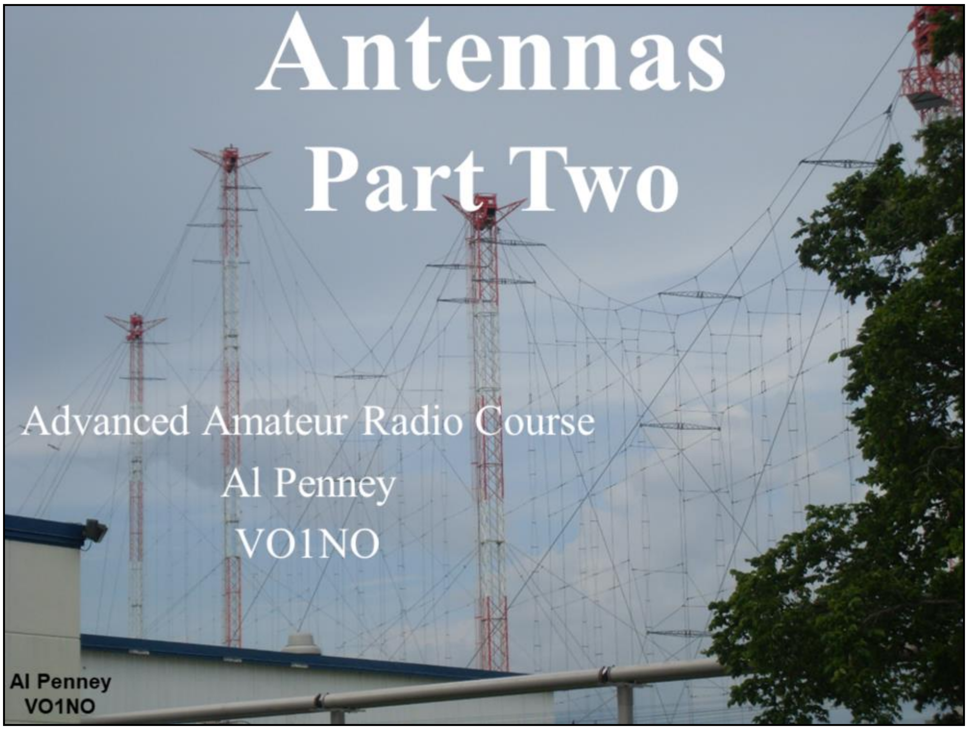

# Antennas
## Part Two

Advanced Amateur Radio Course

Al Penney

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Al Penney
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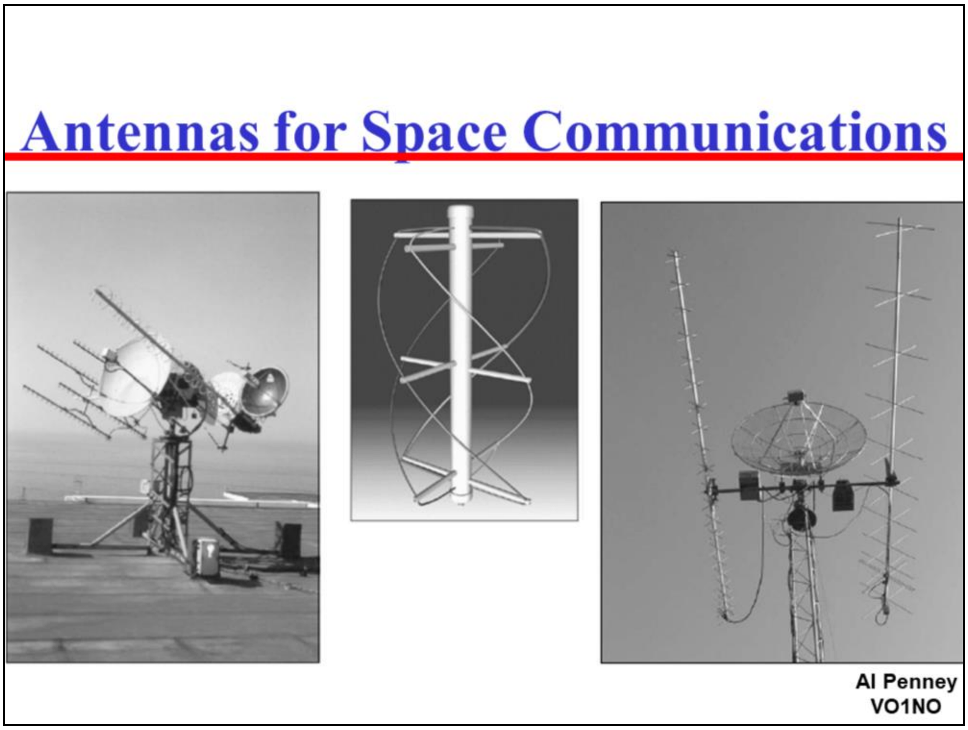

# Antennas for Space Communications

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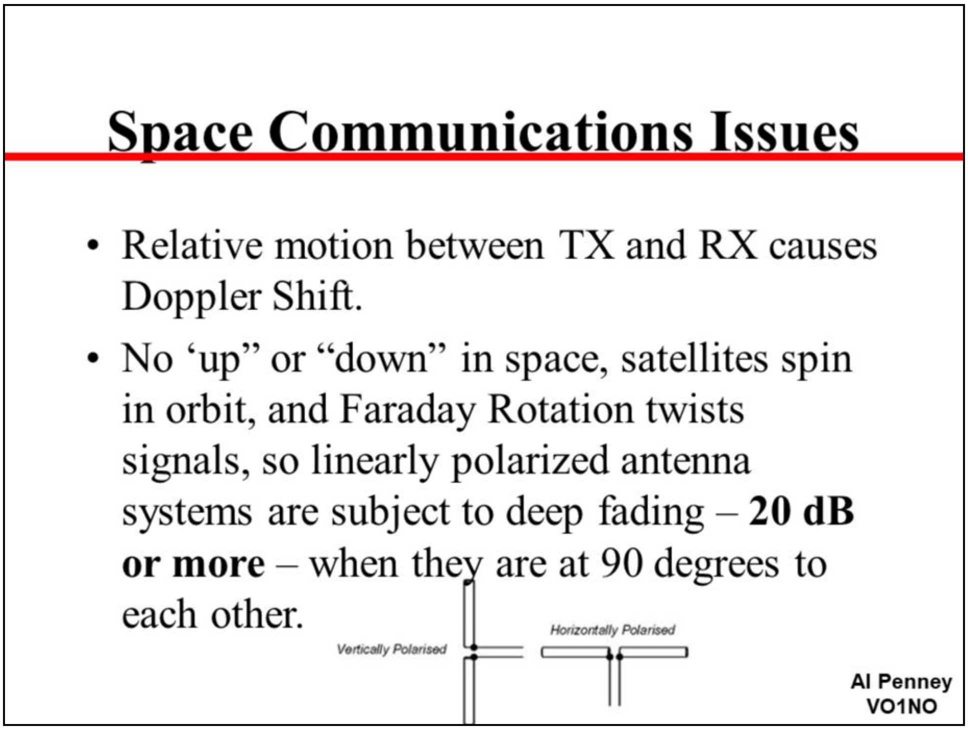

# Space Communications Issues

- Relative motion between TX and RX causes Doppler Shift.
- No ‘up” or “down” in space, satellites spin in orbit, and Faraday Rotation twists signals, so linearly polarized antenna systems are subject to deep fading – **20 dB or more** – when they are at 90 degrees to each other.

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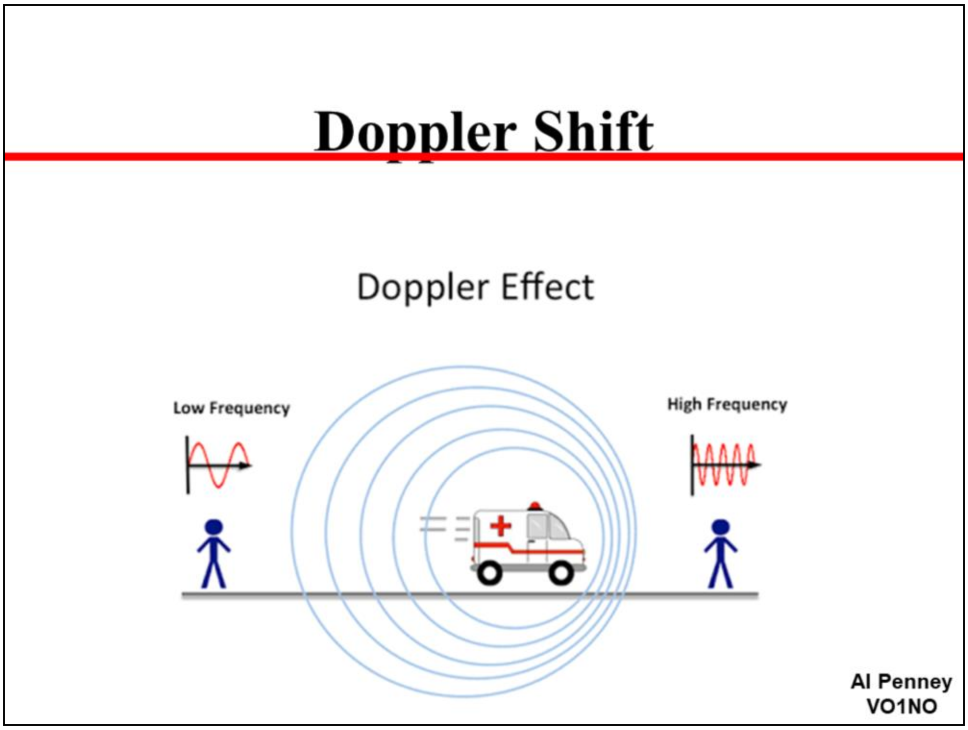
Antenna polarisation (or polarization) is a very important consideration when choosing and installing an antenna and can mean as much as a 20db in signal loss if the receiver and transmitter antenna are not using the same polarisation.

When choosing an antenna, it is an important consideration as to whether the polarization is linear or elliptical. If the polarization is linear, is it vertical or horizontal? If circular, is it RHC or LHC?

On line-of-sight (LOS) paths, it is most important that the polarization of the antennas at both ends of the path use the same polarization. In a linearly polarized system, a misalignment of polarization of 45 degrees will degrade the signal up to 3 dB and if misaligned 90 degrees the attenuation can be 20 dB or more. Likewise, in a circular polarized system, both antennas must have the same sense. If not, an additional loss of 20 dB or more will be incurred.



# Doppler Shift

Doppler Effect

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The **Doppler effect** (or the **Doppler shift**) is the change in frequency of a wave in relation to an observer who is moving relative to the wave source. It is named after the Austrian physicist Christian Doppler, who described the phenomenon in 1842.

A common example of Doppler shift is the change of pitch heard when a vehicle sounding a horn approaches and recedes from an observer. Compared to the emitted frequency, the received frequency is higher during the approach, identical at the instant of passing by, and lower during the recession.

