the antenna being a resistance of 300 ohms, the antenna system had a SWR not more the 2:1 for the amateur ranges of 6-160 meters.

For comparing the efficiency of the spreading antenna, a Beverage antenna was installed having a similar load and power transmitter above the metal enclosure of the roof. The Beverage was at a height of 1.5 meters. The spreading antenna successfully conducted QSOs and when compared to the Beverage antenna on the HF ranges, the signal strength for the spreading antenna was weaker by 2 to 8 dB. On the low-frequency ranges the signals dropped more sharply. Later, I was successful in operating a spreading antenna while lying on a loft of a 9-story building. On this occasion, the antenna managed local and long-distance QSOs on 10-160 meters quite well.

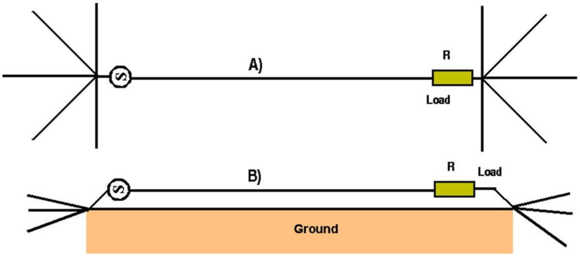
To establish a good ground, the spreading antenna was connected to the metal components of the roof, which in turn were connected to the metal grid work of the concrete building, making for an adequate substitute ground.

Practical Construction of the Underground Antenna

For the construction of underground and spreading antennas, it is desirable to use thick coaxial cable, not less than a 9 mm diameter with the braid removed. The wire core of the cable to be used as an antenna must be weatherproof and the plastic insulation of the cable must be flexible enough to allow the antenna to follow the irregular terrain surfaces of the ground.

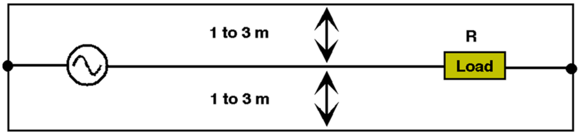
Proper grounding is of great importance for the underground antenna and there are two ways of doing it. The grounding is carried out the conventional way on the transmitter side. The ground load at the opposite end of the antenna is connected to 5-10 non-insulated conductors, each 0.1 the length of the antenna, and buried at a shallow depth in the ground. In **Fig. 6.16a,** the top view of this particular method of grounding is exhibited. In **Fig. 6.16b**, the arrangement of conductors in the earth's surface is shown. It is necessary to make sure the radial grounding wires should extend outward from the sides of the antenna.

Fig. 6.16 Grounding underground and spreading antennas



If the conductors cannot be buried because of hard soil (rocky), they can simply be laid out on the surface of ground, but the efficiency of the antenna will suffer. An alternate ground system for the spreading antenna is exhibited in **Fig. 6.17**. Two ground wires are connected on each side of the antenna. These wires are spaced 1-3 meters from the antenna and lay on ground.

Fig. 6.17 An alternate ground system of the spreading antenna



The radiation pattern and the distribution of current in this antenna using a substitute grounding system differs from the classic spreading antenna. One may readily assume the antenna efficiency factor will be not less than one-third that of the ideal spreading antenna. Its pattern lobe will show an increase in angle of radiation also. But, when it is impossible to establish a reliable direct grounding for the antenna (sandy soil, deep ice or snow), the substitute grounding method for the underground or spreading antenna makes for a good alternative.

Antenna Termination Load

The termination load of an underground and spreading antenna can be made in a similar manner to the "load" used on a Beverage antenna. This is done by using one or more resistors connected to the ground system that will be equal to the estimated impedance of the antenna and to dissipate the power into the antenna. The terminating load of an antenna more than 30 meters long may be calculated to handle an input power equal to about 10% of the input power of the antenna. It is necessary to provide protection of the load against atmospheric effects (rain, fog, moisture, etc.) using any traditional method of choice.

As the input impedance of an antenna on different amateur ranges varies more on high-frequency and less on low-frequency, it is desirable to use a compromise value of 200 ohms of resistance. In this case, the antenna will work satisfactorily in ranges of 6-160 meters and its input impedance will be within the limits of 200-450 ohms, depending on the range of operation. It is likely for the real spreading antenna to use a load adjusted for minimum SWR on any HF band. But, having determined this load for actual conditions with normal soil, the same resistance of a load will not be expected the same or optimum when that soil is frozen, dry or moist.

The input impedance of an antenna may be measured at the input connections by an RF impedance bridge. But, it is preferable to use a battery-powered RF impedance bridge meter. The measurement of the input impedance of an antenna system may be made on its coaxial cable input. However, in this case the exterior cable braid becomes part of the ground system, which will cause an impedance measurement error.

Conclusions

1. The antennas of this type fall into the category of “invisible” espionage antennas. They may be installed on a roof of a house or in a garden section,and will be almost imperceptible. At the same time these antennas can provide both short-range, and long-range QSOs. When operating such antennas with a low efficiency factor, it is necessary to use higher transmitted powers and increased receiver sensitivity.

2. It is desirable to make the antenna from coaxial cable with the braiding removed.

3. An installation of this antenna on or in the ground, even at shallow depth, efficiency will suffer, but at least it will be unnoticeable and allow operation. In my opinion, this type of antenna deserves much more experimentation.

References:

[1] G.A.Lavrov, A.S. Knyazev. Spreading and Underground Antennas. Moscow: Soviet Radio, 1965, 472 pages.

CHAPTER 7: MAKING ANTENNAS WITH COAX

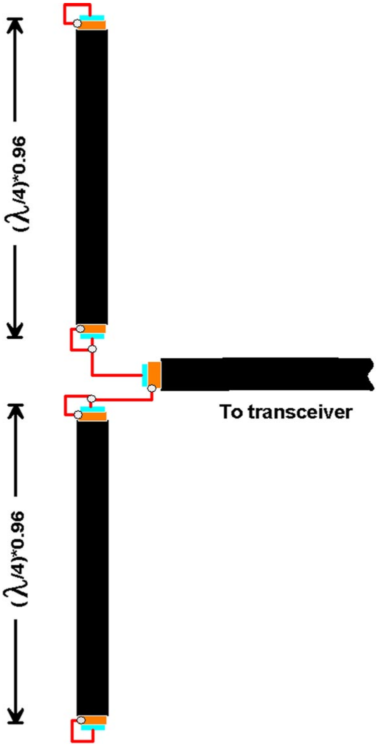
Coaxial cable is the favored means of feeding RF to an antenna, but it is also possible to make an HF amateur antenna out of coax. Frugal hams are scavengers, and tend to hang onto short pieces of coax from previous projects, as well as picking up "bargain" lengths of coax at hamfests. *(Those hams who work in Information Technology may have occasion to pick up short pieces of coax that are waste from building or repairing computer networks, as well. — Ed)* "One man's trash is another man's treasure," the saying goes. If you are one of those frugal hams with a box full of coax pieces too short to use for another feedline (and we know splicing feed lines is trouble), but too long to throw away, pat yourself on the back. You are not an obsessive packrat, but a ham with a good eye for salvage. Those 2M to 5M pieces are the raw material for the "coax antennas" described in this chapter.

In fact, coaxial cable as an antenna material has certain advantages. The coax shield, thanks to the "skin effect" of RF on a conductor, functions as if it were large-diameter wire. However, it is much cheaper, lighter and easier to work with than solid copper wire of the same diameter. Anyone who has tried to work with large-diameter copper wire for grounding or electrical work can testify to its stiffness, weight and expense. Unlike solid copper wire of the same diameter, coax shield can be soldered with a relatively low-powered iron. Because it is built for feeding antennas, coax is mechanically strong, and its jacket makes it resistant to weathering.

A coax dipole

The simplest coax antenna is a common, vertical or horizontal dipole (**Fig. 7.1**). This antenna can be fed with 50-ohm coax, or even better, 75-ohm coax. The lengths of elements for

Fig. 7.1 Simple coax dipole



dipoles from the 2-meter band to 20 meters are shown in **Table 7.1**. Thanks to the relative thickness of coax to a wavelength at the HF, CB and VHF bands, antennas made from it tend to be rather broad-banded, and thus forgiving as to exact dimensions. Tuning the frequency at the time of installation is seldom necessary.

Whether installed vertically or horizontally, the dipole of **Fig. 7.1** is a balanced antenna. Ideally, this antenna should be fed through a balancing device, or balun. Such a balun can be made from the same coax as the antenna, in the form of a coaxial stub balun. A simple coax balun is shown in **Fig. 7.2**, with the lengths required for 2 through 20 meters shown in **Table 7.2**. Dimensions given are for polyethylene dielectric cable with a velocity factor of 0.66. This type of balun is also suitable for feeding balanced antennas made from ordinary wire.

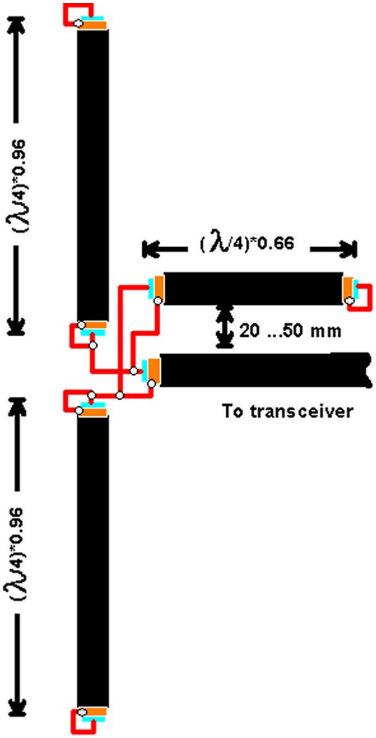
Table 7.2 Coaxial balun dimensions for 2 through 20 meters

Band Meter	(λ/4)*0.66 cm
20	348
17	274
15	231
12	202
11	178
10	174
6	94
2	34

Table 7.1 Coax dipole lengths for 2 to 20 meters

Band Meter	(λ/4)*0.96 cm
20	506
17	398
15	336
12	294
11	259
10	252
6	141
2	49

Fig. 7.2 Construction of a simple coaxial balun



Coaxial dipole with coaxial "tank circuit" resonators

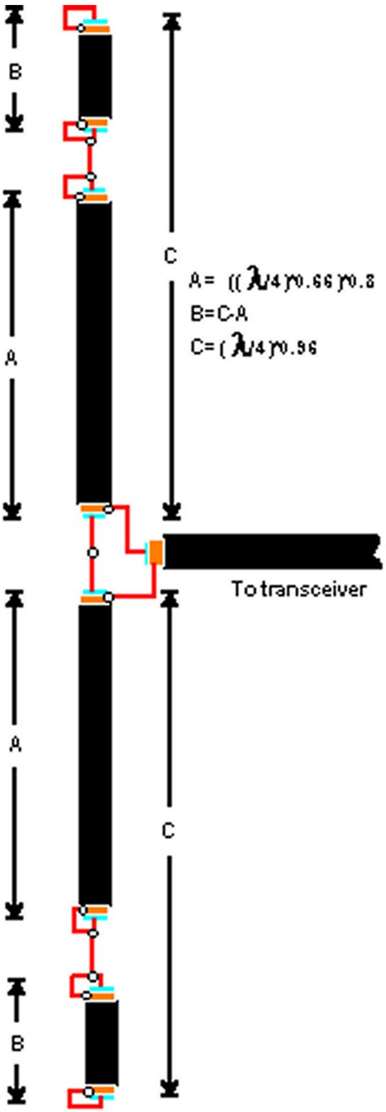
A more effective coaxial tank circuit resonator dipole can be built according to **Fig. 7. 3**.

