THE BUDDIPOLE GUIDE TO EMCOMM

RAPID DEPLOYMENT FOR EMCOMM

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WHAT IS EMCOMM?

Emergency Communications is a strong part of the amateur radio community and has proven particularly vital in times of natural disasters. The characteristics of natural disasters whatever the cause are often so overwhelming in scale that the communications infrastructure of the typical professional emergency response organizations is critically stressed and unable to support the flow of traffic. This is an almost inevitable situation since the cost of a system built for the worst case is almost always well beyond the available budget. The difference in requirements between routine emergency response and the response required for widespread natural disasters is vast and well outside of the typical budget.

One of the big issues of providing a comprehensive professional system large enough to support any perceived problem is that the cost of a fixed and robust communications system to cover the whole of the served area is beyond reach. This is where the amateur radio service excels. The amateur radio service is equipped to provide an effective, temporary communications infrastructure almost anywhere, even in the absence of grid power and in very short time frames. Not only that but the type of service is rather unique because it encompasses local communications, regional communications and long distance communications without any reliance on the commercial communications backbone including the usually ubiquitous internet.

IMPORTANT EMCOMM CHARACTERISTICS

Initially the most important characteristic of emcomm is rapid response and the ability to uniquely configure a communications system to suit the requirements of the emergency. This requires technical and operational skills on the part of the amateur radio community as well in addition to preparation to cope with a largely unknown situation. This means being generally prepared for whatever the situation requires. Effective training drills must be supported by equipment that has good performance, is versatile, portable and robust. This includes radio equipment, the power system and the antenna.

The amateur emergency communications system is largely used to gather information from the field and forwarding it to a control center, often a state or county emergency operations center (EOC). This places a heavy emphasis on field operations and rapid deployment.

Initially the focus may be on local communications but in the case of a wide spread disaster the need to support regional communications may also be required. In the interests of complete preparedness it is also a good idea to be prepared for national communications also.

LOCAL COMMUNICATIONS

The use of analog voice (phone) is a very common requirement. This is augmented by digital messaging which is particularly suited for sending detailed information such as long lists of items many of which may be technical in nature. There is generally excellent coverage by local repeaters, but while the coverage is often better than cell phones, there are some areas that are not well covered. This places some value on having high gain omni-directional and directional antennas and the ability to elevate them. Remote field sites in particular need to have a solid link to the EOC having fade and noise free communications even when operating at relatively low power.

REGIONAL COMMUNICATIONS

VHF communications is a popular means for reliable short range communications but without repeaters it is limited to line of sight. The visual horizon can be calculated knowing the radius of the earth and the height of the observation point by the simple mathematical relationship $d = \sqrt{h(2R + h)}$ where R is the radius of the earth and h is the height of the observation point. With d in miles and h measured in feet the approximate distance $\sim 1.23\sqrt{h}$. The relatively long wavelengths of even VHF signals (relative to light) cause the waves to bend slightly which extends the radio horizon beyond the visual horizon. Empirically this has been estimated and a scaling factor is used which increases the apparent radius of the earth. The radio horizon then is taken to be $d = 1.45\sqrt{h}$ which is an increase of about 15% beyond the visual horizon. Distance beyond this limit can be achieved of course by elevating the antenna at the other end of the communications link so the total distance is $d = 1.45 \times \left(\sqrt{h_1} + \sqrt{h_2}\right)$ where h_1 and h_2 are the respective heights (ft) of the two antennas. The benefits or operating a repeater at high elevations is easily seen but so are the limitations. A repeater antenna at a height of 2500ft will have a theoretical horizon of about 80 miles. Communications range can be extended beyond this however by using the HF bands.

HF bands can provide local communications using ground wave but that limits the range to around 50 miles. Beyond that the ionosphere can be employed to increase the range by refraction of the signal back to earth. The distance between the transmitter and the region that the signal returns to the ground is known as the skip. DX operators are looking for long skip distances so they don't have too many hops to their target area. Regional communications however are much shorter in distance so a short skip mode is preferred. Short skip occurs when the angle of refraction is very acute and the ionosphere returns the signal to the ground almost immediately below it. This is known as Near Vertical Incident Skywave propagation (NVIS).