The reason for the Doppler effect is that when the source of the waves is moving towards the observer, each successive wave crest is emitted from a position closer to the observer than the crest of the previous wave. Therefore, each wave takes slightly less time to reach the observer than the previous wave. Hence, the time between the arrivals of successive wave crests at the observer is reduced, causing an increase in the frequency. While they are traveling, the distance between successive wave fronts is reduced, so the waves "bunch together". Conversely, if the source of waves is moving away from the observer, each wave is emitted from a position farther from the observer than the previous wave, so the arrival time between successive waves is increased, reducing the frequency. The distance between successive wave fronts is then increased, so the waves "spread out".

For waves that propagate in a medium, such as sound waves, the velocity of the observer and of the source are relative to the medium in which the waves are transmitted. The total Doppler effect may therefore result from motion of the source, motion of the observer, or motion of the medium. Each of these effects is analyzed separately. For waves which do not require a medium, such as light or gravity in general relativity, only the relative difference in velocity between the observer and the source needs to be considered.

# Doppler Shift

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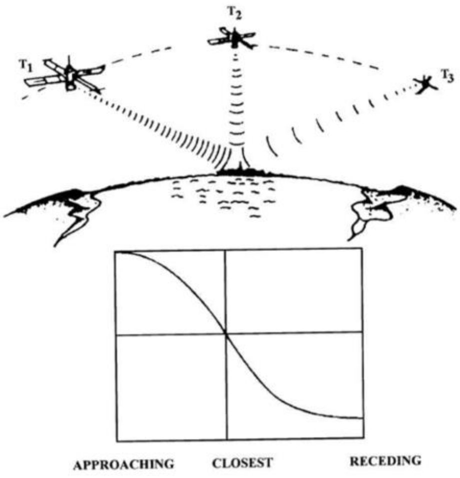
# Satellite Doppler Shift



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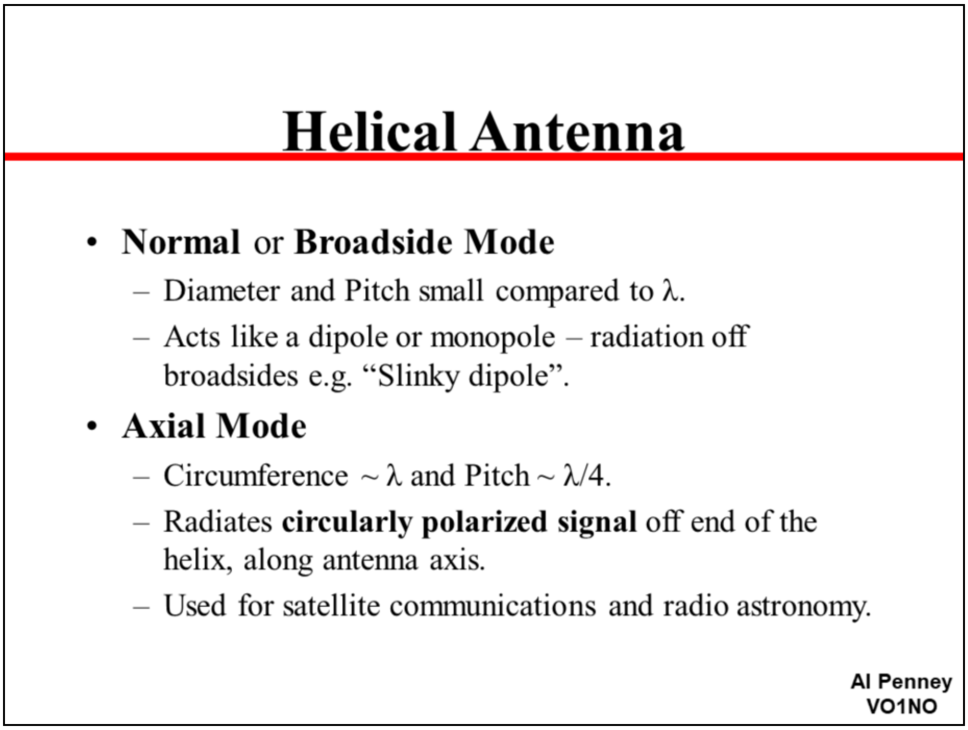
**Doppler shift**

Due to the high orbital speed of the amateur satellites, the uplink and downlink frequencies will vary during the course of a satellite pass. This phenomenon is known as the Doppler effect. While the satellite is moving towards the ground station, the downlink frequency will appear to be *higher* than normal. Hence, the receiver frequency at the ground station must be adjusted *higher* to continue receiving the satellite. The satellite in turn, will be receiving the uplink signal at a *higher* frequency than normal so the ground station's transmitted uplink frequency must be *lower* to be received by the satellite. After the satellite passes overhead and begins to move away, this process is reversed. The downlink frequency will appear *lower* and the uplink frequency will need to be adjusted *higher*. The following mathematical formulas relate the Doppler shift to the velocity of the satellite.

Due to the complexity of finding the relative velocity of the satellite and the speed with which these corrections must be made, these calculations are normally accomplished using satellite tracking software. Many modern transceivers include a computer interface that allows for automatic doppler effect correction. Manual frequency-shift correction is possible, but it is difficult to remain precisely near the frequency. Frequency modulation is more tolerant of doppler shifts than single-sideband, and therefore FM is much easier to tune manually.



# Helical Antenna

- **Normal** or **Broadside Mode**
  - Diameter and Pitch small compared to λ.
  - Acts like a dipole or monopole – radiation off broadsides e.g. “Slinky dipole”.
- **Axial Mode**
  - Circumference ~ λ and Pitch ~ λ/4.
  - Radiates **circularly polarized signal** off end of the helix, along antenna axis.
  - Used for satellite communications and radio astronomy.

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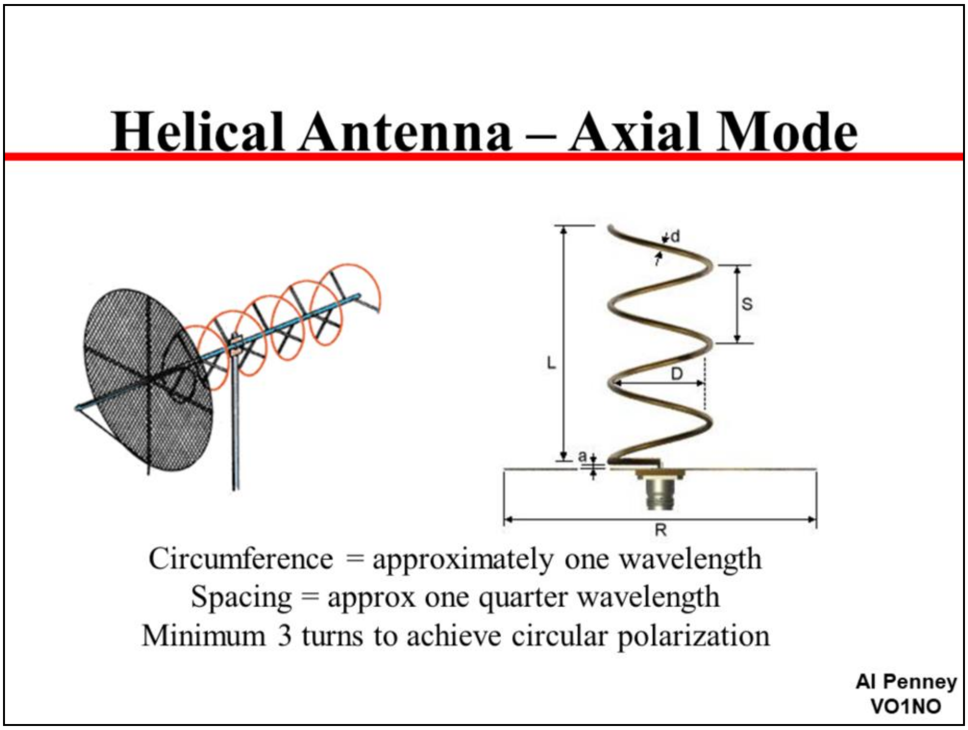
A **helical antenna** is an antenna consisting of one or more conducting wires (monofilar, bifilar, or quadrifilar with 1, 2, or 4 wires respectively) wound in the form of a helix. In most cases, directional helical antennas are mounted over a ground plane, while omnidirectional designs may not be. The feed line is connected between the bottom of the helix and the ground plane. Helical antennas can operate in one of two principal modes — normal mode or axial mode.

In the *normal mode* or *broadside* helical antenna, the diameter and the pitch of the aerial are small compared with the wavelength. The antenna acts similarly to an electrically short dipole or monopole, equivalent to a 1/4 wave vertical and the radiation pattern,[citation needed] similar to these antennas is omnidirectional, with maximum radiation at right angles to the helix axis. For monofilar designs the radiation is linearly polarized parallel to the helix axis. These are used for compact antennas for portable hand held as well as mobile vehicle mount two-way radios, and in larger scale for UHF television broadcasting antennas. In bifilar or quadrifilar implementations, broadside circularly polarized radiation can be realized.

In the *axial mode* or *end-fire* helical antenna, the diameter and pitch of the helix are comparable to a wavelength. The antenna functions as a directional antenna radiating a beam off the ends of the helix, along the antenna's axis. It radiates circularly polarized radio waves. These are used for satellite communication. Axial mode operation was discovered by physicist John D. Kraus



## Helical Antenna – Axial Mode

Circumference = approximately one wavelength
Spacing = approx one quarter wavelength
Minimum 3 turns to achieve circular polarization

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**Helical antenna** or helix antenna is the antenna in which the conducting wire is wound in helical shape and connected to the ground plate with a feeder line. It is the simplest antenna, which provides **circularly polarized waves**. It is used in extra-terrestrial communications in which satellite relays etc., are involved.

It consists of a helix of thick copper wire or tubing wound in the shape of a screw thread used as an antenna in conjunction with a flat metal plate called a ground plate. One end of the helix is connected to the center conductor of the cable and the outer conductor is connected to the ground plate.

The radiation of helical antenna depends on the diameter of helix, the turn spacing and the pitch angle.

**Pitch angle** is the angle between a line tangent to the helix wire and plane normal to the helix axis.

$\alpha=\tan-1(S\pi D)\alpha=\tan-1(S\pi D)$where,

•**D** is the **diameter** of helix.

•**S** is the **turn spacing** (centre to centre).

•**α** is the **pitch angle**.

### Axial mode

In **axial mode** of radiation, the radiation is in the end-fire direction along the helical axis and the waves are circularly or nearly circularly polarized. This mode of operation is obtained by raising the circumference to the order of one wavelength **(λ)** and spacing of approximately **λ/4**. The radiation pattern is broad and directional along the axial beam producing minor lobes at oblique angles.

Helix antennas of at least 3 turns will have close to circular polarization in the +z direction when the circumference *C* is close to a wavelength:

If this antenna is designed for right-handed circularly polarized waves, then it will not receive left-handed circularly polarized waves and vice versa. This mode of operation is generated with great ease and is **more practically used**.