The coaxial tank circuit resonator dipole can be thought of as a coaxial version of the folded dipole. Variations of this antenna design have been around in the amateur literature for half a century, and the idea's country of origin and exact date of birth are impossible to affix with certainty. *(Americans will see a family resemblance between this antenna and the "Double Bazooka," but with outer segments made of coax rather than wire — Ed.)* The coaxial tank circuit resonator is sometimes used as a basic constituent of complex antennas designed for the UHF range.

The coaxial tank dipole works, as mentioned above, as a folded dipole. The physical length of each element "C" is a quarter wave. The "A" segments are quarter-wavelengths (taking the velocity factor into account) folded back on themselves. The "B" segments of shorted coax give a total length of each element "C" of a quarter wave. The "B" segments can also be made from copper wire.

The passband of this antenna is limited both by the length of the dipole comprised of the "C" elements and by the passband of the coaxial tank circuit "A". However, the coaxial tank dipole is an efficient performer on any HF or VHF ham band for which it is built. In theory, the impedance of the coax tank dipole is the same as the characteristic impedance of the coax from which it is made. Being able to build the antenna and feed line all from the same type of coax makes it even more appealing. This antenna design is not

Fig. 7.3 Coaxial tank circuit resonator dipole



often seen in amateur use, but it does appear in the literature, as in reference [1] below.

The coax tank dipole is a balanced antenna, and, as such, requires a balancing device like that illustrated in **Fig. 7.2**. Refer to **Table 7.3** for the correct dimensions for the coax tank dipole antenna for the 2 through 20-meter bands.

Table 7.3 Dimensions for coax tank dipole antenna for the 2M through 20M amateur bands

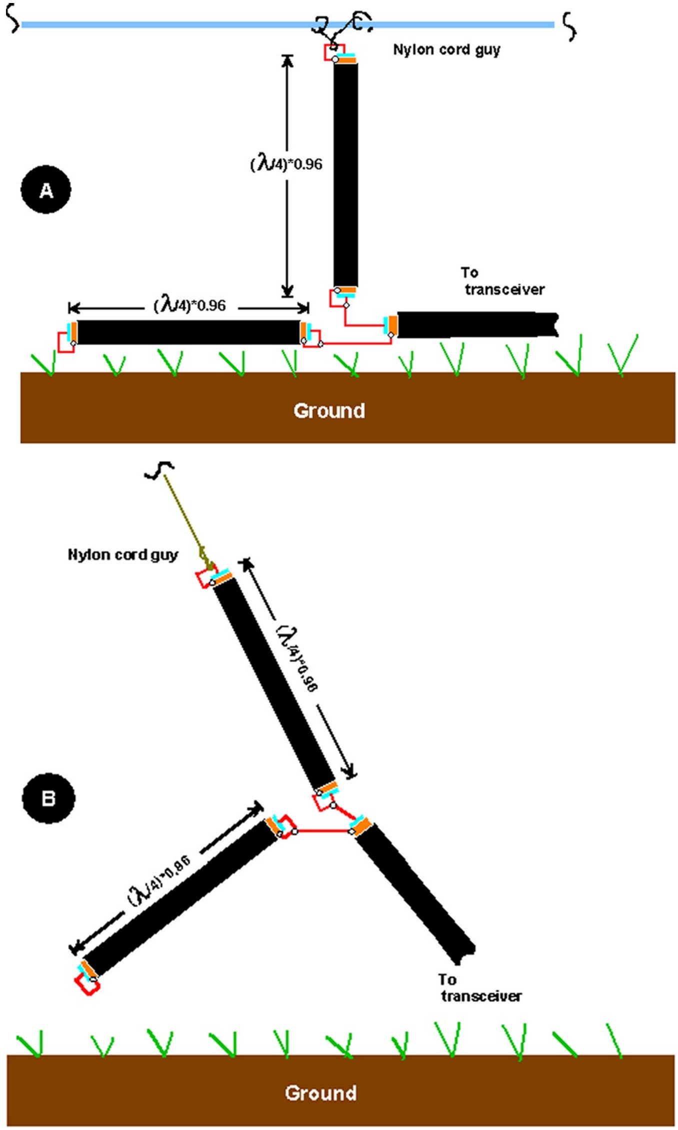
Band meter	A cm	B cm	C cm
20	278	228	506
17	219	179	398
15	184	152	336
12	161	133	294
11	142	117	259
10	140	112	252
6	78	63	141
2	27	22	49

Asymmetrical vertical antennas made with coax

Another variant of the coaxial antenna is the asymmetrical coax vertical. This looks like a 1/2-wave dipole made from two shorted pieces of coax just less than a 1/4-wavelength long, but with one element held vertical, or nearly vertical. The other element, running at close to a right angle horizontally, acts as a counterpoise. The feed point is between the two pieces of shorted coax. Since the two elements are not in the same plane, the influence of ground and nearby conductive objects is very different from one element to the other, making it electrically asymmetrical (i.e., unbalanced), as well as physically. Its unbalanced nature means it does not require a balun.

The simplest example of an asymmetrical coax vertical is shown in **Fig. 7.4**. One element is strung vertically, supported at its end by a nylon cord running between trees, other antenna supports, or other objects of sufficient height, as in **Fig. 7.4a**. It may also be hung as a sloper (**Fig. 7.4b**). In both cases, the other 1/4-wave element acts as the asymmetrical vertical coax antenna's counterpoise and can lie on the ground or near to it.

Fig.7.4 Asymmetrical vertical coax antenna



For vertical counterpoise placement, the counterpoise would be better built according to **Fig. 7.5**. Section A, 0.66 of a 1/4 wavelength piece of shorted coax, forms a quarter-wave insulator-resonant tank circuit. “A” is series-connected with Section B, which provides the remainder of the 0.96 wavelength element C. Section B may be either coax or wire. A list of appropriate lengths for sections A, B**,** and C can be found for several bands in **Tab. 7.4.** This table assumes a coax velocity factor of 0.66

Fig.7.5 Counterpoise for asymmetrical vertical coax antenna

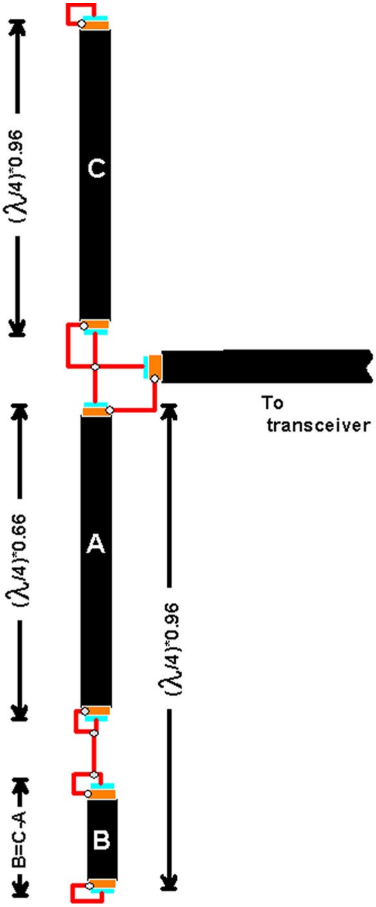


Table 7.4 Asymmetrical vertical coax antenna section’s “A”, “B” , “C” lengths

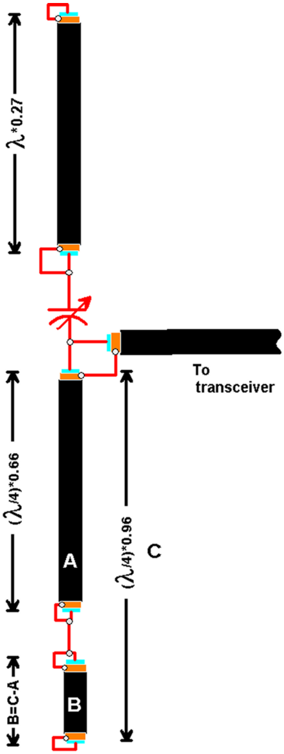
Band meter	A cm	B cm	C cm
20	348	158	506
17	274	124	398
15	231	105	336
12	202	92	294
11	178	81	259
10	174	78	252
6	97	44	141
2	34	15	49

It is important to note that quarter-wave resonant tanks are widely used in communication engineering as “insulators” in high-power, open-wire transmission lines. Coaxial transmission lines for very high power are expensive, and suffer from more attenuation that the same length of open wire.

Although it is more complex, the coaxial vertical with a quarter-wave resonant tank in the counterpoise has certain advantages over a vertical antenna with conventional counterpoises. For one, it is DC-grounded, which makes it safer to operate in thunderstorm season because it can dissipate static charges to ground. The quarter-wave resonant tank offers low resistance at off-resonance frequencies, offering additional harmonic suppression after the signal has already left the transmitter. For a coaxial vertical as described, with a counterpoise leaving the feed point at a 90-degree angle, the radiator has an impedance close to 45 ohms. 50-ohm coax will feed this system very well.

If it becomes necessary to feed this antenna with 75-ohm coax, a match can be made using a shortening capacitor in series with the driven element. The vertical element should be cut to about 0.27 wavelength for matching with the help of a variable capacitor with value of 10/150 pF as in **Fig. 7.6**.

Fig. 7.6 Feeding the coaxial vertical with 75-ohm coax



Simple Asymmetrical Antenna

Experimentation with coax antennas goes back a long way in amateur radio. A very simple unbalanced antenna made from coax was described for the first time in radio amateur publications by W6SAI, in 1956. The design has since come to be known among hams as the “slim cobra”. The evolution of the coax antenna continued, as shown in Reference [2]. Although the coax antenna may exist outside amateur circles, the author has never come across a reference to it in the professional literature.

Let’s take a closer look at the classic, W6SAI antenna, as illustrated in **Fig. 7.7**. This antenna is made completely from coax, with the braid removed from the last 0.24 wavelengths and a choke made from 5 to 7 ferrite beads 0.27 wavelengths back from where the shield resumes. The beads can be secured with tape. The permeability of the beads is not important.

This High Frequency RF choke can handle maximum power in the range of 200 watts in the lower HF bands and up to 100 watts in the upper HF bands. Exceeding these limits in power can cause the beads to saturate, overheat, and shatter, damaging the coax in the process. For use at higher power, the choke should consist of 10 to 20 turns of coax in a coil of 30 to 60 cm in diameter, with no form. Backpacking hams will certainly observe that, while such a choke is effective at higher power, it is, of course, more bulky than the bead-balun version.

The "ground" element of the single-wire coax antenna will be a bit longer than the classic counterpoise. There is an absence of the shortening effect of coupling to ground currents that takes place in common dipole and unbalanced vertical antennas. Practically speaking, minimum SWR at 50 ohms impedance will usually be reached with the choke attached at 0.27 wavelengths. Although part "A "can certainly be made of copper wire, by far the most common practice is to make the entire antenna from coax. Its ease of installation means this antenna lends itself well to field day use or to being tossed up in a tree or hung from a building on short notice as an expedient antenna at home. When cut to the dimensions shown in **Table 7.5** for the band of choice, tuning up is seldom even necessary.