NVIS EXPLORED

NVIS BASICS

NVIS is used when the communication distance is in the range of a fifty to four hundred miles.

To accomplish this an NVIS optimized antenna operation will fire most energy vertically upwards.

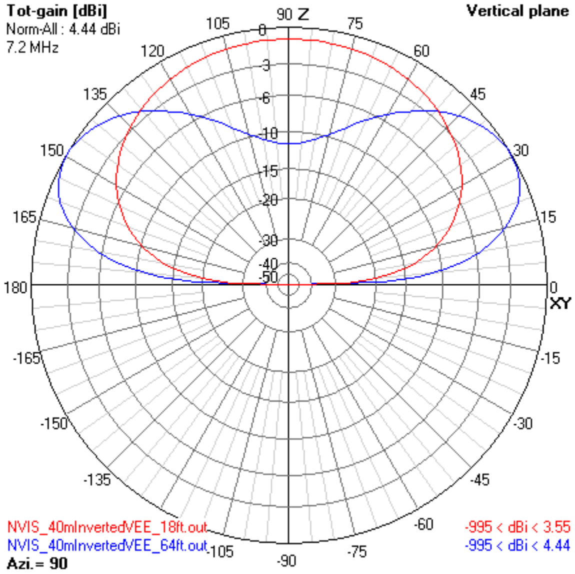


Figure 1 Comparison of NVIS and DX antenna radiation patterns

The chart in Figure 1 compares the elevation pattern of an antenna set up for DX operation with an antenna set up for NVIS operations. Note that the DX antenna has 10 dB less gain than the NVIS antenna for NVIS propagation. We will look at that in more detail later in this document.

Directing the energy upwards is accomplished generally by using a horizontally polarized antenna together with the reflective properties of the ground. The NVIS system depends upon properties of the ionosphere which is affected by "space weather" conditions. This limits the frequency spectrum that can be effectively be used. Also because the ground is used as a reflector the quality of the ground as well as antenna height are also important factors.

USEFUL FREQUENCY SPECTRUM

Because NVIS uses ionospheric propagation it is useful to refresh our understanding of the topic. The ionosphere consists of several layers of charged particles in the atmosphere. These are caused by the action of solar radiation and so the position and depth of the layers differs between day and night. The lowest (innermost) layer known as the D layer does not generally support refraction (except during periods with solar flares).

The D layer is virtually absent during nighttime but during the day it absorbs (attenuates) low frequency signals passing through it. Signal absorption is approximately proportional to the square of the reciprocal of the signal frequency, $absorbtion \propto \frac{1}{f^2}$ which shows a fairly dramatic reduction in signal strength as frequency decreases. This aspect of the D layer establishes a lowest practical operating frequency known as the lowest usable frequency (LUF).

For this reason lower frequencies are limited to ground waves during daytime hours but increased distances during nighttime when the D layer disappears.

The highest layer of the ionosphere is mainly responsible for refraction and is known as the F layer. Signals within a certain frequency range that pass through the D layer and E layer are refracted by the F layer. This outermost layer is only 90 to 300 miles above the surface of the earth. During the daytime it is split into two distinct layers (F1 and F2) but at nighttime they merge into a single F1 layer. The relatively low height means the round trip for an NVIS signal is relatively short and this means lower losses. For example assuming a ground distance of 100miles and F layer height = 280miles, the NVIS path length is about 569 miles total.

Figure 2 shows the optimum take off angle for different heights of the F layer and for different distance between stations showing the dramatic difference in take-off angle between regional and DX communications.