### Advantages

The following are the advantages of Helical antenna −

- Simple design
- Highest directivity
- Wider bandwidth
- Can achieve circular polarization
- Can be used at HF & VHF bands also

### Disadvantages

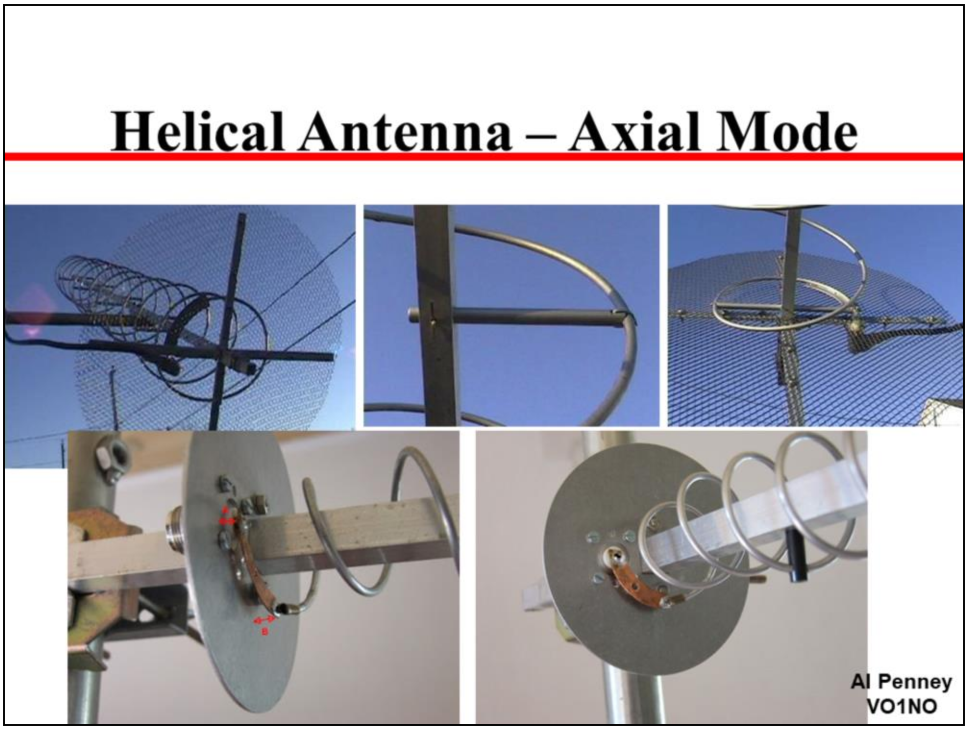
The following are the disadvantages of Helical antenna −

- Antenna is larger and requires more space
- Efficiency decreases with number of turns

### Applications

The following are the applications of Helical antenna −

- A single helical antenna or its array is used to transmit and receive VHF signals
- Frequently used for satellite and space probe communications
- Used for telemetry links with ballastic missiles and satellites at Earth stations
- Used to establish communications between the moon and the Earth
- Applications in radio astronomy



## Helical Antenna – Axial Mode

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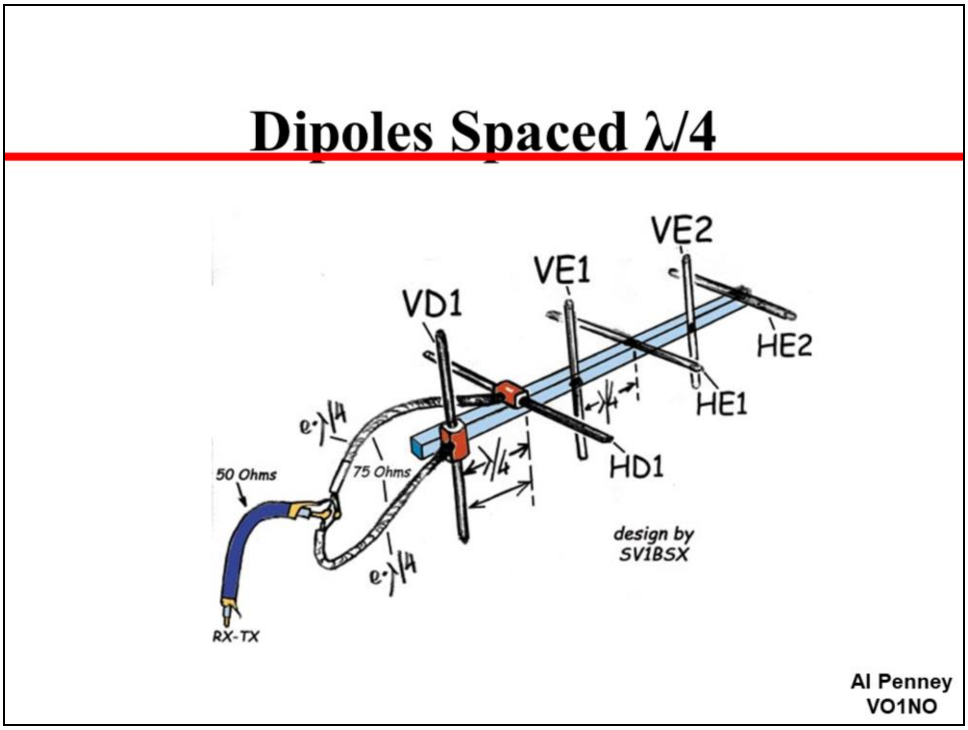
Terminal impedance in axial mode ranges between 100 and 200 ohms, approximately[citation needed]

Z ~ 140 (C / Lamda)

where C is the circumference of the helix, and λ is the wavelength. Impedance matching (when C=λ) to standard 50 or 75 ohm coaxial cable is often done by a quarter wave stripline section acting as an impedance transformer between the helix and the ground plate.

http://ve2zaz.net/SatAnt/435Helix.htm



# Dipoles Spaced λ/4

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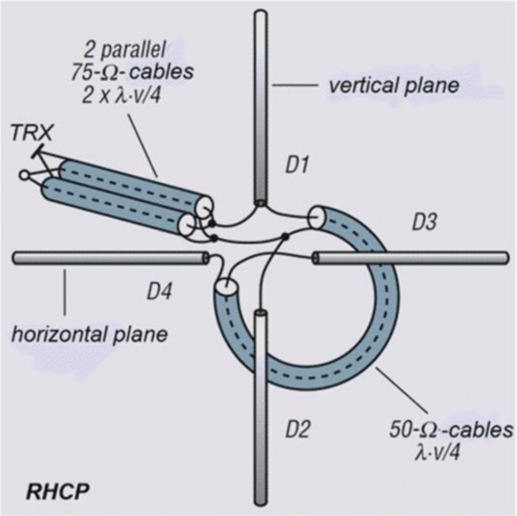
Quarter wavelength 75 ohm cables are of equal length, and serve to match the pair of dipoles to 50 ohm feedline to station. A relay (not shown) located at the junction point of the three pieces of coax can switch between Left Hand and Right Hand Circular Polarization.

# RHCP – 2 Dipoles in Same Plane



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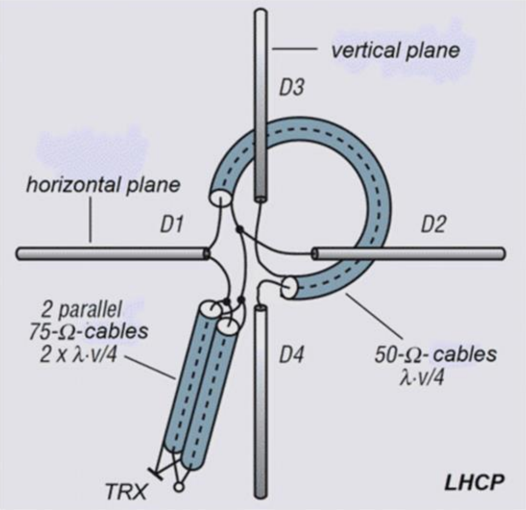
**Circuit for right-hand circular polarisation (RHCP)**

**The horizontal dipole is connected to the vertical dipole with a phasing line of a quarter-wave cable of 50-Ohm-coax. At this point the impedance is 25 Ohm, which is transformed to 50 Ohm again with two parallel 75-Ohm-quarter-wave cables. The phase shift between D1/D2 and D3/D4 is +90°. It is possible to run with two cables from each plane to the station with the box for circular polarisation.**

# LHCP – 2 Dipoles in Same Plane



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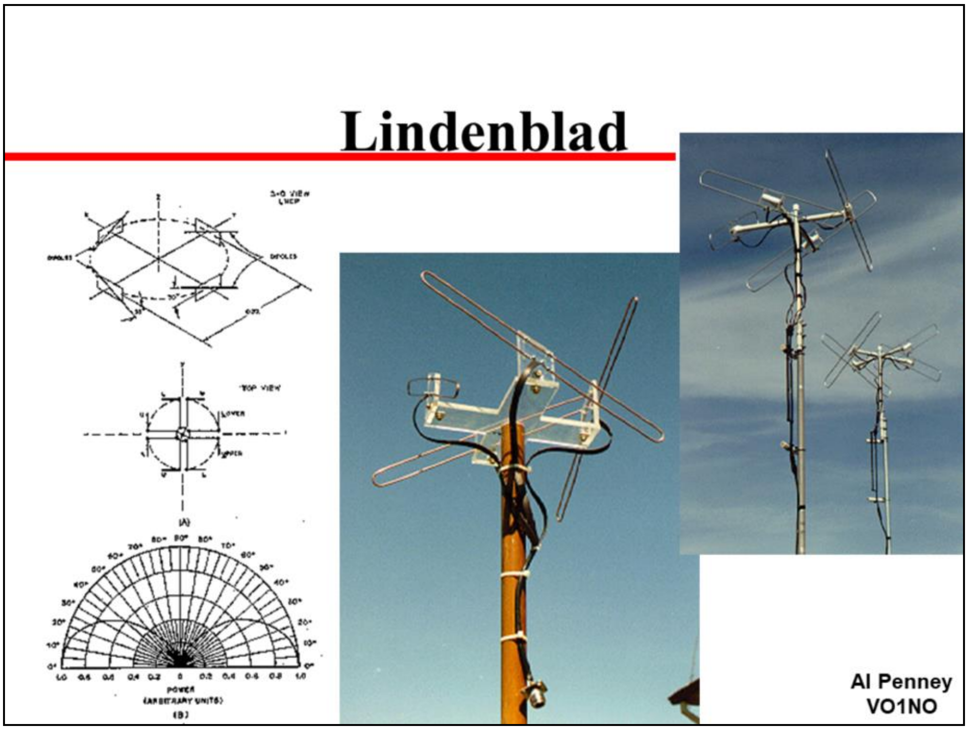
## Circuit for left-hand circular polarisation (LHCP)

**The horizontal dipole is connected to the vertical dipole with a phasing line of a quarter-wave cable of 50-Ohm-coax. At this point the impedance is 25 Ohm, which is transformed to 50 Ohm again with two parallel 75-Ohm-quarter-wave cables. The phase shift between D1/D2 and D3/D4 is -90°. It is possible to run with two cables from each plane to the station with the box for circular polarisation**