Fig. 7.7 Classic W6SAI coax antenna

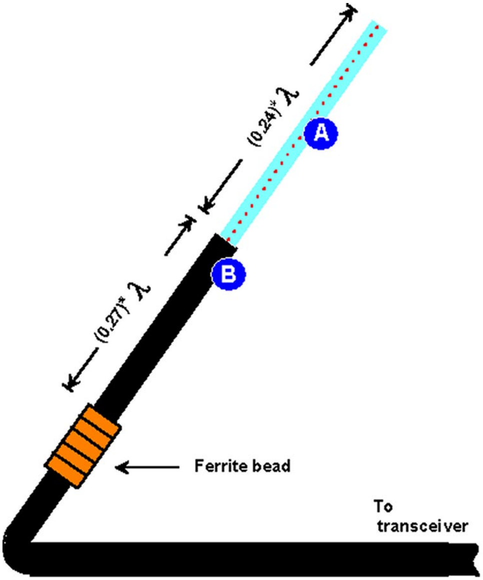


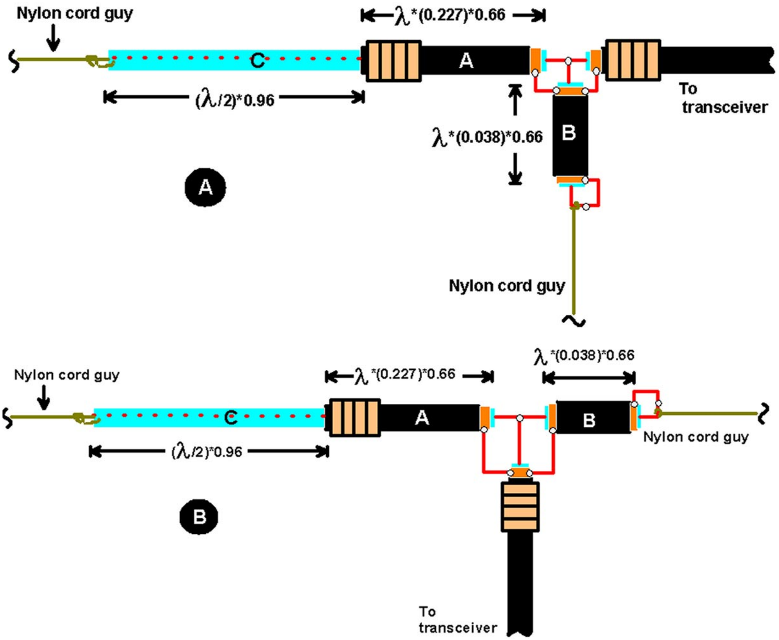
Table 7.5 Dimensions for a classic W6SAI antenna on 2-40m amateur bands

Band meter	A cm	B cm
40	1014	1096
30	707	764
20	506	547
17	395	426
15	331	390
12	294	324
11	252	280
10	249	275
6	138	152
2	49	53

A coaxial "J-pole" antenna

Twinlead "J-pole" antennas are familiar in amateur circles, but the same sort of antenna can be made from a length of coax. The Coaxial "J" is shown in **Fig. 7.8**. In this design, the radiator is cut to a half wavelength. The half-wave radiator has greater gain than a quarter wave, but the half wave end feeding radiator's impedance is high; on the order of a kilohm. This radiator is fed with the quarter-wave, coaxial resonant tank circuit illustrated as part "A" and "B" in **Fig. 7.8**, which is made from the same coax the antenna is made from. The tank circuit is fed at a point where its input impedance matches the characteristic impedance of the feed coax.

Fig. 7.8 Coaxial Cable "J" antenna



This antenna can be made from a single piece of 50-ohm coax, cut according to the dimensions shown in Fig.7.8. In this case, very little initial set-up is involved, and the antenna is "plug and play" on its design frequency as soon as it is assembled. **Table 7.6** shows appropriate coaxial "J" antenna dimensions for 2M to 40 M, assuming the coax used has a Velocity Factor of 0.66. The only potential "down side" of this antenna is the necessity for preserving the right-angle arrangement at the junction of the antenna, the tank circuit and the feed cable. This provision implies the need for two guys: one for the vertical length, and one for the "arm." At higher frequencies in the range of 2 through 15 meters, a non-conductive brace may provide the support for the horizontal element leaving only one guy required for the main antenna. As before, this antenna lends itself to use by the “urban warrior” and the backpacker, as well as the homebound operator with limited space for antennas.

High SWR at the feed point of this antenna effectively changes the electrical length of sections “A” and “B”. High SWR may be the result of building this antenna from poor quality cable, or from coax that does not have the specified 0.66 Velocity Factor, or by installing it near to large, conductive objects.

Because the quarter-wave coax resonator tank is a closed circuit at DC, it has the advantage of draining atmospheric static to ground. The quarter-wave tank makes harmonic suppression at the transceiver important, as the radiator can be active at multiple half wavelengths of the design frequency.

Table 7.6 Dimensions for Coaxial “J” antenna

Band	A	B	C
meter	cm	cm	cm
40	637	107	2010
30	444	74	1424
20	316	52	1012
17	248	42	796
15	212	35	672
12	183	31	588
11	166	27	518
10	157	26	504
6	88	18	282
2	30	5	98

Bead-balun HF chokes of 5 to 7 beads are recommended on both the feed line at the tank (**Fig. 7.8b**) and at the output end of the resonant tank, where the radiator begins. Both chokes will improve the operation of the coax “J” system.

Elementary “J” antennas are an important component of modern HF, VHF and UHF communication and direction finding equipment.

Dual-band antennas from coax

A coax dual-band dipole antenna (**Fig. 7.9**) is simple to build, if not quite so simple to set up.

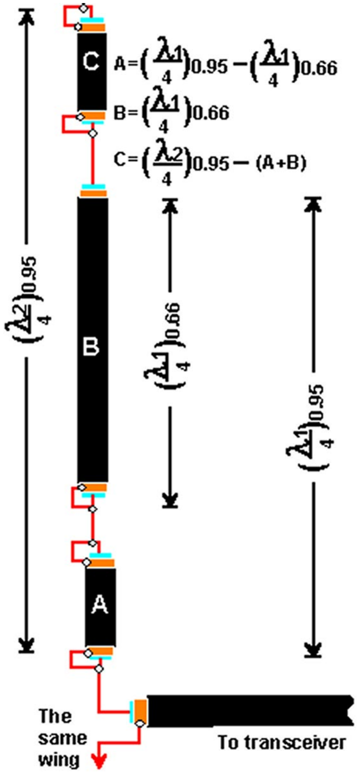
The overall lengths of the elements of the dipole are roughly a quarter-wavelength at the lower of the two frequencies of operation. On its upper design frequency, the quarter-wave tank circuit, “B,” in **Fig. 7.9** traps out the “C” sections that are active on the lower frequency.

Setup for this antenna is a bit “labor-intensive”. Begin by tuning the antenna for the higher frequency, by adjusting the length of section “A”. Arrive at the lower operating frequency by trimming section “C”. The dimensions for both elements are given in **Fig. 7.9**. Note that the actual length of section “C” may differ from the drawing, tending to be longer.

Although in theory an antenna of this design could be built for three bands, the complexity of initial setup makes this impractical. The most common application of this type of antenna would be on bands that are whole number multiples, such as 10-20 meters, or 20-40 meters

It’s also possible to build a dual band vertical coax antenna, as illustrated in **Fig. 7.10**, and applying the coaxial resonant tank. The upper sections of the antenna are cut to the same dimensions used in **Fig. 7.9** but the counterpoise for the higher frequency is made separately. The braid of the coax on which the familiar ferrite beads are placed at 0.27 wavelengths furnishes the lower-frequency counterpoise.

Fig. 7.9 Coaxial cable dual-band dipole



Dual band coax vertical for 2-10 meters

A fairly simple coax vertical for 2 and 10 meters can be built as shown in **Fig.7.11**. On 2 meters, the antenna is the broadband radiator composed of four conductors made from sections of coax with the shield removed. The radiators and their corresponding counterpoises are soldered together to give them an electrically “large” diameter, and thus, greater bandwidth. The 10-meter radiator, in similar fashion, is made of coax with the shield removed. The coax shield supplies the 10-meter counterpoise with ferrite beads fixed in place at a distance of 2.7 meters down the cable. For durability and mechanical strength, the 2-meter radiator and counterpoise elements are attached to the 10-meter section with electrical tape.

For best results, start building this antenna with a radiator of the right length to resonate on 10 meters at minimum SWR. To build along the lines of the antenna designs of **Fig. 7.9** and **Fig. 7.11**, we can probably succeed with either 50-ohm or 75-ohm coax.

Fig. 7.10 Dual band coaxial vertical

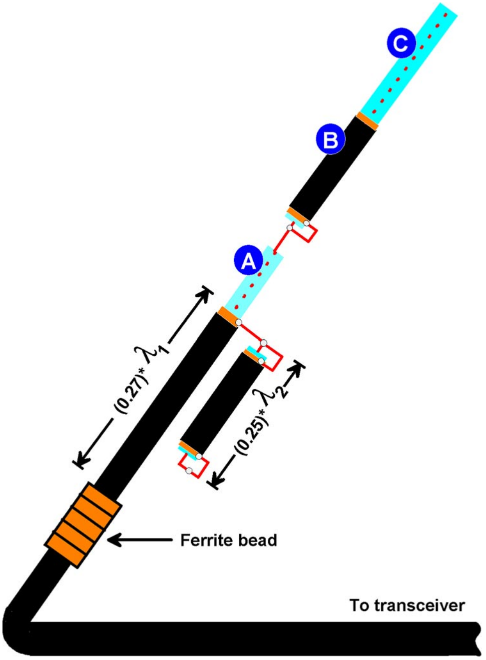
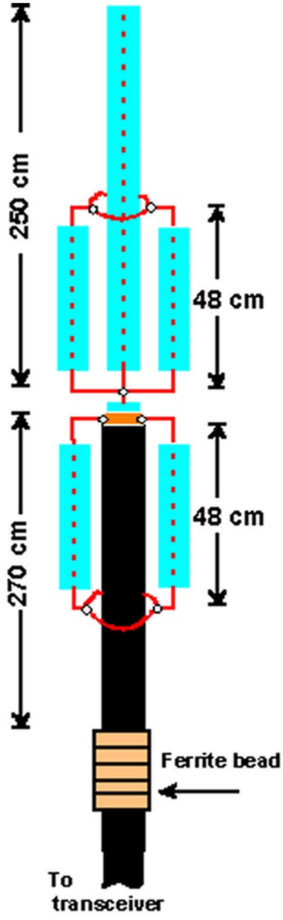


Fig. 7.11 Simple coax vertical for 2 and 10 meters



REFERENCES:

1. Hans Tscharner, “HB9XY “BaZooka” DX-antenna on QRP” // ***OQI**. - # 30, Vol. 8, 1997. - P. 22-23.*

2. J. Heys (G3BDQ). “The Slim Cobra.”// ***Practical Wireless**. August 1995, P. 28-29.*

CHAPTER 8: MAKING TV ANTENNAS WORK FOR AMATEUR RADIO

When you go to the trouble to put up a TV antenna, why not make it useful on the amateur HF bands, as well? Yes, as unlikely as it sounds, it can be done. A TV antenna can serve both as originally intended, and as an HF antenna, for both receiving and transmitting. The advantages are obvious. The frugal ham gets two antennas for the price of one, and the “low-profile” ham gets a TV antenna that is also an “invisible” HF antenna.

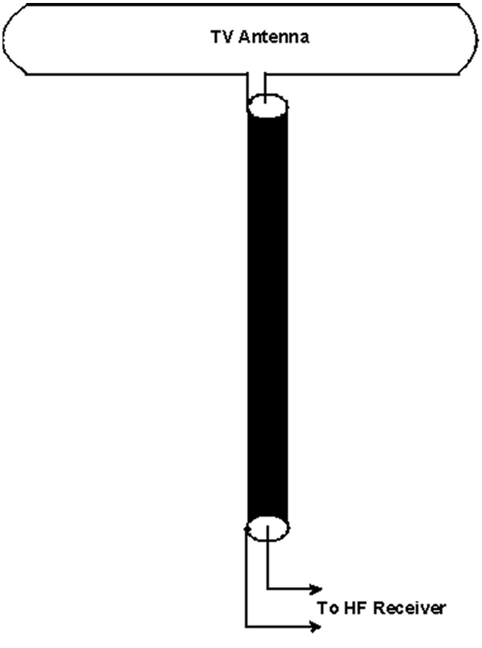
Of course, any such dual-purpose arrangement is a compromise, and we must take for granted that the video and power supply circuits of an average TV set are often a source of interference on HF. Likewise, some radio receivers, especially those with tubes, can also interfere with TV reception. These are facts of life, but simply setting aside separate times for TV watching and amateur radio may allow TV watchers and hams to get along in the same household.