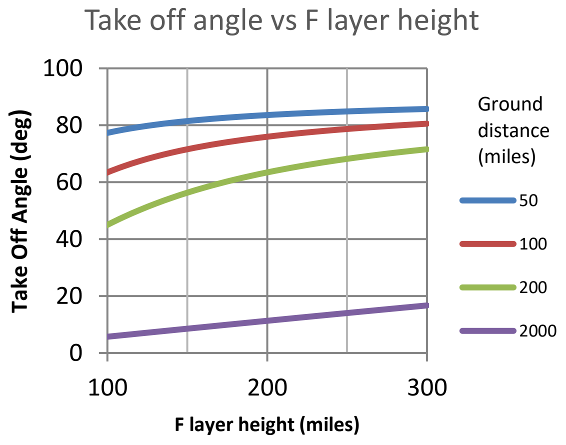


Figure 2 Optimum Take off angle

The D layer establishes a low frequency limit to ionospheric propagation but there is a high frequency limit too. The interaction between a signal and the ionized particles is interesting because as frequency increases the degree of interaction becomes less. This means that the F layer refracts signals below a certain frequency but as the frequency increases further the F layer signals pass through the layer without refraction. The highest frequency that is refracted is known as the critical frequency. Another more general restriction on the upper frequency is known as the Maximum Usable Frequency (MUF) which is related directly to the critical frequency. When the signal is fired straight up into the ionosphere, the MUF is equal to the critical frequency. As the angle of incidence is reduced the MUF is also reduced.

NVIS propagation works in a window of the frequency spectrum between the lowest usable frequency (LUF, due to D layer absorption) and the maximum usable frequency (MUF = critical frequency for NVIS).

Recommended Amateur Bands

Since the critical frequency is dependent upon solar activity, the critical frequency falls at night which moves the window down favoring operation on the 75m band. The best performance is normally just below the critical frequency.

The channelized 60m band introduced in 2002 is considered by some to be the best overall NVIS band even though there is very limited band space.

The rule of thumb is:

- 40m band for daytime operations
- 75m band at night

Note that this depends upon current propagation conditions which vary from hour to hour. You can establish the conditions by checking up to date propagation information at spaceweather.com

GROUND QUALITY

The vertical radiation pattern of a dipole in free space extends all the way round the element. When it is set up over a ground however the radiation pattern is distorted because of reflection of the radiated energy from the ground. This is not surprising since the ground also reflects sunlight, (an electromagnetic wave with much shorter wavelengths) so why not radio waves? This distortion is beneficial since it redirects what some of the energy that would otherwise be going in the wrong direction and reinforces the radiated energy going vertically upwards.

In the same way that light reflects differently from different types of ground, RF energy is reflected differently by differing types of ground. The amount of reflection is dependent upon the conductivity of the ground which is typically quite lossy. Secondly, signal strength is not generally a serious problem with NVIS because the total path length is quite short and NVIS signals therefore do not suffer as much path loss as a DX signal does.

Ground losses can be minimized by changing the antenna height but as we will see later there is a tradeoff.

Some NVIS stations use an additional horizontal wire suspended just above the ground, immediately below the antenna. This will be discussed more in the next section.

ANTENNA HEIGHT

A popular, effective and convenient antenna choice for NVIS is the simple horizontal dipole or its cousin the inverted Vee. The take-off angle can be adjusted by changing the height of the antenna above ground. The ground loss for a horizontal half wave dipole at different heights over average ground is indicated in Figure 3 below.

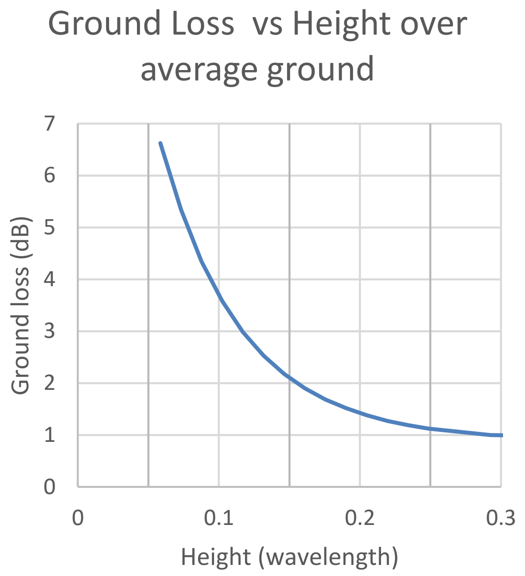


Figure 3 Ground Loss for half wave horizontal dipole.