# Lindenblad

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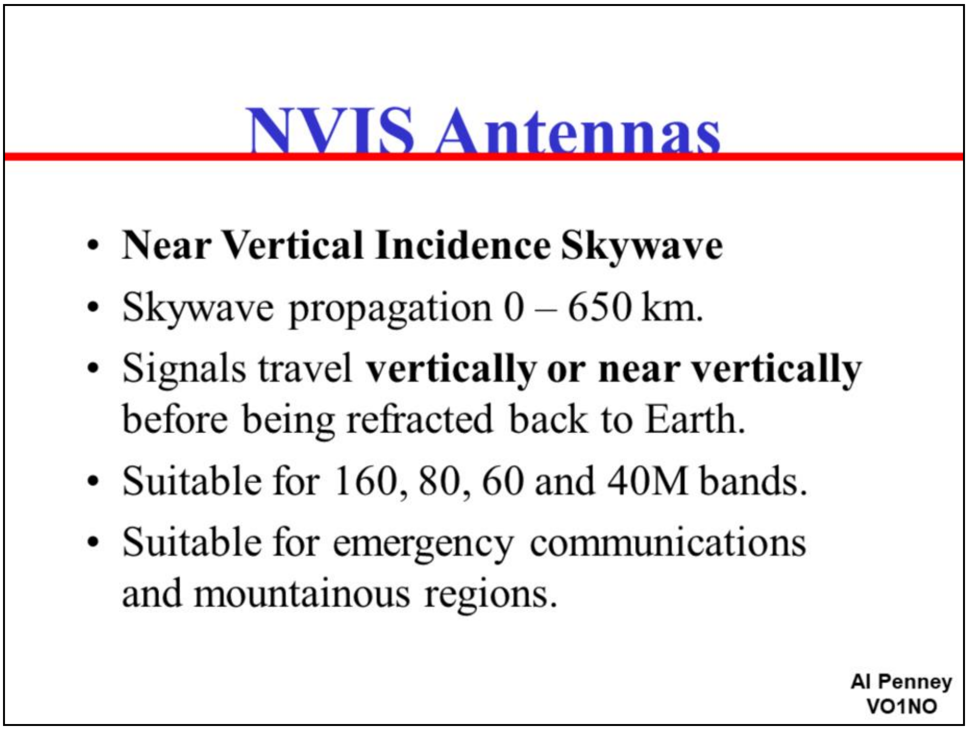
https://www.amsat.org/amsat/articles/w6shp/lindy.html

As can be seen in Figure 1 above, the Lindenblad antenna consists of four half wave folded dipoles slanted 30 degrees to the horizon, oriented 90 degrees to each other in azimuth, spaced 0.3 wavelength apart. They are tied together by four half wave 300 ohm twinlead lines that divide the folded dipole's impedance by four where they connect to the coax feedline (see Figure 2 below). A remote coax relay switch selects either the RHCP (Right Hand Circular Polarized) or LHCP (Left Hand Circular Polarized) antenna which then goes to a GaAs FET preamp.



# NVIS Antennas

- **Near Vertical Incidence Skywave**
- Skywave propagation 0 – 650 km.
- Signals travel **vertically or near vertically** before being refracted back to Earth.
- Suitable for 160, 80, 60 and 40M bands.
- Suitable for emergency communications and mountainous regions.

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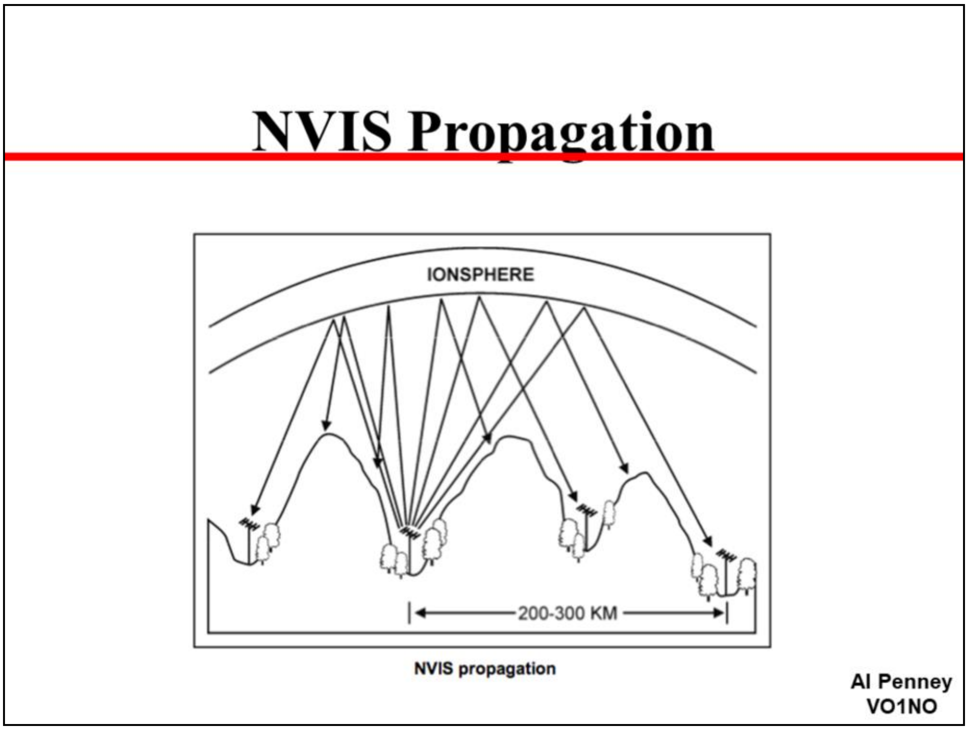
**Near vertical incidence skywave**, or **NVIS**, is a skywave radio-wave propagation path that provides usable signals in the distances range — usually 0–650 km (0–400 miles). It is used for military and paramilitary communications, broadcasting,[1] especially in the tropics, and by radio amateurs for nearby contacts circumventing line-of-sight barriers. The radio waves travel near-vertically upwards into the ionosphere, where they are refracted back down and can be received within a circular region up to 650 km (400 miles) from the transmitter.[2] If the frequency is too high (that is, above the critical frequency of the ionospheric F layer), refraction fails to occur and if it is too low, absorption in the ionospheric D layer may reduce the signal strength.

There is no fundamental difference between NVIS and conventional skywave propagation; the practical distinction arises solely from different desirable radiation patterns of the antennas (near vertical for NVIS, near horizontal for conventional long-range skywave propagation).



# NVIS Propagation

NVIS propagation

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**Near vertical incidence skywave**, or **NVIS**, is a skywave radio-wave propagation path that provides usable signals in the distances range — usually 0–650 km (0–400 miles). It is used for military and paramilitary communications, broadcasting,[1] especially in the tropics, and by radio amateurs for nearby contacts circumventing line-of-sight barriers. The radio waves travel near-vertically upwards into the ionosphere, where they are refracted back down and can be received within a circular region up to 650 km (400 miles) from the transmitter.[2] If the frequency is too high (that is, above the critical frequency of the ionospheric F layer), refraction fails to occur and if it is too low, absorption in the ionospheric D layer may reduce the signal strength.

There is no fundamental difference between NVIS and conventional skywave propagation; the practical distinction arises solely from different desirable radiation patterns of the antennas (near vertical for NVIS, near horizontal for conventional long-range skywave propagation).

The most reliable frequencies for NVIS communications are between 1.8 MHz and 8 MHz. Above 8 MHz, the probability of success begins to decrease, dropping to near zero at 30 MHz. Usable frequencies are dictated by local ionospheric conditions, which have a strong systematic dependence on geographical location. Common bands used in amateur radio at mid-latitudes are 3.5 MHz at night and 7 MHz during daylight, with experimental use of 5 MHz (60 meters) frequencies. During winter nights at the bottom of the sunspot cycle, the 1.8 MHz band may be required. [3] Broadcasting uses the tropical broadcast bands between 2.3 and 5.06 MHz, and the international broadcast bands between 3.9 and 6.2 MHz. Military NVIS communications mostly take place on 2–4 MHz at night and on 5–7 MHz during daylight.

Optimum NVIS frequencies tend to be higher towards the tropics and lower towards the arctic regions. They are also higher during high sunspot activity years. The usable frequencies change from day to night, because sunlight causes the lowest layer of the ionosphere, called the D layer, to increase, causing attenuation of low frequencies during the day [4] while the maximum usable frequency (MUF) which is the critical frequency of the F layer rises with greater sunlight. Real time maps of the critical frequency are available. [5] Use of a frequency about 15% below the critical frequency should provide reliable NVIS service. This is sometimes referred to as the optimum working frequency or FOT.

NVIS is most useful in mountainous areas where line-of-sight propagation is ineffective, or when the communication distance is beyond the 50 mile (80 km) range of groundwave (or the terrain is so rugged and barren that groundwave is not effective), and less than the 300–1500 mile (500–2500 km) range of lower-angle sky-wave propagation. Another interesting aspect of NVIS communication is that direction finding of the sender is more difficult than for ground-wave communication (i.e. VHF or UHF). For broadcasters, NVIS allows coverage of an entire medium-sized country at much lower cost than with VHF (FM), and daytime coverage, similar to mediumwave (AM broadcast) nighttime coverage at lower cost and often with less interference.

# NVIS Antenna Pattern

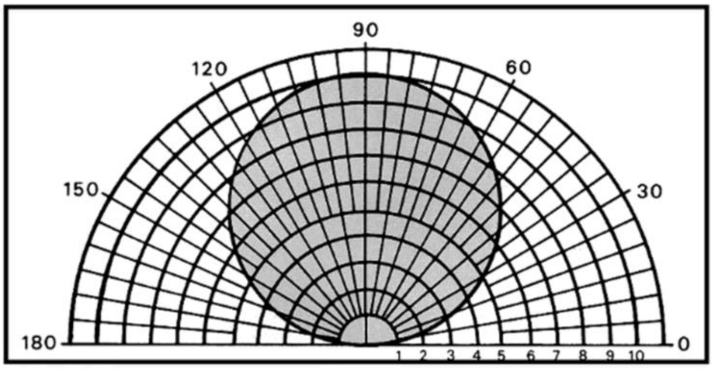

*Figure M-4. Typical elevation plane pattern.*

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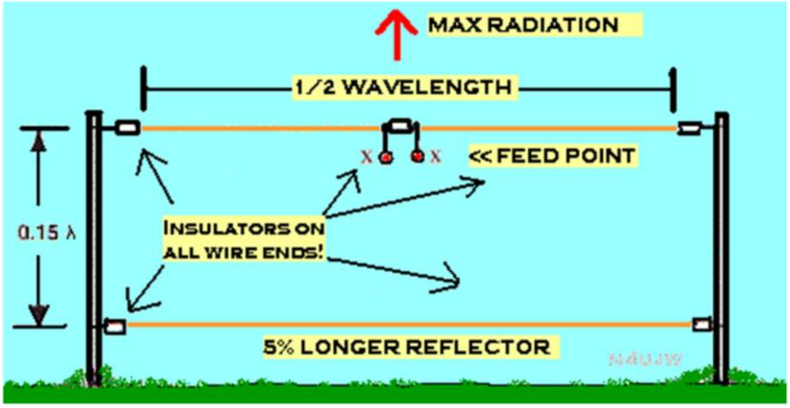
# Simple NVIS Antenna