In this chapter, we will explore some circuits for adding to the TV antenna system that allow both TV watching, and transmitting and receiving on the HF bands.

Receiving the HF Bands on a TV Antenna

The simplest way to use a TV antenna for HF reception is to connect it directly to the HF receiver, as shown in **Fig. 8.1**. If the TV antenna is a folded dipole or loop design, it behaves in the HF bands as an electrically short magnetic loop. If it is a dipole (two elements with an insulator in the center), it behaves as an electrically short linear antenna. Electrically short antennas have a small component of resistive impedance at the feed point. The remaining impedance of an electrically short loop

Fig. 8.1 Direct Connection of HF receiver to TV antenna



will be inductive reactance, and a short linear antenna will have capacitive reactance as the other component of its impedance.

If direct connection is the way you approach this situation, you will have to remove any balancing devices ("baluns") at the TV antenna feed point. Baluns work well for TV, but they might as well be a dead short at HF frequencies. Since the impedance of the TV antenna's feed point is nowhere near the characteristic impedance of the coax when the system is used at HF, we can't have very high expectations for its performance. We are not disappointed though because the coax acts as an "accidental" attenuator at the desired HF frequencies. However, we benefit from the "antenna effect" of the coax shield acting as an antenna in the HF bands. While this arrangement can only be used when the TV is not in use, and vice versa, it is possible to get respectable results on HF with a modern, sensitive HF receiver.

Obviously, the next step in the evolution of the TV antenna into an HF antenna is to permit both uses at the same time. For simultaneous reception of TV and HF signals, we can install some simple isolation filters that are illustrated in **Fig. 8.2**.

Fig. 8.2 Isolation filters that separate TV signals from HF

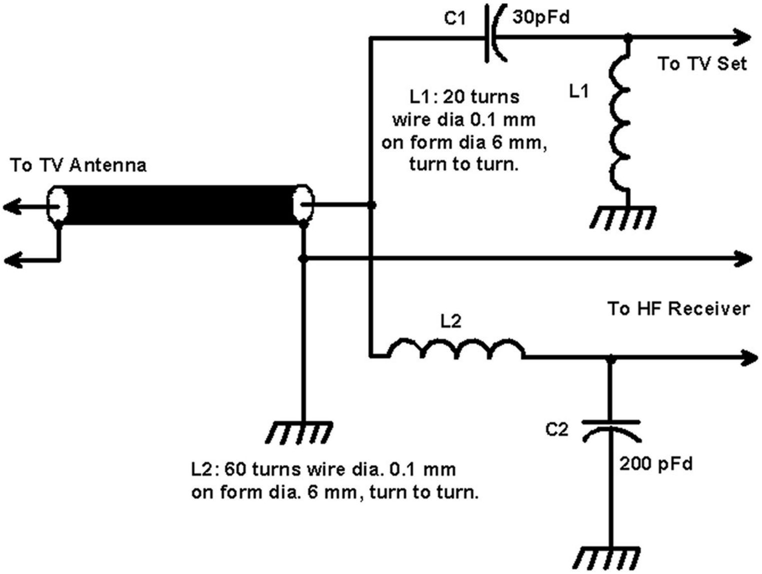
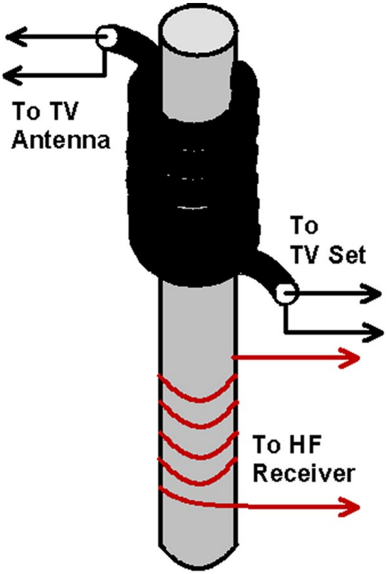


Fig. 8.3 Isolation/coupling transformer for coupling to TV antenna coax shield

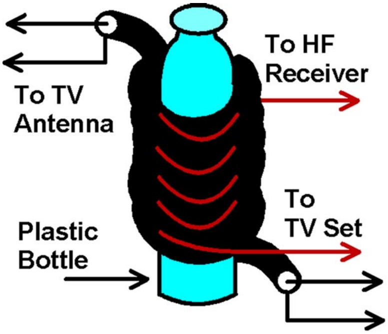


If the TV antenna is already installed, or for whatever reason it is not possible to remove the balun from it, the HF reception will be lacking, as mentioned earlier. In this case, the coax shield braid may serve as an HF antenna. The simplest way to accomplish this is to connect the TV antenna coax shield directly to the receiver's antenna input port, but this has at least two disadvantages. One is that the TV and HF receiver can't be used at the same time. The other is that the shield carries a lot of local, low frequency electrical noise into the HF receiver, which degrades its performance and your enjoyment.

The best remedy for this situation is to couple the shield to the receiver with a transformer. The transformer effectively cuts off the LF part of the spectrum that contains the local RF electrical noise. The ferrite rod from the AM antenna of an old transistor radio will serve well as the core for this device, but any ferrite rod with a permeability of about 600, and a length of 160 mm and a diameter of at least 6 mm will do nicely. Wrap about 10 or 20 turns of the TV coax on one end, and the same number of turns of any multi-conductor cable of 0.5 mm to 3 mm in diameter on the other. Construction details of this transformer are shown in **Fig. 8.3**. Connect the transformer to the HF receiver as shown in the drawing.

If the TV cable is too thick to wind on a ferrite rod, such as RG-6 (about 8mm), it can be wound on a form made from a glass jar (1/2 or 1 liter), or a rigid plastic bottle. Close-wrap the coax "primary" winding on the jar, and secure it with electric tape. Wrap 10 to 20 turns of stranded, copper wire of 3 to 5mm in diameter directly over it as the secondary, and secure that with tape. For construction details, refer to **Fig. 8.4**. Please note that, when using the isolation transformer

Fig. 8.4 Isolation transformer wound on a bottle



described here, the coax to the TV should always be grounded. That is nearly always the case if the coax is connected to the TV.

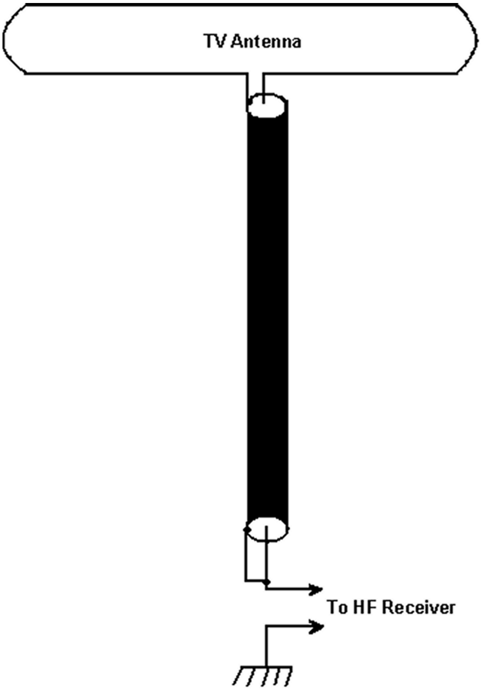
Using a TV antenna for HF transmitting

Using a TV antenna for receiving on HF is a fairly simple matter. Using it for transmitting is as bit more complicated, but it can be done. First, transmitting on HF and watching TV at the same time is not an option. The two activities are definitely incompatible, and call for careful scheduling and separation.

The simplest solution is to use the coax and TV antenna as a random-length long wire. The center conductor is simply shorted to the braid at the transmitter, and the shorted wire serves as the connection to the radio (see **Fig. 8.5**). If this method of operation is a possibility when the antenna is installed, it should be mounted on a non-conductive mast, such as wood or plastic, and situated as far away as possible from large metallic objects.

Using a TV antenna coax feed line as an expedient HF antenna is a practical measure where a classic wire or aluminum antenna structure is out of the question. For best results, the coax should be no shorter than a quarter wavelength at the lowest HF frequency to be used. However, it is a solution bound to cause problems of interference and “RF in the shack” if the cable is routed near radio equipment. There is no question that a good, high-quality RF ground is a necessity in this application.

Fig. 8.5 Using the braid of the coax as a long wire antenna



Since the chances that the TV coax is resonant on any ham band of interest is remote, some kind of matching network will be required. Fortunately, the shield of the coax is electrically like a large-diameter wire in the HF spectrum, so matching should not be a problem. A typical such antenna should have impedance in the range of 50 to 500 ohms, which should be possible to match with commonly-available matching networks.

Combining a Half-Wave Resonant Wire Antenna with the TV Antenna

It's possible to use the TV coax to feed both the TV antenna and a resonant HF antenna if we are careful to separate the two signals with appropriate filters.

A very simple, single-band "high-ohmic" (high resistive impedance) half-wave antenna and a TV antenna can be fed from the same point as shown in **Fig. 8.6**. We place a parallel-resonant, LC circuit, tuned to the desired HF operating range, at the common feed point of the two antennas (See **Table 8.1** for appropriate L and C values for each ham band). A wire antenna, consisting of one or more one-half wavelength at the frequency of choice, is connected to the "hot" point on the resonant circuit. The TV antenna is connected to a tap on the coil about 1/4 to 1/6 of the total number of turns from the "cold" terminal.

Fig. 8.6 Combination, half-wave (or multiple-half-wave) HF antenna and TV antenna fed from a common point

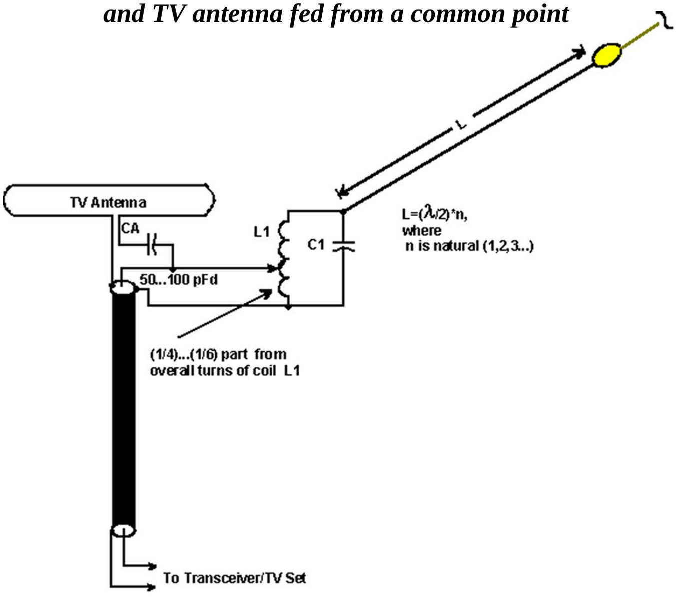


Table 8.1 Parallel resonant circuit component values for the ham bands

Range Meter	Induct. of Spool	Cap. of Cap. pFd	Dia. of Spool	Length of Winding mm	Dia. of Spool Wire mm	No. of Turns
160	6.8	1000	40	50	2.0	18
80	6.0	330	30	50	2.0	20
40	2.4	220	40	50	2.0	10
30	2.0	130	30	30	0.8	10
20	1.4	100	30	50	1.0	10
17	1.25	85	25	40	2.0	10
15	1.05	75	25	50	2.0	10
12	0.85	65	50	50	2.0	5
11	0.8	50	18	25	1.5	9
10	0.7	50	50	60	2.0	5
6	0.3	35	18	20	1.5	5

The TV antenna is connected through capacitor CA (50 to 100 pF) to the coax. The LC circuit has no effect on the operation of the TV antenna for its intended use. Also, TV signals don't arrive at the TV set's antenna terminals via the HF antenna, causing "ghosts". The LC circuit is acting as a band pass filter at the HF operating frequency, and is very "lossy" for the TV signals that happen to be captured by the HF antenna.