Because we are usually interested in efficiency it is tempting to think that we should elevate the antenna to reduce the ground loss, but we also have to take into account the radiation pattern and that will vary by band assuming that the various antennas are at the same physical height. Although we looked at the losses introduced by the ground in the previous figure, the ground does in fact act as a reflector, even though it is a lossy reflector. The signal reflected from the ground reinforces the signal radiating from the antenna in the vertical direction which is effectively power gain. As the height above ground is increased the loss goes down and so the gain goes up as shown in Figure 4.

It has been noted by NVIS operators that it is sometimes of advantage to deliberately lower the antenna so that is below the optimum height for signal strength as this may reduce the noise level quite considerably. Assuming that the noise drops more than the signal this can distinctly improve the quality of the communications channel.

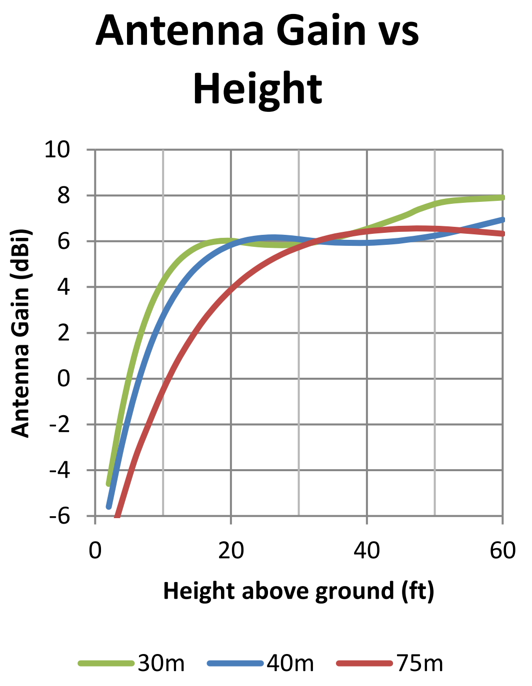


Figure 4 Gain vs height for 30m 40m, and 75 m half wave dipoles

The gain of the individual antennas is different because of the different effective electrical height above ground on the three different bands. The effective electrical height of the75 m is only half that of the 40m antenna. At the same physical height then the 75m antenna is at a disadvantage relative to the 40m or 30 m antenna. For example the gain for the 75 m at 10 ft above the ground is 0dBi (assuming average ground) but is almost +3dB on the 40m band and +4 dB on the 30m band. The 75m antenna has a gain of about +2dBi at 15ft height and the gain of the 40 and 30m antennas are about +5 and +6 dBi respectively.

There is a limit to how high the antenna should be mounted for NVIS operation. When the height is increased to ½ wavelength above ground the reflected signal will be 180 degrees out of phase with the signal leaving the antenna which causes cancellation of the main and reflected signals. This results in a shallow null which can be readily seen as the DX case in Figure 1. At this point you can also see the formation of two lobes on either side of the antenna. These are the points of maximum gain and it is the angle of these points to the horizontal that is known as the take-off angle. As the antenna height is increased the take-off angle decreases which is not desirable for NVIS communications.

The ideal height for NVIS then is generally recommended to be between 10ft and 18ft above ground level. This height range suits all three of the bands that we are looking at and allows the use of a single support structure.

Since ground conditions vary considerably it is possible that the ground you have is not the same as the average ground we have assumed so far. Usually it will be worse, but there is a really special case which can assist the performance of the antenna and that is known as the Perfectly Electrically Conductive ground (PEC). An example of this might be a metal roof structure, but bear in mind that the roof should really be connected as a continuous ground to be effective.

Another strategy to reduce losses is to place a horizontal wire immediately below the antenna. This will clearly not be as effective as the ground plane we have just discussed but has been reported to make a positive improvement in efficiency (your mileage will vary based upon how bad your real ground is). It is important to elevate this reflector wire a minimum of 2 ft above ground or the positive effects will be swamped by ground losses.

ANTENNA OPTIONS

For DX operations a horizontal or vertical antenna can be employed. It is known that a vertical antenna has a low angle of radiation making it suitable for DX, but this characteristic is not ideal of NVIS operation. A more effective choice for NVIS is a horizontal dipole mounted at a height of less than ¼ wavelength and for the three bands we have been looking at this means a height between 10 and 20 ft. Figure 1 compares the radiation pattern of a horizontal dipole (inverted vee) setup at NVIS height and also at a height more suited for DX operation. The red curve shows the elevation pattern of the antenna at a height of 18ft over average ground while the blue curve shows the same antenna at a height of 64 ft (about ½ wavelength).