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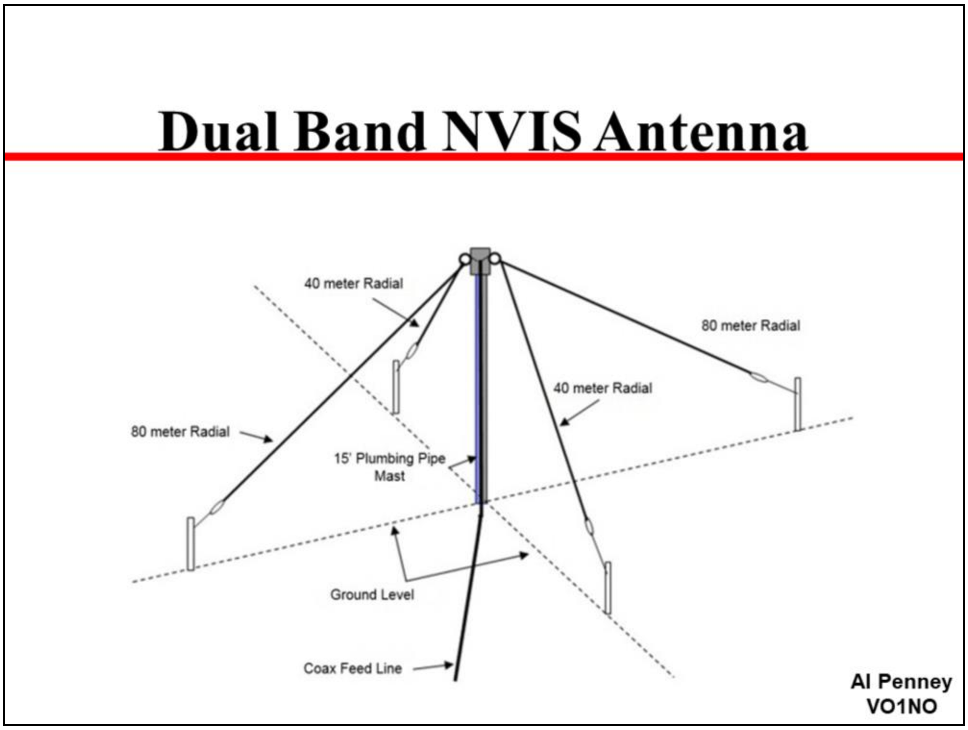
## Antennas[edit]

An NVIS antenna configuration is a horizontally polarized (parallel with the surface of the earth) radiating element that is from 1/20th wavelength (λ) to 1/4 wavelength above the ground. Optimum height is about 1/4 wavelength, and high angle radiation declines only slightly for heights up to about 3/8 wavelength. [6] That proximity to the ground forces the majority of the radiation to go straight up. Overall efficiency of the antenna can be increased by placing a ground wire slightly longer than the antenna parallel to and directly underneath the antenna. One source says that a single ground wire can provide antenna gain in the 3–6 dB range.[7] Another source indicates 2 dB for a single wire and nearly 4 dB for multiple ground wires.[8] Ground wires are more necessary when using lower dipoles over poor soils as without them considerable energy goes into heating the ground.

Depending on the specific requirements, various antennas (i.e. Sloper, T2FD, Dipole) can be used for NVIS communication, with horizontal dipoles or inverted V dipoles at about 0.2 wavelengths above ground giving the best results on transmit and at about 0.16 wavelengths on receive, according to military sources and an extensive study by Dutch researchers. [9] [10] Very low antennas are much inferior on transmit, less so on receive, where both noise and signal are attenuated.

Significant increases in communication will obviously be realized when both the transmitting station and the receiving station use NVIS configuration for their antennas. In particular for low profile operations NVIS antennas are a good option.[11]

For broadcasting, typical antennas consist of a dipole about 1/4 wavelength above ground, or arrays of such dipoles.[12] Up to 16 dipoles can be used, allowing strong signals with relatively low power by concentrating the signal in a smaller area. Limiting the coverage may be dictated by licensing, language or political considerations. Arrays of dipoles can be used to "slew" the pattern, so that the transmitter need not be in the center of the coverage footprint. Broadcast NVIS antennas usually use an extensive ground screen to increase gain and stabilize the pattern and feed impedance with changing ground moisture.



# Dual Band NVIS Antenna

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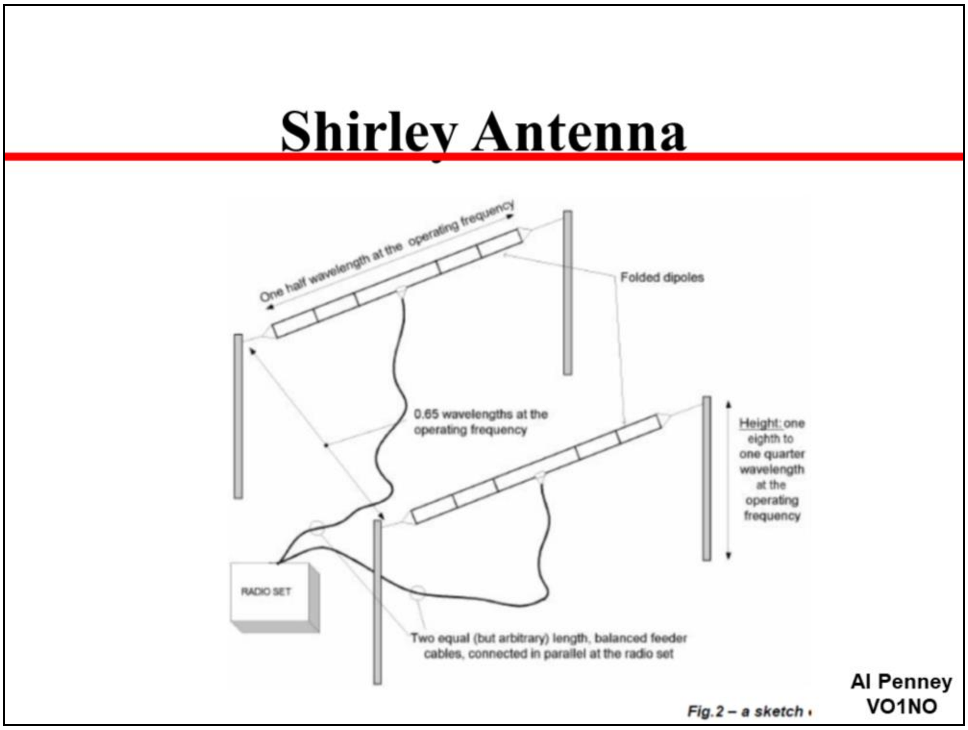
By “radial” they mean half of a dipole antenna in this illustration.



# Shirley Antenna

*Fig.2 – a sketch*

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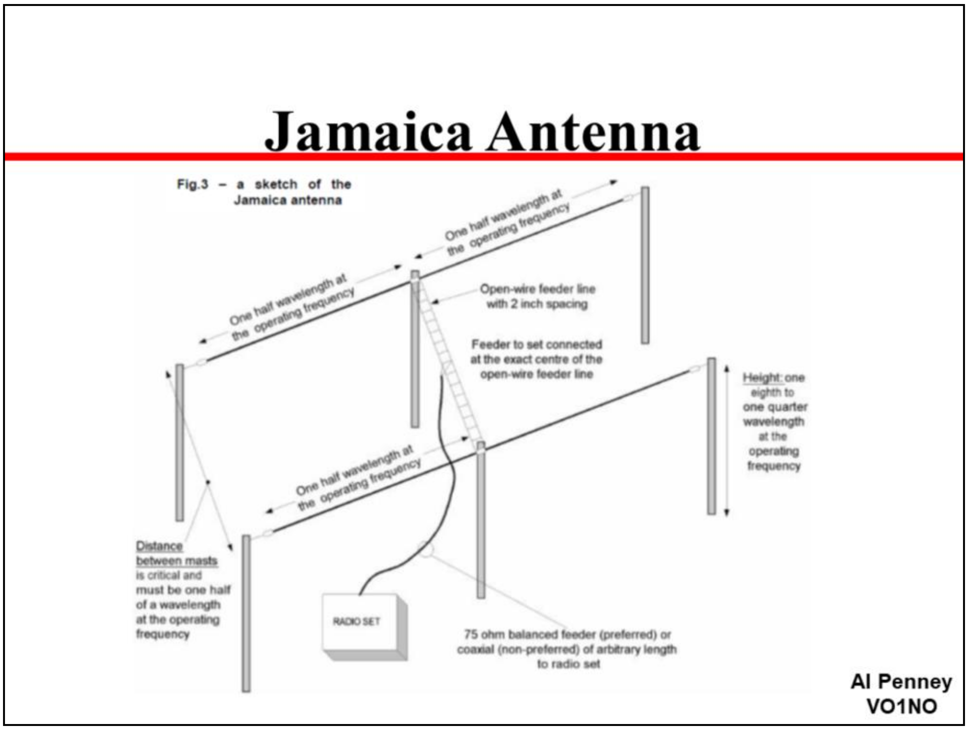
The Shirley aerial The Malayan emergency led directly to the development of perhaps the best known NVIS aerial, and one of the most efficient. This is the Shirley, which is actually two phased dipoles with the ground as a reflector; further details are given in the appendix. In some respects it is the reference aerial for NVIS work. [See Fig.2 – Ed] It was designed in about 1950 by (the then) Major John Shirley, a New Zealander who was by all accounts a most enterprising and engaging character. At the time, he was serving in the Royal Signals and on attachment to the Army Operational Research Group in Malaya. The problem was communicating with small units in the jungle. The base station, in these operations, were usually outside the main jungle and relatively static. In addition, the same frequency could be used day and night (E region propagation, possibly?) and the opposition was not thought to have much in the way of a signals intelligence capability. After some thought and research, the Shirley aerial was the result. In Shirley's own words, 'the results were spectacular'. Although troublesome to construct – a problem obviously shared with any multi-element system - the Shirley aerial remained in the Army's repertoire for many years, and probably still does. As well as being used in Malaya, a classic example of the system is given in The Vital Link3 , during the Kenyan emergency. Communication had to be established across 50-100 miles, the area including the 12,000 foot high and thickly forested Aberdare Mountains. Shirley aerials and the A510 were used 'with good results.'

In its original and simplest form, the Shirley aerial seems to have comprised two half wave open dipoles, fed by twin mine detonating cable. An important factor was ease of construction from readily available stores!  In this configuration, the dipoles have a rather low input impedance and there must have been mismatches all over the place. The whole system, however, could be resonated with the aid of the output tuning circuits in the transmitter. If necessary, the length of the feeders could be altered, by equal amounts, to enable this to be done.

A development of the original version is to raise the input impedance by using folded dipoles. 150Ù twisted feeder can then be used to give an approximate 75Ù match. Again, it seems possible to use a variety of more or less ad hoc feeders - including lighting flex, which often has an impedance of about the right figure.

The ultimate stage, perhaps, is to make the whole thing out of 300Ù ribbon, with a balun transformer in the middle.