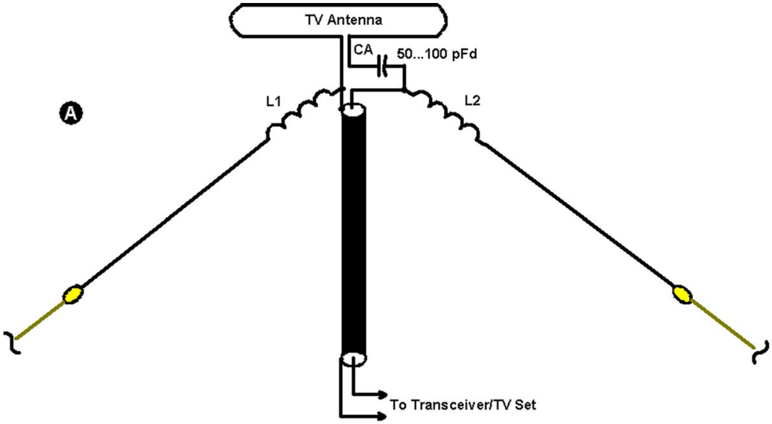
This system is set up by selecting a tap on the inductor that results in the lowest SWR on the coax at the HF operating frequency, while selecting the value of the tuning capacitor in the tank circuit that maintains resonance. On the TV side, the best value of CA is experimentally found that results in the best TV signal.

The HF element can also serve as a guy wire for the TV antenna, making it even less conspicuous, and serving two purposes. Installed as a half-wave sloper and tied to a metal mast, it can turn in respectable performance on DX. The most glaring deficiencies of this antenna are being tied to one band and a somewhat complex setup. However, once in place, this kind of antenna performs well in the range of 160 to 20 meters. At higher frequencies 17 through 6 meters), the LC circuit doesn't provide the needed rejection of TV signals, and TVI will be more of a problem as will "ghosts" from TV signals entering via the HF antenna. The circuit formed by capacitor CA and the TV antenna may have resonances in the upper HF range that make tuning up on these bands impossible and that greatly reduce the efficiency of the HF antenna. Where you can operate on a low enough HF band and where only one wire can be put up for that band, this is a practical way to meet the need for discretion and economy and still get on the air.

Combining a Half-Wave Dipole with a TV antenna

Compared to the half-wave sloper above, a dipole antenna is easier to make and set up. Of course, installing this dipole as an inverted V lends itself to using the antenna as a pair of guy wires on the TV antenna mast, which makes it “invisible” and practical at the same time. Refer to **Fig. 8.7** for a drawing of the TV antenna/ dipole combo.

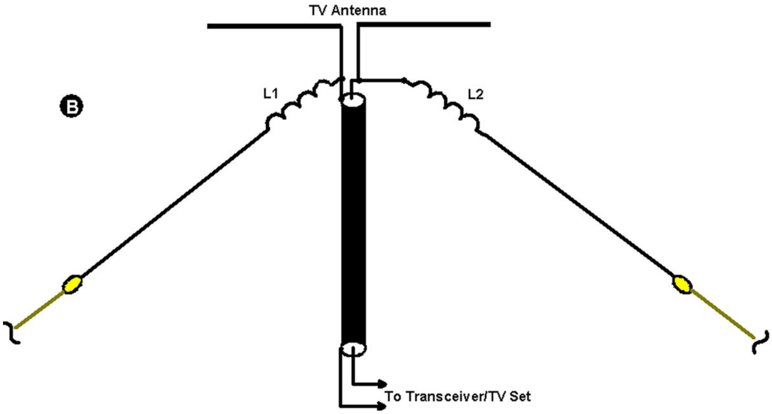
Fig. 8.7a HF dipole/TV antenna combo



For the folded-dipole-type of TV antenna, use **Fig. 8.7a**. The inside ends of the inverted V elements are connected at the TV antenna feed point through HF chokes L1 and L2. The TV antenna connects to the center conductor of the coax through capacitor CA, which has value between 50 and 100 pF. The HF chokes electrically “disconnect” the TV antenna from the HF antenna and capacitor CA has little effect on the HF signals.

If the TV antenna’s driven element is a dipole with no electrical connection between the elements other than the feed line, capacitor CA is not needed (see **Fig. 8.7b**). The most significant characteristic of the chokes is mechanical strength and that they be as nearly identical as possible. Inductance value will be from 3 to 10 µH depending on the chosen HF operating frequency. A convenient form for the coils can be made from a section of a plastic ski pole, or any other piece of plastic rod from 12 mm to 16 mm in diameter. They should be wound with 20 to 40 turns of 1.0 mm copper wire.

Fig. 8.7b HF dipole/TV antenna combo



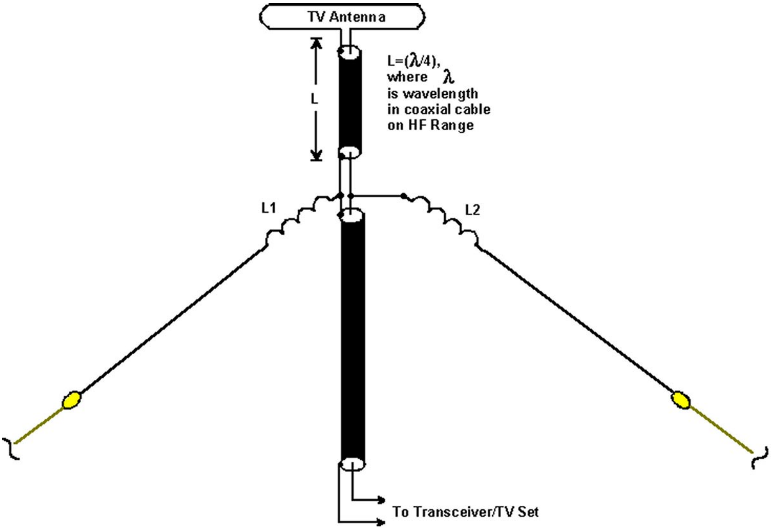
The wire runs from the coax to the chokes should be as short as possible. The chokes will increase the antenna's electrical length, so the starting length for the dipole elements should be 10% or 15% shorter than usual for the frequency of operation. Tune-up of this antenna consists of simultaneous trimming a little off of each element of the dipole while checking it with an SWR meter or RF bridge.

This arrangement works with a folded-dipole-type TV antenna between 160 and 15 meters, but it begins have a small antenna factor at higher frequencies as they begin to treat capacitor CA as a bypass capacitor and at the points where the system TV antenna and CA become a resonant circuit. In the case of the open-centered dipole-type TV antenna, these limitations don't apply.

The strategy of using the TV antenna and its coax to feed an HF antenna can be applied to other types of HF antenna, such as a vertical whip, or a loop, but matching them is much more of a challenge. The sloping ends of the antennas described make them much more convenient to tune, as well.

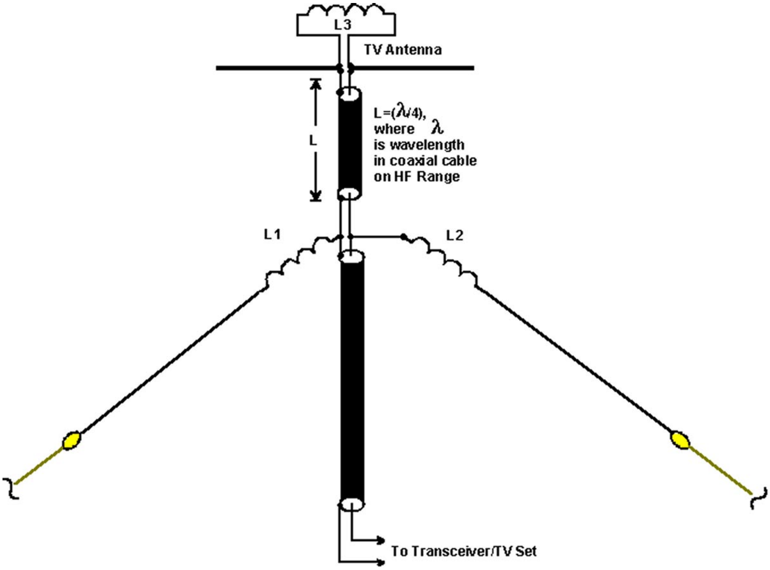
The presence of the HF antenna very close to the TV antenna can affect the performance of the TV antenna, but this effect is only noticeable on weak TV signals. The effect appears as a "ghost" image on the TV screen. If this is a problem, connect the TV to the original feed point with an additional length of coax that is a quarter wavelength long at the HF operating frequency **(Fig. 8.8)**. The stub offers a high-impedance path on the HF operating frequency without interfering with the TV signals. Thus, an HF antenna and a TV antenna occupy almost the same roof space, and without interfering with each other.

Fig. 8.8 Combo antenna with quarter-wave stub



This antenna is first tuned without the TV antenna and quarter-wave coax connected. When the SWR is acceptable, connect the TV antenna and gradually shorten the quarter-wave stub while watching for the maximum reduction of ghosting while preserving the low SWR at HF. In this version, the TV antenna should “look” like a short circuit at HF. TV antennas with u-shaped wire baluns at the center, folded dipoles and loops already satisfy this condition, but dipole-type TV antennas need an inductor to provide the short at HF as illustrated in **Fig.8.9**. The RF choke consists of 10 to 20 turns of copper, 1-mm wire on a form 10 to 20 mm in diameter.

Fig. 8.9 Combo antenna design for dipole-type TV antennas



The cave's beauty

CHAPTER 9: MULTI-PURPOSE ANTENNAS

In this chapter, we will be looking at several antenna designs that operate in more than one frequency range. Many of them operate in combinations of bands that are not the ones you expect to find in off-the-shelf, “multi-band” antennas, such as 2 meters and 440MHz. Hence the name, “Multi-purpose Antennas”. Some of them may be especially suited to working with the new, “all-band, all-mode” radios, such as the IC 706 series, or with the newer HF radios that include 6 Meters along with the HF bands. These designs will include some that work on 144MHz and 28 MHz, and some that combine 50 MHz and 28 MHz.

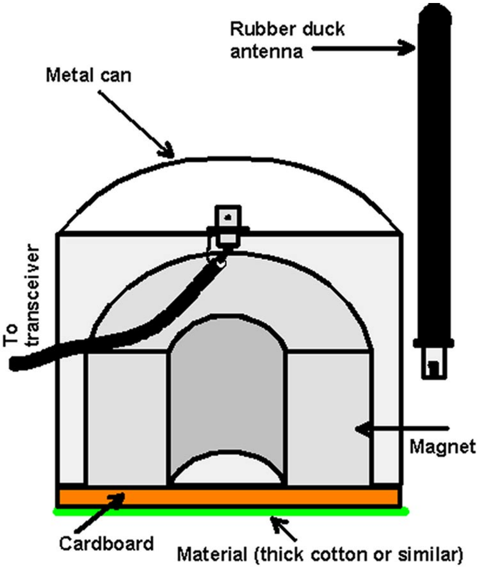
Amateurs with limited space for dedicated, single-band antennas for the above ranges will find these designs useful. They are also appealing to hams that, based on the sporadic propagation in these bands, may not want to spend the time and money on dedicated antennas for each band. All of these simple designs will help take advantage of good propagation conditions when they arise without taking up excessive space or hard-earned money. Because they are compact and inexpensive to build, they should also be considered for the amateur’s Field Day kit, and for backup antennas at the club’s emergency operations center.