SITE SELECTION

For NVIS there is no strong need for an elevated site. For best results however the antenna should be setup in the center of a clear area. For reasons of safety and electrical interference is best to install the antenna away from power lines.

NVIS SUMMARY

NVIS has become popular with the military and emcomm for regional communications. NVIS is the ideal system for regional communications exploiting the best that HF can give for short skip communications. Although this does depend upon ionospheric conditions they are generally favorable to this type of operation. Propagation tends to favor reliable communications using NVIS on the 75m, 40m and 30m bands.

A horizontal antenna setup at a height between 10 and 18 ft above ground will result in the desired radiation pattern optimized for peak output directly upwards.

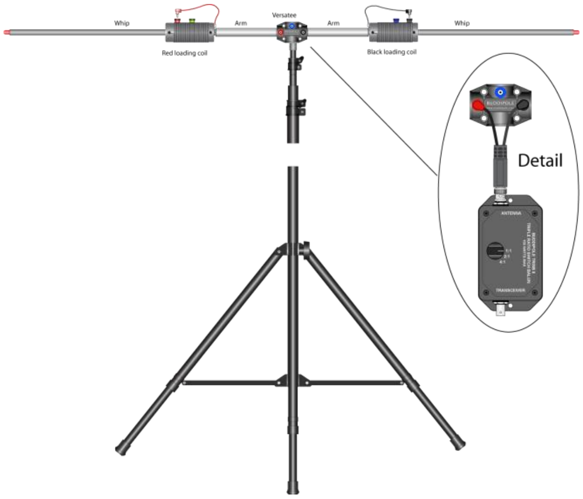
Adding a quarter wave reflector below the antenna can improve antenna efficiency in situations where poor ground quality is an issue.

PRACTICAL SOLUTIONS

We have seen that the horizontal dipole configured correctly is a good choice for regional communications (50 to 400 miles). Reliable communications requires operation in the75, 40 or 30m bands and these long wavelengths imply large antennas which can be difficult to install. However a rapid deployment system can be created by using a horizontal dipole suspended from a single mast. An equivalent alternative arrangement is an inverted Vee configuration using wire ends. Because these are self-supporting antenna they can be erected in a wide variety of environments. Also the footprint can be kept reasonably small by the use of loading coils.

40m HORIZONTAL LOADED DIPOLE

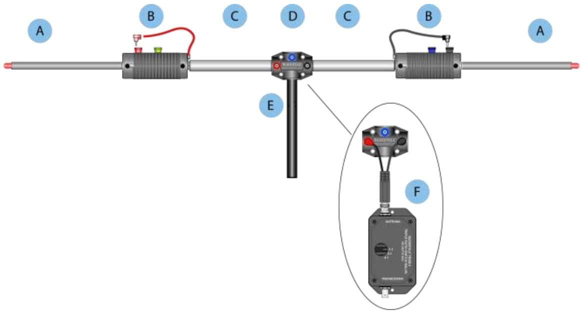
The Buddipole long telescopic mast and tripod make an excellent support for a horizontal loaded dipole. The overall span of the antenna can be significantly reduced by using loading coils as shown below. For simplicity the guy wires are not shown, but it important for the stability of the antenna that these employed.



The illustration here is to show the major parts of the system setup for NVIS operation as a loaded horizontal dipole. A more detailed parts list is provided in the next section.

HORIZONTAL DIPOLE PARTS LIST

The horizontal dipole parts list is shown in the table below the illustration.



	QTY	DESCRIPTION
A	2	Long whip, telescopic 9.5 ft
B	2	Loading coil, standard
C	2	Arms, fixed 22 in.
D	1	VersaTee antenna adapter
E	1	Mast, telescopic 18 ft.
F	1	TRSB – variable ratio balun with adapter
G	1	Tripod, telescopic
H	1	50 ft coaxial cable assy with BNC adapter
I	1	Guying kit

HORIZONTAL DIPOLE ASSEMBLY

Assembly consists of the following steps.