# Jamaica Antenna

Fig.3 – a sketch of the Jamaica antenna

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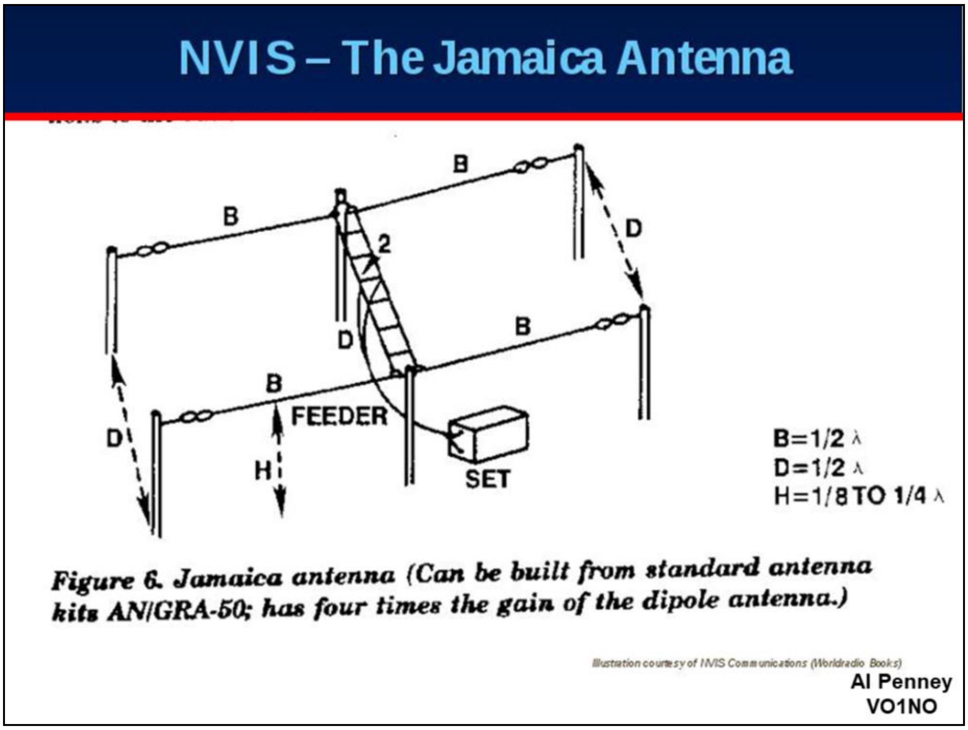
**VO1NO**

The Jamaica

A relative of the Shirley is the Jamaica, so called from its use on that island. In this case, the dipoles are full wave, but it is otherwise similar in design.



# NVIS – The Jamaica Antenna

***Figure 6. Jamaica antenna (Can be built from standard antenna kits AN/GRA-50; has four times the gain of the dipole antenna.)***

*Illustration courtesy of NVIS Communications (Worldradio Books)*

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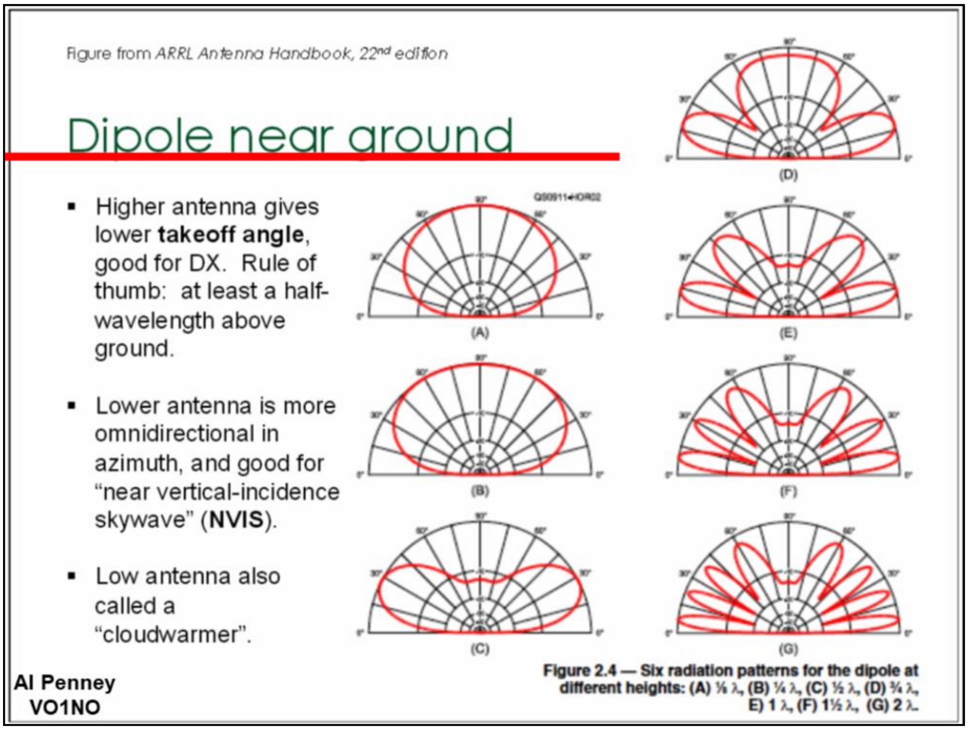

Figure from *ARRL Antenna Handbook, 22nd edition*

# Dipole near ground

- Higher antenna gives lower **takeoff angle**, good for DX. Rule of thumb: at least a half-wavelength above ground.
- Lower antenna is more omnidirectional in azimuth, and good for "near vertical-incidence skywave" (**NVIS**).
- Low antenna also called a "cloudwarmer".

**Figure 2.4 — Six radiation patterns for the dipole at different heights: (A) ⅛ λ, (B) ¼ λ, (C) ½ λ, (D) ¾ λ, E) 1 λ, (F) 1½ λ, (G) 2 λ.**

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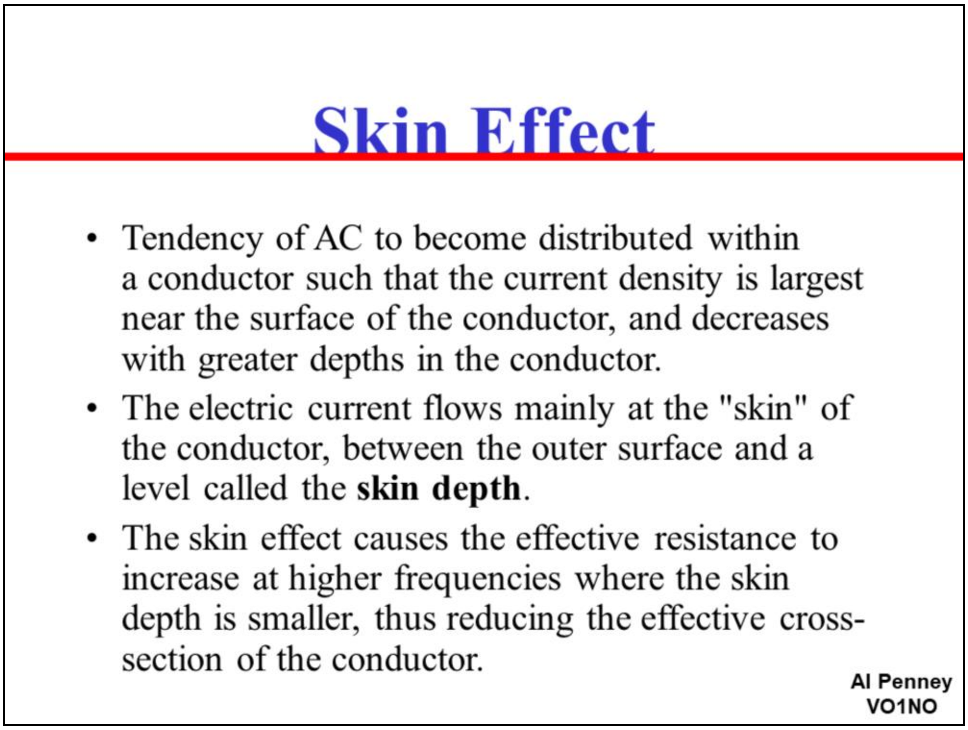

# Skin Effect

- Tendency of AC to become distributed within a conductor such that the current density is largest near the surface of the conductor, and decreases with greater depths in the conductor.
- The electric current flows mainly at the "skin" of the conductor, between the outer surface and a level called the **skin depth**.
- The skin effect causes the effective resistance to increase at higher frequencies where the skin depth is smaller, thus reducing the effective cross-section of the conductor.

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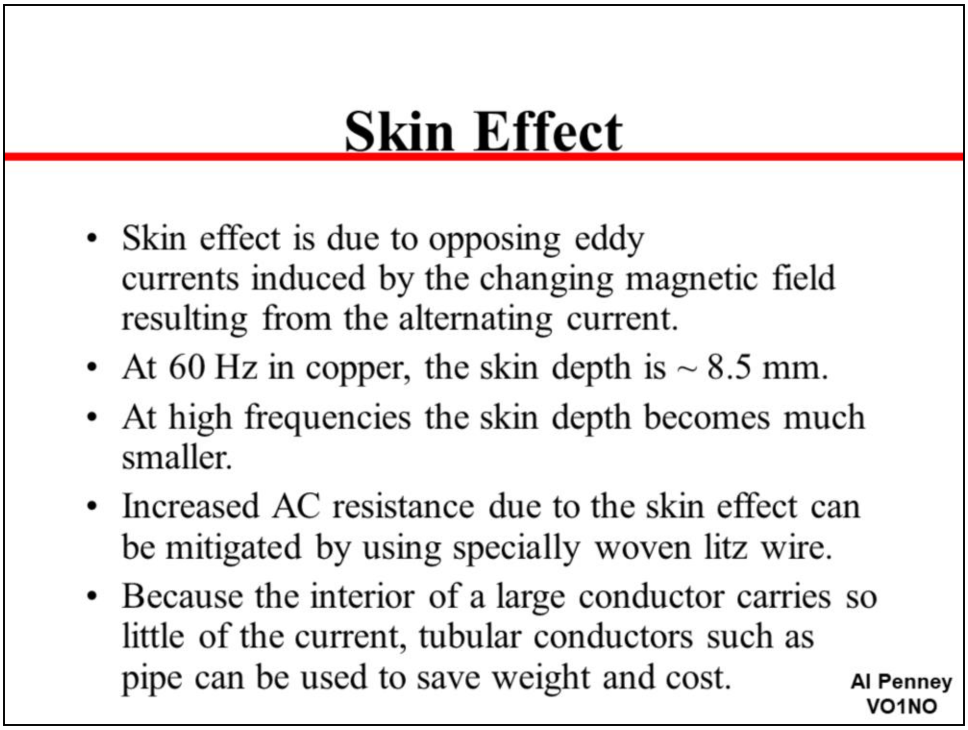

# Skin Effect

- Skin effect is due to opposing eddy currents induced by the changing magnetic field resulting from the alternating current.
- At 60 Hz in copper, the skin depth is ~ 8.5 mm.
- At high frequencies the skin depth becomes much smaller.
- Increased AC resistance due to the skin effect can be mitigated by using specially woven litz wire.
- Because the interior of a large conductor carries so little of the current, tubular conductors such as pipe can be used to save weight and cost.