Homebrew Mag Mount

Hand-held radios for 27 MHz and 145 MHz have appeared on the scene in abundance, but they suffer from impaired performance when used inside a car without an external antenna. Building magnetic mobile antenna mounts isn’t cheap, especially if two are required for separate, 27MHz and 145 MHz antennas.

Handheld radios are usually sold with a short, vertical, spiral-wound antenna commonly known as a “rubber duck”. The amateur who doesn’t want to buy a “mag mount” to use this antenna while mobile will have to build one. Start with a metal can (a beer can will do), a permanent magnet from an old dynamic speaker, a coaxial connector that fits the radio, a length of coax and a lot of care in the construction. A cross-section of the “homebrew mag mount” is shown in **Fig. 9.1**. Good contact between the ground terminal of the connector and the metal can is essential, because there is not a reliable RF ground connection to the car chassis from a handheld radio. Any “rubber duck” or other portable radio antenna with a compatible connector can be connected to this mount for testing or operation. This mount also can be used to support an outdoor antenna for an apartment dweller, when mounted on a ferrous metal windowsill, or a wrought iron patio railing, for example.

Fig. 9.1 Homebrew "mag mount"



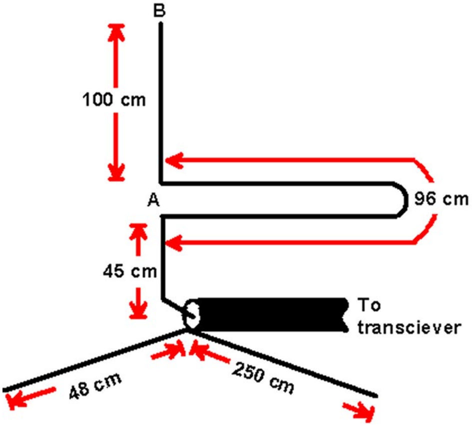
The "10-2" Dual-band HF/VHF Antenna

The dual band ("10-2") HF/VHF antenna permits the amateur to work both Two Meters and Ten Meters. On Two, this antenna has a 2 dB gain advantage over a quarter-wave vertical.

This antenna is illustrated in **Fig. 9.2**. On Two Meters, it works as a collinear with an overall height of 3/4λ, but its vertical-plane radiation pattern has a main lobe that is closer to the horizontal than that of a non-collinear 3/4λ antenna. On Ten, it is close to a quarter wave in electrical length and thus is resonant on that band. For successful operation, the ham should add at least three counterpoises for each band, or it needs to be mounted over a conductive surface. This antenna can be fed with a 50-ohm coaxial line.

When cut and assembled correctly, this antenna requires no tune-up at installation. If the SWR on Two is higher than 2:1, the antenna can be tuned by varying the spacing inside the "hairpin" phasing section (A), or by adjusting the length of top section (B). Once this antenna is tuned for Two, it should also be tuned on Ten.

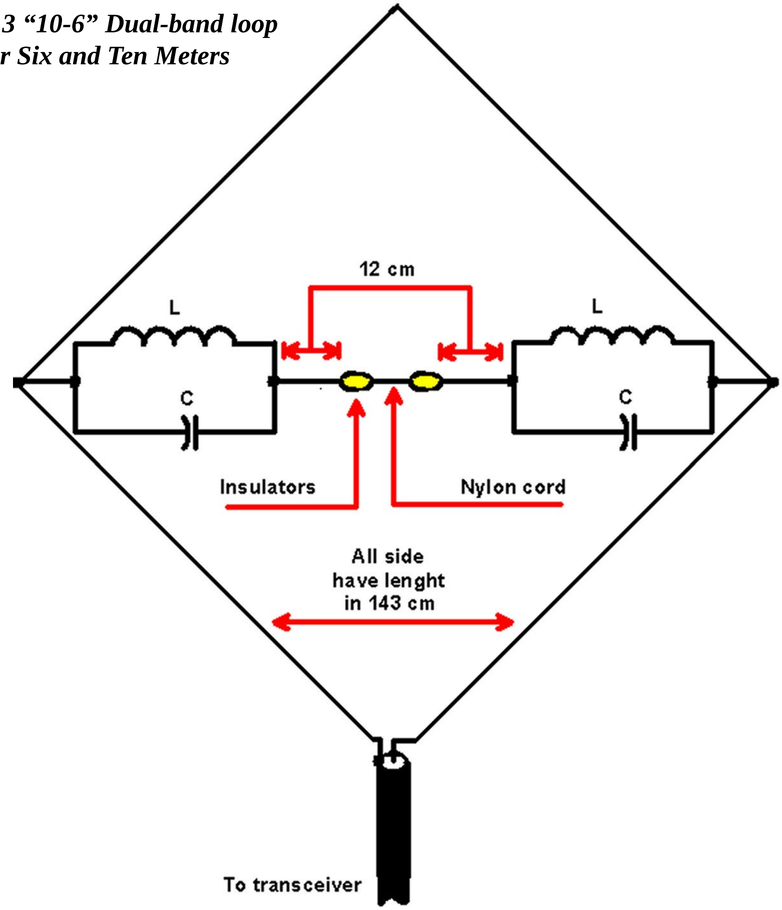
Fig. 9.2 Dual-band antenna



The “10-6” square loop for intermediate VHF bands

It’s not always cost-effective, or even possible, to have a separate antenna for each of the two bands at the borderline between VHF and UHF — Ten Meters and Six Meters. Propagation on these two bands is widely variable, and every-day DX is out of the question. However, DX is well within reach during favorable conditions on either band with simple antennas such as this, even at low power. Here is just the antenna for taking advantage of one of those new HF radios that includes 6 Meters!

Fig. 9.3 “10-6” Dual-band loop for Six and Ten Meters

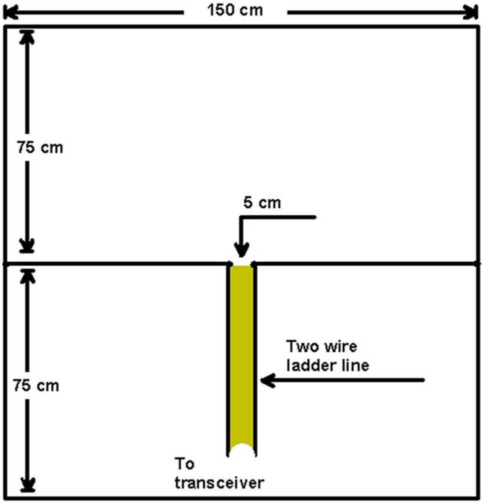


A square-shaped loop antenna can be made to work on two bands with more gain than either a half-wave dipole or a quarter-wave vertical. A dual band loop antenna for Six and Ten Meters (“10-6”) is shown in **Fig. 9.3**.

On Six, this antenna is a full-size loop, and on Ten it is a capacitively-loaded loop. The capacitive load across the center of the loop, is tuned out on Six with the help of the LC traps and is functionally “invisible” to 6-meter RF. Tuning on 6 meters is done simply by lengthening the loop if it resonates higher in the band than desired, and vice versa, or by making slight adjustments to the resonant frequency of the traps. Tune for resonance in the 10-meter band by lengthening or shortening the spacer between the insulators in the loading element.

The coils for the trap circuits are wound on a 18-mm core, with 20 mm of close-wound 1.5-mm wire. The capacitors are 36 pF. Building the traps to these specifications will reliably produce resonance at 50 MHz, but it’s prudent to check them with a GDO (grid-dip oscillator, or solid state equivalent) or RF analyzer. The traps should be weatherproofed after assembly and testing. This antenna is better suited to feeding with 75-ohm coax, but may be fed with 50-ohm coax with some loss of performance.

Fig. 9.4 “6-15 Square”
A square loop antenna for
6, 10, 11, 12 and 15 meters

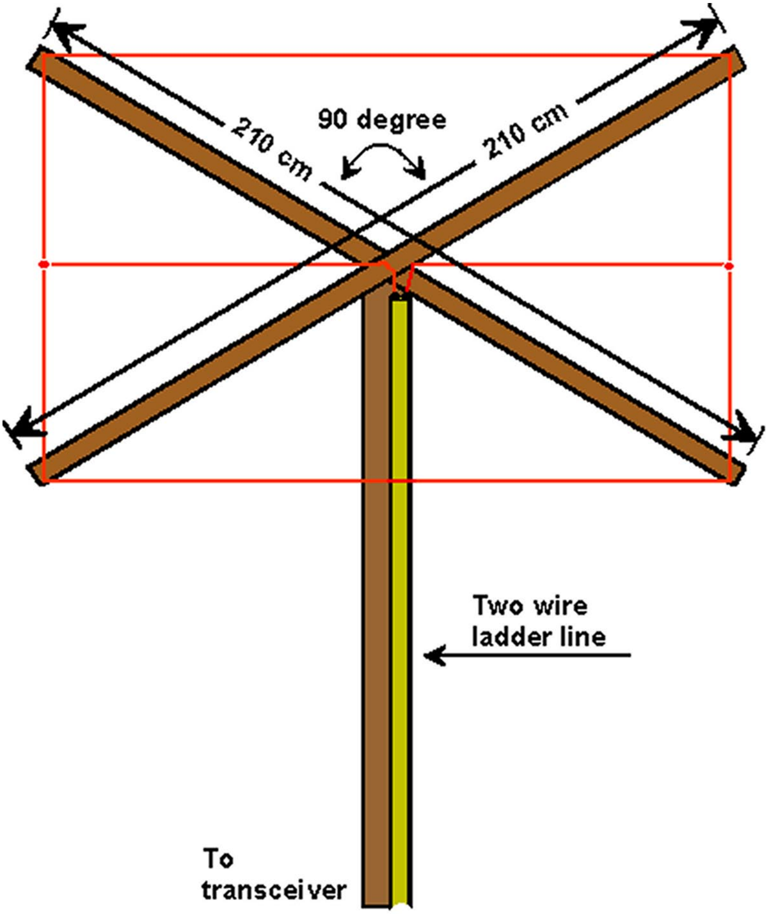


The “6-15 Square” — A Stub loop for the upper HF bands

A three-band square loop is described in reference [1]. Based on that design is the four-band square loop in **Fig. 9.4**. This antenna covers 6, 10, 11, 12 and 15 meters. Depending on the band of operation, this antenna has a theoretical input impedance between 100 and 300 ohms with a small capacitive component.

The feed line that the author used for this antenna is a type of telephone wire known by the nickname, “noodles”. This antenna, shown in **Fig. 9.5**, consists of two crossed-wood spars 220-cm long, forming a “spider” on which the wire is strung. The “noodles” feed is about 20 meters long.

Fig. 9.5 Construction of multi-band rectangular loop on “spider”



As we know from theory, by carefully selecting the length of a feed line, we can arrive at a match to the resistive component of a load’s impedance. The length of the line in this case was found by making small cuts in the line at the PA end until the following impedances were arrived at in the respective operating ranges:

70 ohms @ 50 MHz
40 ohms @ 29 MHz
50 ohms @ 27 MHz
180 ohms @ 24 MHz
110 ohms @ 21 MHz

At lower frequencies, the reactive component of the input impedance of the antenna increased in relation to the resistive component, but the antenna was still an efficient radiator on 18 MHz and 14 MHz.

By the time the impedance adjustment was satisfactory, one meter of the feed line had been cut off in 5 cm increments. The impedance at each frequency was measured on 6M, 10M, 11M, 12M, and 15M with an RF bridge.

This antenna has mostly horizontal polarization, but, oriented vertically, it will have a component of vertically-polarized radiation. Despite its simplicity, this antenna enabled the author to make DX QSOs easily in the 10 and 15-meter bands. A simple matching device was used to deliver 50 watts to this antenna for the tests.