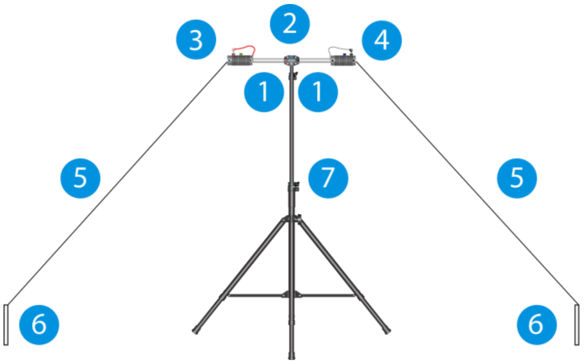
1. Setup the tripod by extending the telescoping legs and securing the mast in the center. The length of the telescopic legs may be individually adjusted to level the tripod on uneven ground.
2. Attach the VersaTee tightly to the top of the mast.
3. Attach a rigid antenna arm to each side of the VersaTee.
4. Attach a loading coil to each side of the Versatee.
5. Attach a telescopic whip to the outboard end of each of the loading coils.
6. Extend each whip to the required length for the band you have chosen to operate on.
7. Make sure that the tap position for each coil is set according to the band that you are going to operate on.
8. Suspend the TRSB from the VersaTee using the cord attached to the TRSB. Connect the

TRSB adapter cable between the TRSB Antenna port and the VersaTee red and black mini banana plug connectors.

9. Switch the TRSB to the 4:1 position.
10. Connect the coaxial cable to the Transceiver port of the TRSB and use the Velcro strap to snugly attach the coax cable to the mast immediately below the TRSB.
11. Attach guy wires to the top of the mast.
12. Raise the mast to the maximum height and stabilize the mast by fastening the guy wires to the ground stakes.
13. If available use an antenna analyzer to verify that the antenna is tuned for the operating frequency.

80m INVERTED VEE

The large element lengths for 80m operation are usually very challenging because of the physical size of the antenna. This inverted Vee version of an 80 m horizontal antenna is relatively compact.



The horizontal arms provide mounting for the high efficiency loading coils. These allow the use of wire assemblies to form the ends of the antenna sloping to ground supports which keep the antenna at least 2ft above ground level.

INVERTED VEE PARTS LIST

	QTY	DESCRIPTION
1	2	22” Antenna Arms
2	1	Buddipole VersaTee
3	1	Red Loading Coil
4	1	Black (or Red) Loading Coil
5	2	Radial wire winder kits
6	2	2x2’ non-conducting posts
7	1	16 ft Tripod/Mast
8	1	Triple Ratio Switched Balun (TRSB)

INVERTED VEE ASSEMBLY

Assembly consists of the following steps.

1. Setup the tripod by extending the telescoping legs and securing the mast in the center. The length of the telescopic legs may be individually adjusted to level the tripod on uneven ground.
2. Attach the VersaTee tightly to the top of the mast.
3. Attach a rigid antenna arm to each side of the VersaTee.
4. Attach a loading coil to each side of the VersaTee.
5. Attach a radial wire to the end of each loading coil.
6. Measure out the length of radial wire needed (see Table 1).
7. Make sure that the tap position for each coil is set according to the band that you are going to operate on (see Table 1).
8. Suspend the TRSB from the VersaTee using the cord attached to the TRSB. Connect the TRSB adapter cable between the TRSB Antenna port and the VersaTee red and black mini banana plug connectors.
9. Switch the TRSB to the 4:1 position.
10. Connect the coaxial cable to the Transceiver port of the TRSB and use the Velcro strap to snugly attach the coax cable to the mast immediately below the TRSB.
11. Attach guy wires to the top of the mast.
12. Raise the mast to the maximum height and stabilize the mast by fastening the guy wires to the ground stakes.
13. Position the radial posts on the ground stretching out the radial and ensuring that the radial does not touch the ground. Excess radial wire should be left wound on the winder so that it does not detune the antenna.

14. If available use an antenna analyzer to verify that the antenna is tuned for the operating frequency.

Table 1 provides settings for 80m, 60m and 40m bands.