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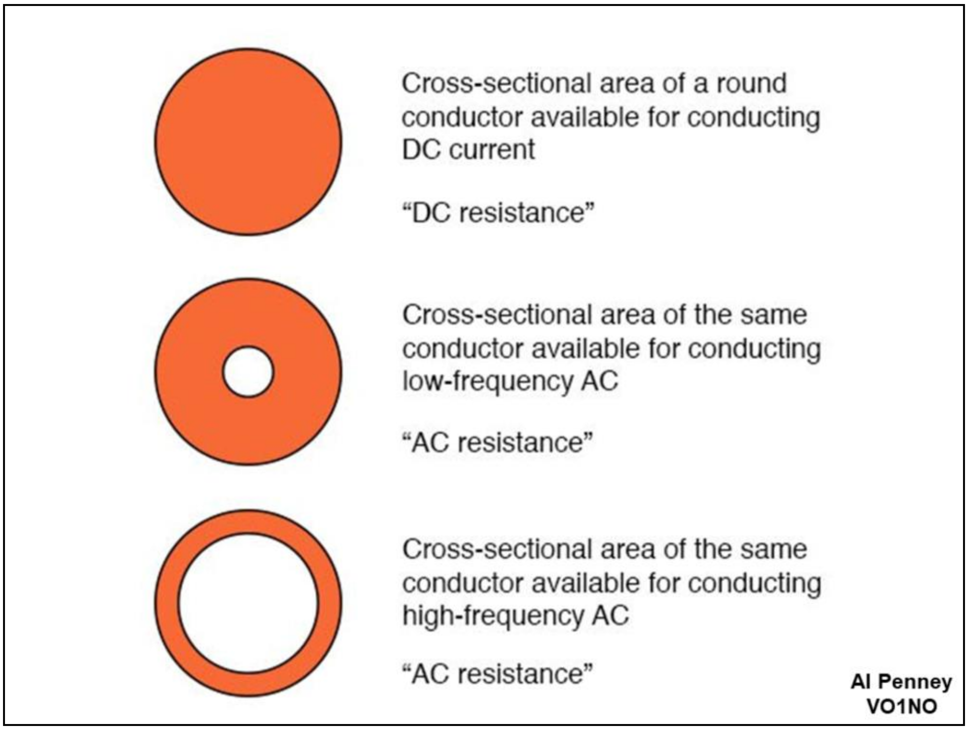

Cross-sectional area of a round conductor available for conducting DC current

“DC resistance”

Cross-sectional area of the same conductor available for conducting low-frequency AC

“AC resistance”

Cross-sectional area of the same conductor available for conducting high-frequency AC

“AC resistance”

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# Other interesting antennas…

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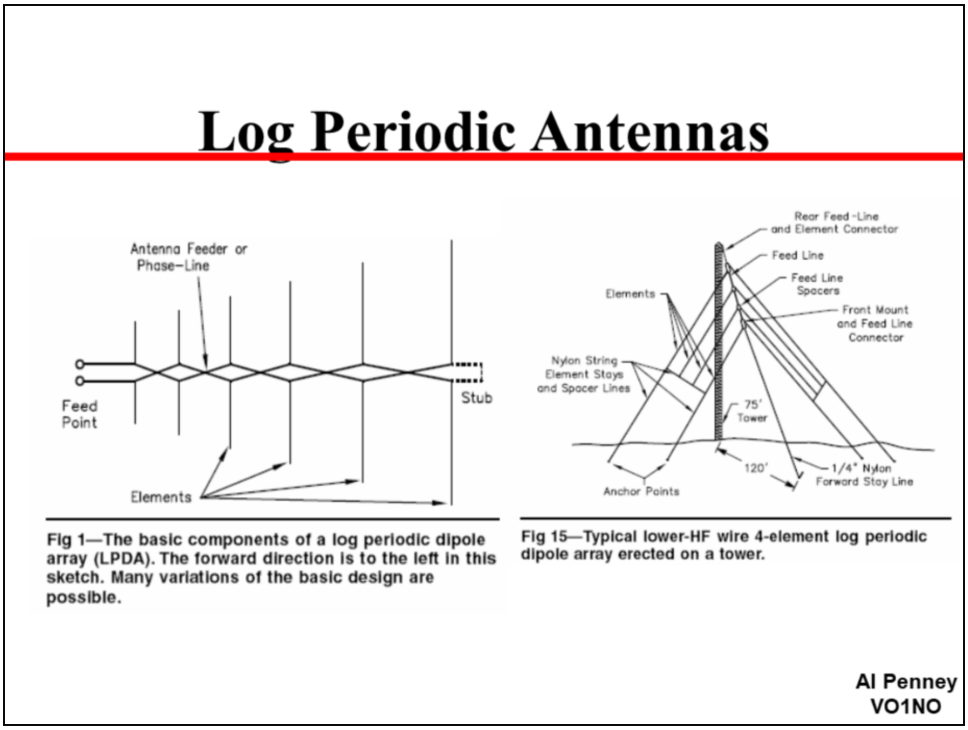

# Log Periodic Antennas

**Fig 1—The basic components of a log periodic dipole array (LPDA). The forward direction is to the left in this sketch. Many variations of the basic design are possible.**

**Fig 15—Typical lower-HF wire 4-element log periodic dipole array erected on a tower.**

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A log periodic antenna is a system of driven elements, designed to be operated over a wide range of frequencies. Its advantage is that it exhibits essentially constant characteristics over the frequency

range—the same radiation resistance (and therefore the same SWR), and the same pattern characteristics (approximately the same gain and the same front-to-back ratio). Not all elements in the system are

active on a single frequency of operation; the design of the array is such that the active region shifts among the elements with changes in operating frequency.

Several varieties of log periodic antenna systems exist, such as the zig-zag, planar, trapezoidal, slot, V, and the dipole. The type favored by amateurs is the log-periodic dipole array, often abbreviated

LPDA. The LPDA, shown in **Fig 1**, was invented by D. E. Isbell at the University of Illinois in 1958. Similar to a Yagi antenna in construction and appearance, a log-periodic dipole array may be built as a

rotatable system for all the upper HF bands, such as 18 to 30 MHz. The longest element, at the rear of the array, is a half wavelength at the lower design frequency.

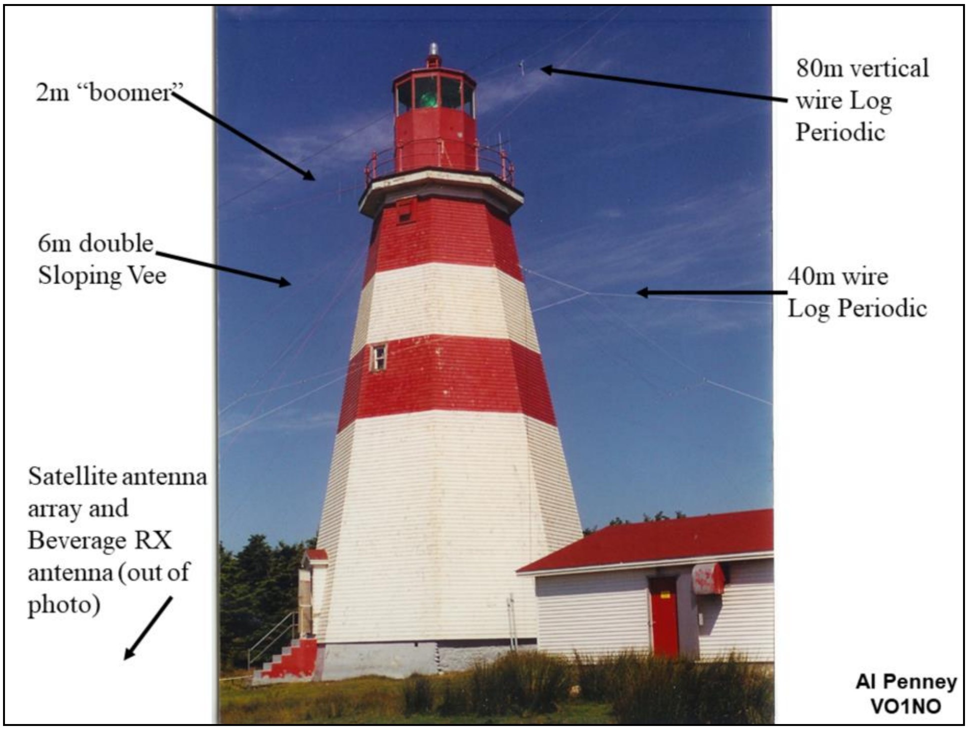
Depending on its design parameters, the LPDA can be operated over a range of frequencies having a ratio of 2:1 or higher. Over this range its electrical characteristics—gain, feed-point impedance, front-to back ratio, and so forth—remain more or less constant.

As may be seen in Fig 1, the log periodic array consists of several dipole elements which are each of different lengths and different relative spacings. A distributive type of feeder system is

used to excite the individual elements. The element lengths and relative spacings, beginning from the feed point for the array, are seen to increase smoothly in dimension, being greater for

each element than for the previous element in the array. It is this feature upon which the design of the LPDA is based, and which permits changes in frequency to be made without greatly affecting the electrical operation. With changes in operating frequency, there is a smooth transition along the array of the elements which comprise the active region.

Feedpoint impedance is approximately 200 ohms, so it can be fed using a 4:1 balun and 50 ohm coax.



2m "boomer"

6m double Sloping Vee

Satellite antenna array and Beverage RX antenna (out of photo)

80m vertical wire Log Periodic

40m wire Log Periodic

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Two log periodic antennas (and other types) I used on Seal Island for an IOTA expedition.

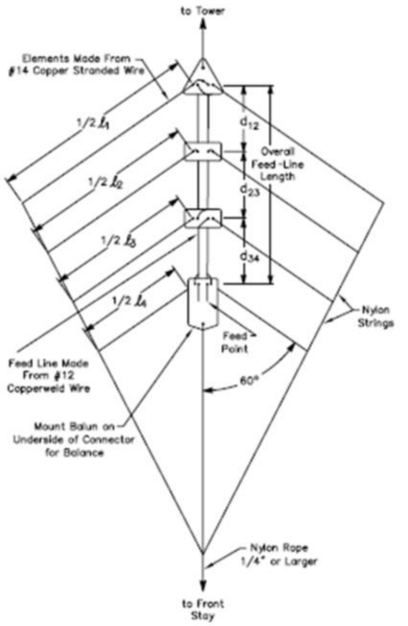

Fig 8—Typical layout for the LPDA. Use a 4:1 balun at the point indicated. See Tables 2 and 3 for dimensions.