Test-Bench Special — Experimental antenna for the intermediate VHF bands

In the process of testing transmitting equipment in the 6M, 10M and 11M bands, there is sometimes no substitute for connecting the radio to a real antenna. There is not always an external antenna, or at least a feed line to it, that is available at the workbench.

Table 9.1 Construction data for L1 on each band

Band MHz	Spool Dia. mm	Length of Winding	No. of Turns	Tap to Coax (from cold end)	Wire mm
27	20	70	28	5	2.0
20	20	60	25	5	2.0
52	20	20	6	2	2.0

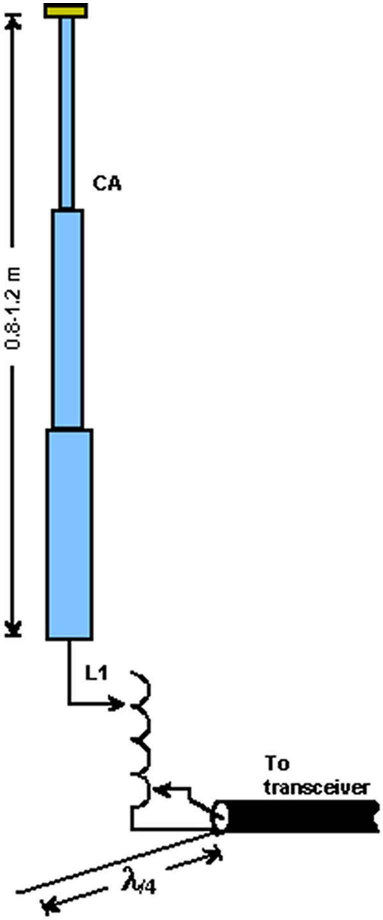
The author built this simple “test bench” antenna for 6M to 11M shown in **Fig. 9.6**. A telescopic whip antenna from an old TV set, which extends to 1.2 meters, is the radiator. The loading coil (L1) is tapped for each band of operation, according to the data in **Table 9.1**, with a 1-meter coax pigtail for temporary hookup to the radio under test. The quarter wave counterpoise is made of insulated stranded copper wire and is not critical as to placement.

Either 50-ohm or 75-ohm cable can serve as a feed line for the Test-Bench Special. Tuning consists of selecting the tap that produces the lowest SWR with centering in the band accomplished by stretching or compressing the coils slightly. Once the antenna is in place, the last step in fine-tuning is done by varying the length of the telescopic whip to the optimum position. The author managed to tune to an SWR of 1.3:1 or better on all bands with a 50-ohm coax connected. The 2:1 SWR bandwidth was found to be 2 MHz in the 50-MHz range and 400 kHz from 26 MHz to 30 MHz. With the closest tap selected, the author could finish tuning within each band by adjusting the whip's length. For maximum efficiency, the coil should be made from silver-plated wire.

With the loading coil set for 10 meters, the test bench antenna can be used on the CB section of 11 meters if a shunt variable capacitor of 2.5pF to 10 or 15 pF is added. With the capacitor in place, the 11-meter performance diminishes.

This antenna relies on the telescopic element's distributed capacity to ground in series with loading coil L1, in the virtual circuit "L1-CA," where CA represents the antenna capacitance. This means nearby conductive objects, including a hand, can detune the antenna, so it should be located with care.

Fig. 9.6 Test-Bench Special — Simple, experimental antenna for 6 through 11-meter bands



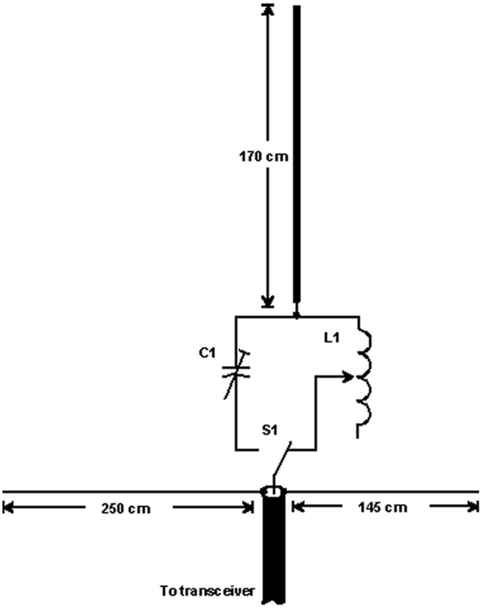
While it is designed for the test bench, this antenna can provide good service in regular use. One of these antennas placed on a windowsill delivered local and DX contacts on 10 and 11 meters.

The 6-10 Spike — 6M/10M vertical antenna

While most hams would like to install an effective beam for working 6 and 10 meters, space and financial considerations may rule that out. However, they shouldn't rule out using a vertical antenna, which can be easily installed on a balcony for these bands. With 10 watts and good propagation, 6 and 10 meters can produce DX QSOs.

A practical 6 and 10-meter vertical antenna is shown in **Fig. 9.7**. This antenna consists of a copper or aluminum rod with a length between 1.6 and 1.7 meters and between 2 mm and 40 mm in diameter. The larger the diameter of the rod, the greater the passband, but the stronger the rod-to-base insulator must be. Copper tubing, aluminum, or two ski poles will suffice.

Fig. 9.7 The 6-10 Spike
6 and 10-meter vertical antenna



Let's break down the operating theory behind this antenna system. We are all familiar with the way nearby metal objects can affect the length at which a vertical antenna for the amateur bands will resonate. The degree to which this effect influences the resonance depends on the antenna's proximity to the nearby metallic objects, and on the size of those objects. For this reason, the element may need to be built a little bit long for quarter-wave resonance, and then "shortened" with the help of a series capacitor when it is placed at its permanent mounting site.

This is the principle behind the construction of the 6 and 10-meter vertical. Capacitor C1 will allow tuning the radiator to any point in the 6-meter band with either 50-ohm or 75-ohm coax. The RF voltage on C1 is not high, so it doesn't need to be an expensive, high-voltage, transmitting-type capacitor.

In the 10-meter band, loading coil L1 tunes the radiator to resonance. It consists of 15 turns of 1-mm wire on a 20-mm diameter form. Ten of the turns are anchored to the form with epoxy, hot glue, etc., and five are left unanchored. Spreading or compressing these turns on the form for lowest SWR accomplishes the tuning. If the coil doesn't tune even when fully spread, clip off one or two turns and repeat the tune-up procedure. Using the coil construction details described here, the author was able to achieve an SWR no higher than 2:1 at both ends of the amateur 10-meter band from 28.0 MHz to 29.5 MHz.

Fig. 9.8 Spiral Counterpoise

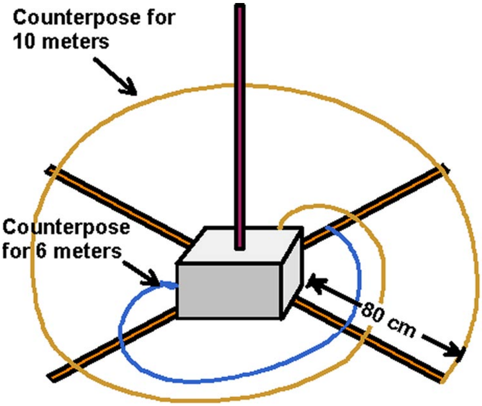
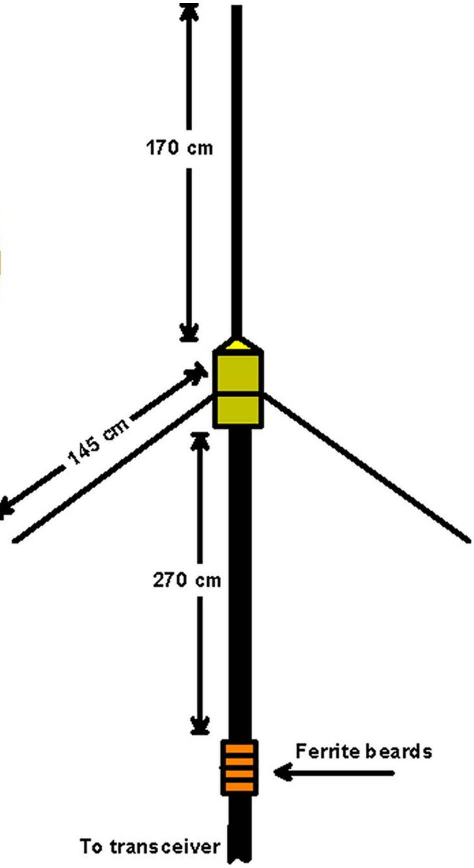


Fig. 9.9 Using the braid of the coax as a counterpoise for 10 meters



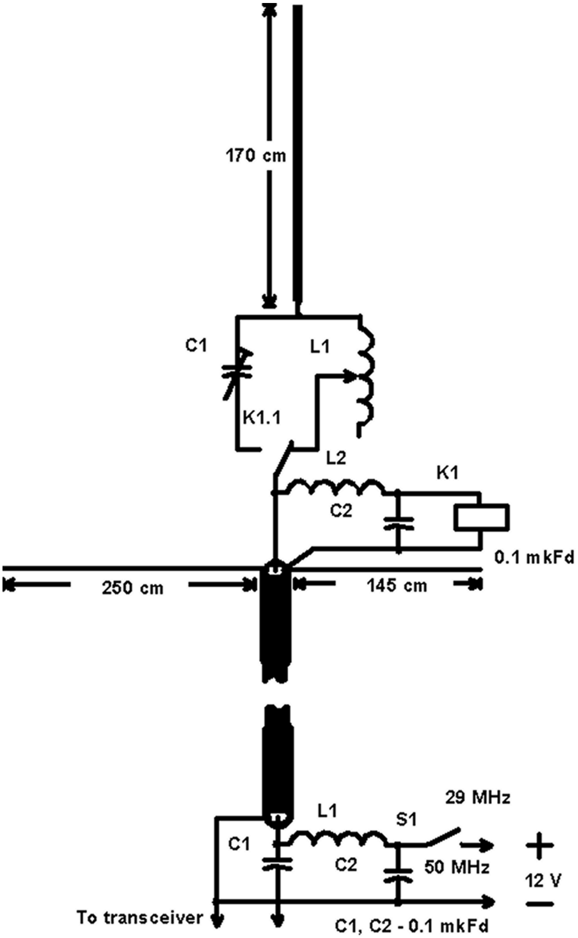
For this antenna to work effectively, it should be used with two or three resonant counterpoises for both the 6 and 10-meter bands. With some sacrifice of efficiency, it's possible to operate with only one counterpoise per band. If it is to be used as a backup antenna, or where full-length counterpoises are out of the question such as on a balcony or mounted to a wall, try using a spiral counterpoise as illustrated in **Fig. 9.8**. Two wires, one 2.5-meters long for the 10M band and one 1.5-meters long for the 6M band, are attached to wooden cross-pieces as shown. This spiral counterpoise is less effective than several fully extended counterpoises for each band, but it is a surprisingly workable arrangement.

“In-between band” Vertical from Military Surplus

Another type of “in-between” band antenna can be salvaged from a military surplus antenna system like that from the Soviet-era “Len” radio that operates in the 48 to 56-MHz range (see **Fig. 9.9**). The counterpoises of this antenna are shortened to a length of 1.5 meters. The center element may need to be lengthened so that the total length of the feed line going to the LC matching circuit at the base (a selectable capacitor for shortening and a coil for lengthening), plus the length of the vertical element, equals 1.65 to 1.75 meters. Some types of radios, including the Len, can operate at frequencies below 50 MHz, which is below the frequencies at which the center element can be tuned. As a counterpoise for the 10-meter band, the braid of the coax will suffice if we put a series of ferrite beads at a point 2.7 meters down the coax from the base of the antenna. Fasten these beads (permeability factor is not important) to the coax at this point with electrical tape.