Table 1 Wire and Tap setting chart

	RED SIDE		BLACK SIDE	
Band	*Wire length*	*Tap*	*Wire length*	*Tap*
80 m	28’	NC	29’	NC
60 m	12’	37	15’	NC
40 m	14’	16	17’	20

NC – No Connection, leave the tap wire disconnected.

DUAL BAND HORIZONTAL ANTENNA

A combination of the horizontal and the inverted Vee can be setup so that dual band operation is possible on both the 80m and 40m bands. For convenience the antennas are setup 90 degrees to each other. The radials from each can then double as guy wires.

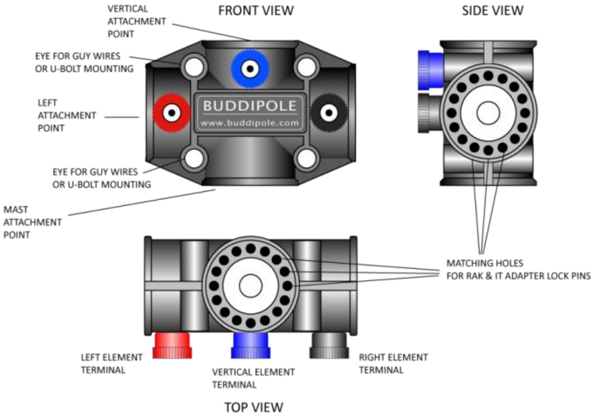
This uses stacked VersaTees rotated 90 degrees from each other. The two VersaTees are stacked together so that the two antennas are each connected to the TRSB. This provides a single feedline for the two bands. Alternatively using two TRSB units, separate feed lines can be provided for each band.

BUDDIPOLE PARTS LIST

This section provides an illustrated guide to the items used for the Buddipole NVIS solution.

The VersaTee™

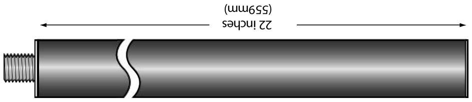
The heart of this system is the central hub known as the VersaTee which provides the ability to configure the antenna in different ways



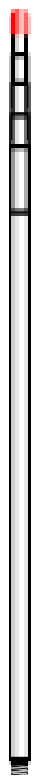
The red and black and terminals are the connection points used in the NVIS horizontal configuration. The horizontal antenna arms screw into the threaded inserts in the VersaTee body.

ANTENNA ARMS

Loading coils are mounted to rigid antenna arms that are connected to the VersaTee and telescopic whips are attached to the outside ends of the coil



TELESCOPIC WHIPS



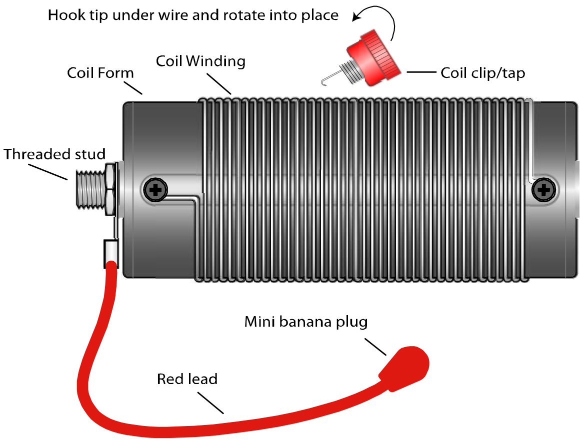
Telescopic whips provide not only the convenience of small size when collapsed, but also the ability to trim the length of the antenna to resonate the antenna at the desired frequency. In conjunction with the loading coils this provides an antenna system that can be tuned for the HF bands

For NVIS a long whip (9.5 ft extended length) is used.

There are six sections on each whip (including the base section) and it is important to ensure that all sections are fully extended.

LOADING COILS

Loading coils provide the ability to shrink the overall footprint of the antenna. The coils are provided with taps so that the exact amount of inductance required for each band can be set. The amount of inductance can be set by the position of coil clips that attach to the coil. The clips have little hooks that attach to the coil so they can be placed along the length of the coil. The tap point is set by the position of the clip, so multiple taps can be set by adding clips to the coil at the desired position. This allows quick switching between bands. The clips are held in place by tightening the terminal screw. The active tap is selected by plugging in the mini banana plug into the appropriate clip terminal.