If this antenna is installed on a balcony or another accessible place, you may select 6 or 10-meter operation with a simple throw of a toggle switch. If the antenna is installed in an inaccessible place, a network and relay system such as the one in **Fig. 9.10** may be used to switch

Fig. 9.10 Remote band-switching setup for 6 through 10 meters



bands. RF choke L2, that keeps RF from feeding into the relay coil, is homemade by wrapping 0.5-mm copper wire on a core made of a 10 kilohm, 5-watt carbon resistor uniformly with turn spacing of 0.5 mm. The usual small power relay, with all contacts live in bridge, will work at RF power going to the antenna up to 100 watts. The best relay is one with a ceramic body, which is suitable for RF use.

The enclosure for the shortening capacitor and lengthening coil should be weatherproofed after the antenna has been tested and installed, with appropriate, waterproof material.

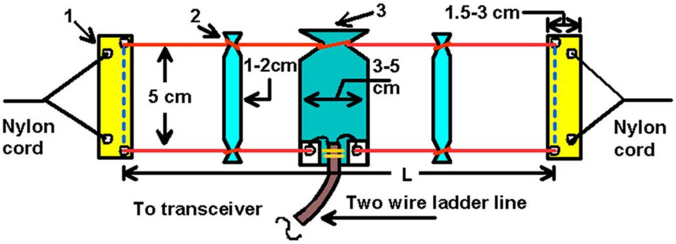
Three simple dipole antennas for the "in-between" bands — 6 to 11 meters

The "in-between" bands of Six through Eleven Meters share many of the more interesting characteristics of both HF and VHF regions. While DX in these bands is not common during the low points of solar activity cycles, these bands can become hotbeds of activity during sunspot peaks. DX becomes plentiful even with low power and small antennas. For those of us with simple means who don't aspire to "DX Big Gun" status and demand award-winning results, simple antennas will serve us well. **Let's see the antennas!**

"In-between Band" Monoband Folded Dipole for 6 or 10 meters

The simplest, and yet most effective antenna for these bands is the classic folded dipole. With a theoretical input impedance of 240 ohms, the folded dipole lends itself to feeding with the inexpensive "noodles" phone cable mentioned earlier. The construction of this antenna is shown in **Fig. 9.11** and measurements for various operating frequency ranges are shown in **Table 9.2**.

Fig. 9.11 Construction of "in-between band" folded dipole



The spacing between the folded elements is held at 5 cm by insulating spreaders (“2” in **Fig. 9.11**) made from PC board with the copper foil stripped off 1 to 1.5 cm from the ends and spaced 20 to 50 cm apart, depending on the rigidity of the wire. Solid copper wire of 1 to 2 mm in diameter is fastened to these spreaders with a loop of wire that wraps around the notched ends and solders to the element on each side of the spacer. The end spreaders (“1” in **Fig. 9.11**) are made of PC board with the copper foil intact to which the element wires are soldered for added rigidity. The center feed insulator (“3” in **Fig. 9.11**) is made from a broader (5 cm.) section of PC board with the foil removed. The guys are made from nylon cord.

Although this antenna is a monobander, its passband is greater than that of a conventional dipole. With the dimensions specified in **Table 9.2**, there is no initial adjustment required. The folded dipole can be installed horizontally, slanted, or vertically. If installed horizontally, best performance will result with the antenna at least a quarter wavelength above ground. If installed on a slant, or vertically, the lower end should be at least 1 meter above ground and the feed line should leave the antenna at a right angle for at least 2 or 3 meters.

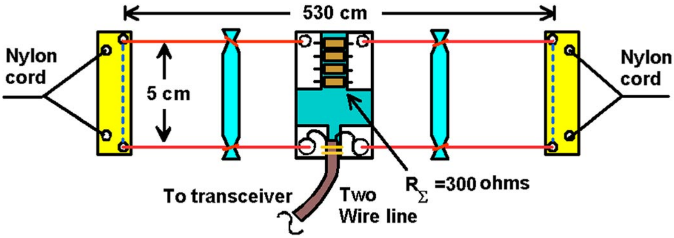
Table 9.2
Dimensions of
“in-between band”
folded dipole
for 6 or 10 meters

Band MHz	Antenna Length cm
27	520
29	506
52	282

Broadband Loaded, Folded Dipole for 6 through 11 meters

A broadband folded loaded dipole can be built according to **Fig. 9.12** that will operate on all bands from 6 through 11 meters continuously. This design represents a folded dipole with a 300-ohm load. This 5.3-meter long antenna has a 2 dB disadvantage in gain compared to the monoband folded dipole (**Fig. 9.11**) on 10 and 11meters but is on a par with it around the 6-meter band. The center feed point insulator is the mounting place for a network of 2-watt resistors with a non-reactive,

Fig. 9.12 Broadband, loaded folded dipole

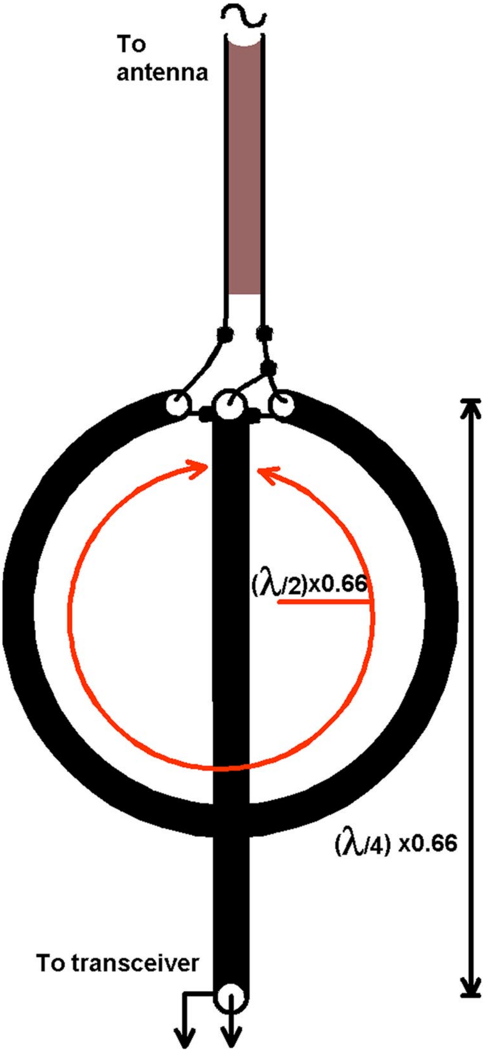


net resistance of 300 ohms. It is not necessary to protect the resistors against the weather. The network should be capable of dissipating at least 30% of the power applied to the antenna. The loaded, folded dipole may be installed vertically as a sloper, or horizontally.

Both folded dipoles have an input impedance around 240 ohms, which will permit them to be fed with telephone cable as mentioned earlier. If fed by a tube amplifier, which is capable of matching both low impedance and high ohmic loads, they can be connected directly with this type of feeder. The majority of older military surplus radios that operate in this frequency range (6 to 11 meters), of both tube and solid-state variety, are designed to feed antennas with high ohmic resistance. These folded dipoles match nicely to this type of radio.

The typical modern, solid-state transceiver, with its 50-ohm final output impedance, will require some impedance transformation to be used with the folded dipoles. A simple matching device for folded dipoles to a 50-ohm transmitter is shown in **Fig. 9.13**. This is a 4:1 coaxial stub transformer, which can match 200-ohm antennas to a 50-ohm transmitter, or a 300-ohm load to a 75-ohm transmitter. The coax connecting the stub transformer to the transceiver is an electrical quarter wavelength (taking velocity factor into account).

Fig. 9.13 Simple 4:1 matching device for a folded dipole



Initial adjustment of this antenna consists of gradually trimming the quarter-wave coax section coming from the transformer for maximum RF voltage across the connection between the transformer and the coax to the transmitter. Coax lengths for the stub and transformer are listed in **Table 9.3**, for cable with a Velocity Factor of 0.66, as in the case of commonly available coax with a dielectric of polyethylene.

Table 9.3 Length of the stub and quarter-wave transformer

Band MHz	Quarter Wave stub length cm (with V.F.=0.66)	Half Wave stub length cm (with V.F.=0.66)
27	178	356
29	174	348
52	97	194

If the stub transformer is installed directly at the antenna feed point, coax may be used for the entire length of the feed line rather than telephone cable. While more expensive, coax is much more durable than telephone cable and should be considered for a permanent, outdoor installation.

Compact, Combined Dipole for 6 and 10 meters

Where space limitations won’t allow even a full-size 10-meter dipole, this compact, combined dipole antenna will accommodate both 10 and 6 meters in limited space with a common feed as shown in **Fig. 9.14**.

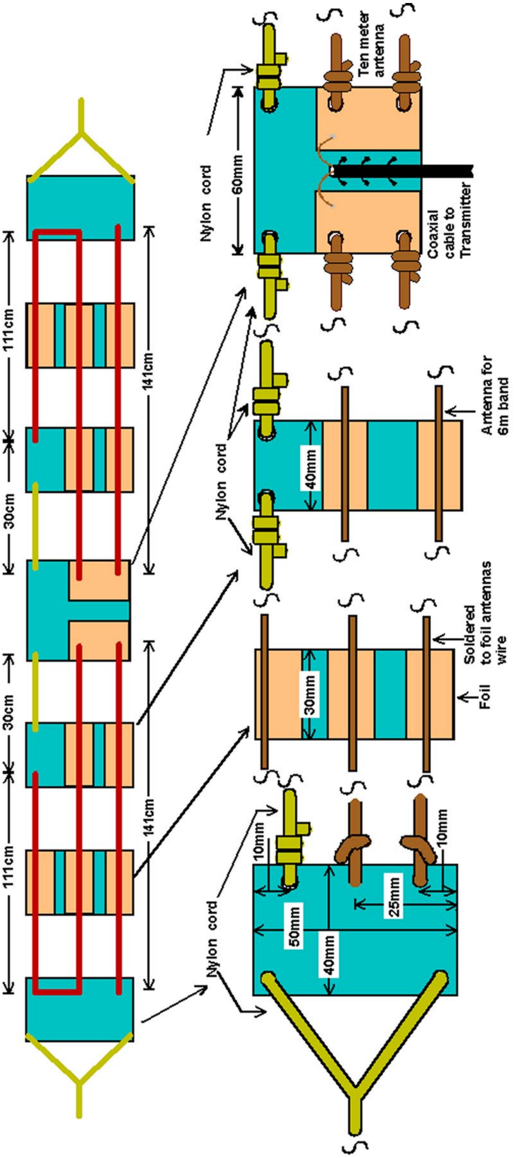
This design puts both a full-size, half-wave 6-meter dipole and a 10-meter dipole, with its elements folded back on themselves, inside the space required for the 6-meter dipole and with a common feed point. One element of the 6-meter dipole is 141-cm long, while one element of the 10-meter dipole is 252-cm long, including the portion that folds back toward the center insulator. The elements are made from 2-mm diameter copper wire. The spreaders, as in the case of the folded dipoles above, are made from PC board with bands of copper cladding left intact. The element wires are soldered to these bands to maintain their rigidity. This antenna may be fed directly with 50-ohm coax, but SWR will be somewhat lower if 75-ohm coax is used. The compact, combined dipole assembled by the author registered an SWR no higher than 1.6:1 on either band.

The author weatherproofed the coax connection by coating it with a solution made with the body of a ballpoint pen dissolved in acetone and painting it. This antenna is a space-saver that can be installed hanging between a balcony and a window, for example, or in a small amount of roof area. It can hang vertically, horizontally, or as a sloper, but it will work best if the coax leaves the feed point at a right angle for as long as possible.

REFERENCE:

1. New driven element for “ double quadrate” // ***Radio* -** # 4, 1977. – p. 61.

Fig. 9.14 Compact, combined dipole for 6 and 10 meters



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