Changing the position of the coil clips or adding additional ones is easy if you follow a few simple tips. Before installing the clip unscrew the terminal knob almost completely to expose the maximum length of the clip. Then angle the clip sharply to the coil and slip the clip under the coil turn that you want. Tighten the terminal gently taking care not to overtighten as that may stretch the coil winding. Take care not to twist the clip when tightening or it may short to an adjacent turn which will inadvertently change the inductance.

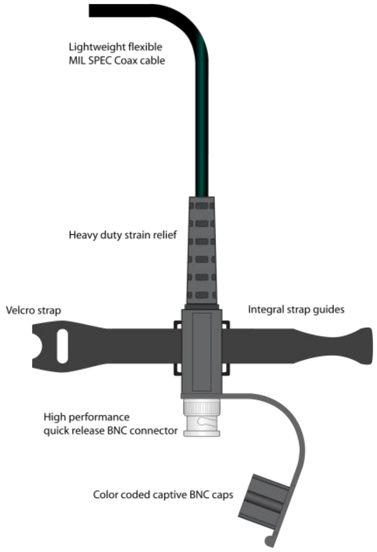
TRIPLE RATIO SWITCHED BALUN

The system is normally used with coaxial cable (as supplied). It is important to have the antenna isolated from the coax by a balun which provides a conversion between the unbalanced coax and the balanced antenna.

The TRSB also provides the vital function of converting the low radiation resistance of the loaded antenna to 50 ohms. The TRSB switch must be set to the required position noted in the setup instructions.

COAXIA CABLE

The coaxial cable provided is Mil spec RG58 style cable 50 feet in length and terminated with male BNC connectors at each end. This cable is well suited for use on the HF bands and also VHF bands for moderately long lengths of cable



Be sure to use the Velcro straps attached to the strain relief to secure the cable to the mast or any suitable point so that the connector is not subject to the full weight of the cable. Use the straps to keep the cable conveniently coiled when the cable is stored.

The connectors are also provided with captive end caps so the connectors can be protected when not in use.

The majority of HF transceivers are designed to be used with a PL 259 connector (sometimes called a UHF connector). The Buddipole system uses the smaller BNC connector since it has better performance and is quicker to connect and disconnect. A UHF- BNC adapter is included to support use with radios equipped with the UHF connector.

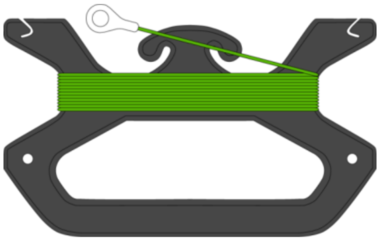
TELESCOPIC MAST

The mast has six sections and an extended length of 18ft. The VersaTee is threaded at the bottom to accept the mast. Be sure to fully screw the mast into the VersaTee to prevent rotation in the wind. Also be sure to fully clamp each section in place as the mast is extended.

The bottom (base) section of the mast is 1.5 inches in diameter and Is clamped into the tripod. Note that each leg of the tripod is telescopic and can be finely adjusted for length to accommodate uneven ground.

RADIAL AND WINDER

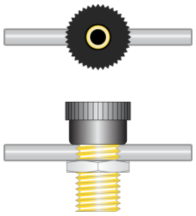
An NVIS antenna can utilize the radial wire as radiating elements for the horizontal antenna. This is especially convenient in the inverted Vee configuration.



The standard wire winder has 33 ft of wire which is sufficient for creating a loaded dipole for 80m. The winder should be used for storing excess wire. Pay out the amount required for tuning the antenna and hook the wire into the notches on the winder to prevent further unwinding. Note that the length of wire remaining on the winder does not add to the effective length of the antenna.

COUNTERPOISE WIRE ADAPTER

The counterpoise adapter is used to connect the radial wires to the ends of the coils or antenna arms.



The ring terminal of the coil should be slipped onto the threaded portion of the adapter which is then threaded into the coil or arm and tightened using the long pin as leverage.