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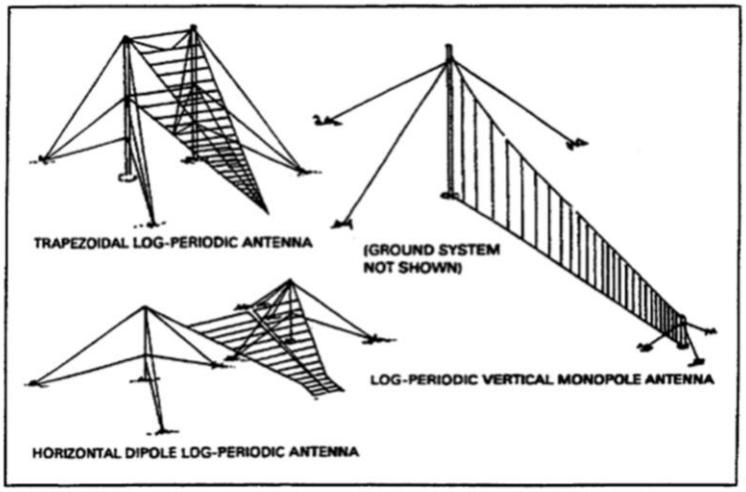
# Log Periodic Antennas



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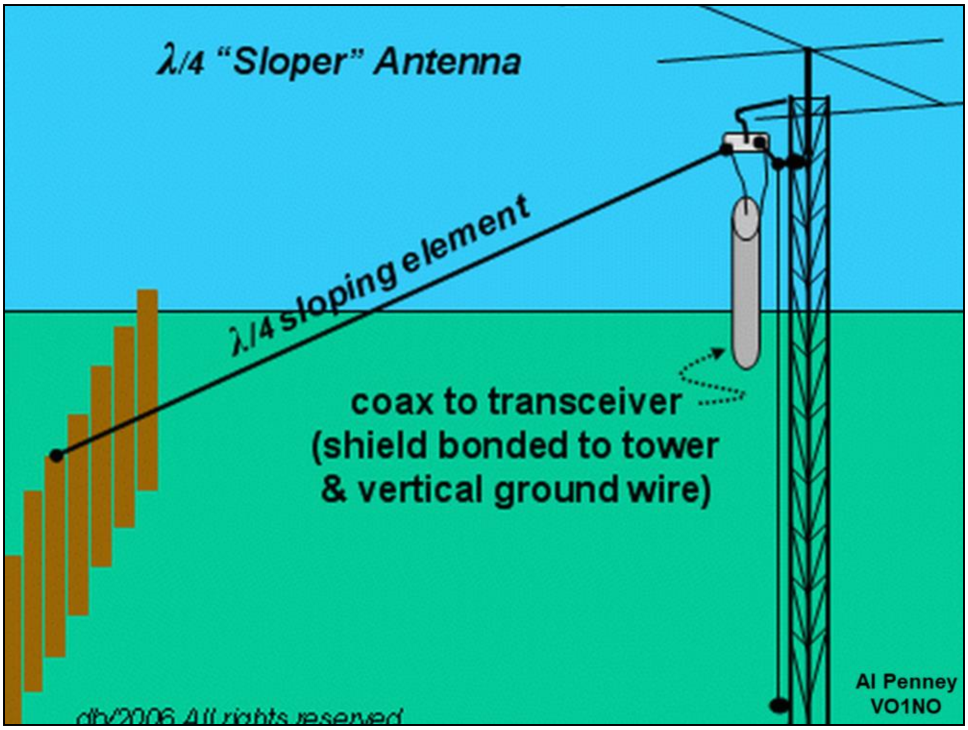


A sloping λ/2 wl dipole is known among radio amateurs as a "full sloper" or just "sloper." If only one half of it is used it becomes a "half sloper." The performance of the two types of sloping antennas is similar:

They exhibit some directivity in the direction of the slope and radiate energy at low angles respective to the horizon. The wave polarization is vertical. The amount of directivity will range from

3 to 6 dB, depending upon the individual installation, and will be observed in the slope direction.

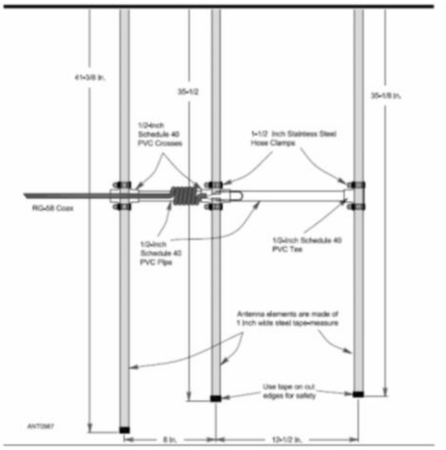
The advantage of the half sloper over the full sloper is that the current portion of the antenna is higher. Also, only half as much wire is required to build the antenna for a given amateur band. The

disadvantage of the half sloper is that it is sometimes impossible to obtain a low SWR when using coaxial-cable feed, especially without a good isolating choke balun. (See the section above on isolating

ground-plane antennas.) Other factors that affect the feed impedance are tower height, height of the attachment point, enclosed angle between the sloper and the tower, and what is mounted atop

the tower (HF or VHF beams). Also the quality of the ground under the tower (ground conductivity, radials, etc) has a marked effect on the antenna performance. The final SWR can vary (after optimization) from 1:1 to as high as 6:1. Generally speaking, the closer the low end of the slope wire is to ground, the more difficult it will be to obtain a good match.

# Tape Measure Yagi



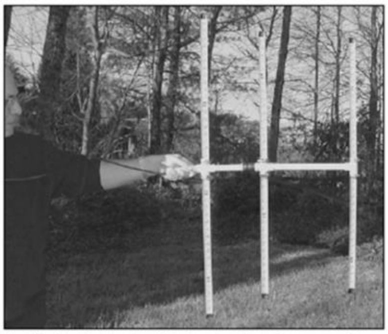


Fig 46—Photo of complete tape-measure beam, ready to hunt foxes!

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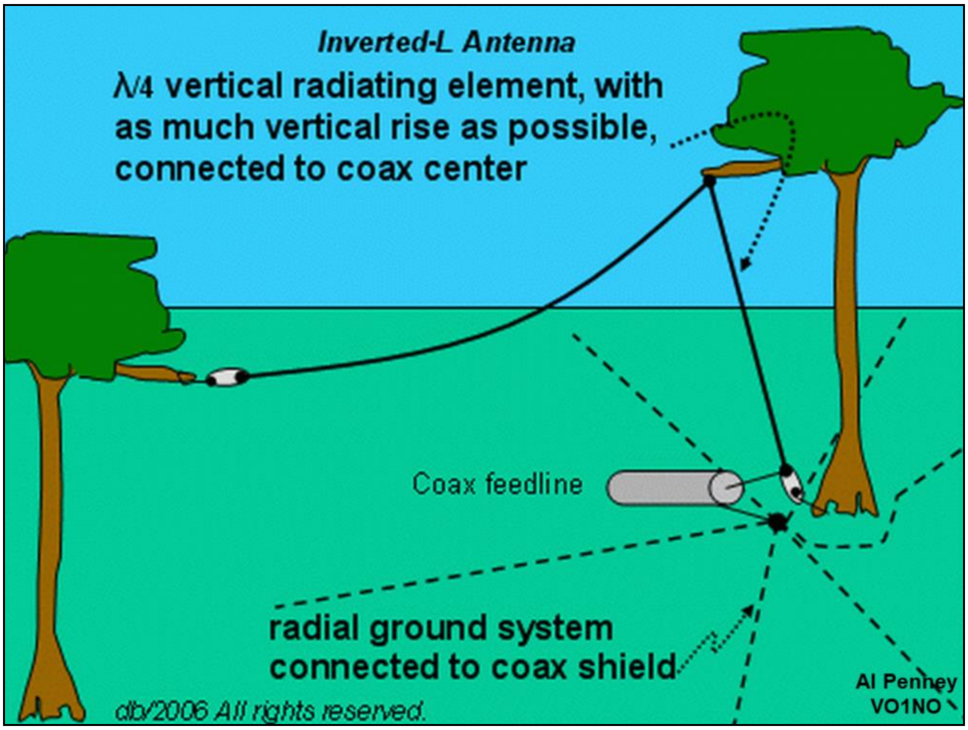
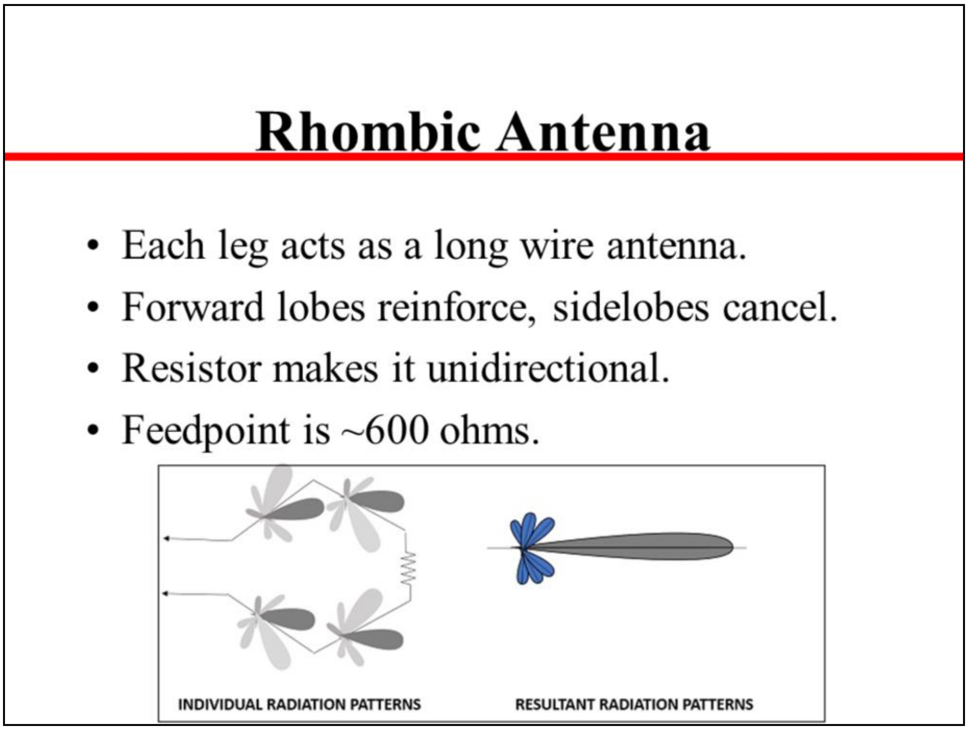

*Inverted-L Antenna*
λ/4 vertical radiating element, with as much vertical rise as possible, connected to coax center
Coax feedline
radial ground system connected to coax shield
Al Penney
VO1NO
db/2006 All rights reserved.



## Rhombic Antenna

- Each leg acts as a long wire antenna.
- Forward lobes reinforce, sidelobes cancel.
- Resistor makes it unidirectional.
- Feedpoint is ~600 ohms.

The **Rhombic Antenna** is an equilateral parallelogram shaped antenna. Generally, it has two opposite acute angles. The tilt angle, θ is approximately equal to 90° minus the angle of major lobe. Rhombic antenna works under the principle of travelling wave radiator. It is arranged in the form of a rhombus or diamond shape and suspended horizontally above the surface of the earth.

### Frequency Range

The frequency range of operation of a Rhombic antenna is around **3MHz to 300MHz**. This antenna works in **HF** and **VHF** ranges.

### Radiation Pattern

The radiation pattern of the rhombic antenna is shown in the following figure. The resultant pattern is the cumulative effect of the radiation at all four legs of the antenna. This pattern is **uni-directional**, while it can be made bi-directional by removing the terminating resistance.

The main disadvantage of rhombic antenna is that the portions of the radiation, which do not combine with the main lobe, result in considerable side lobes having both horizontal and vertical polarization.

### Advantages

The following are the advantages of Rhombic antenna −

•Input impedance and radiation pattern are relatively constant

•Multiple rhombic antennas can be connected

•Simple and effective transmission

Disadvantages

The following are the disadvantages of Rhombic antenna −

•Wastage of power in terminating resistor

•Requirement of large space

•Redued transmission efficiency

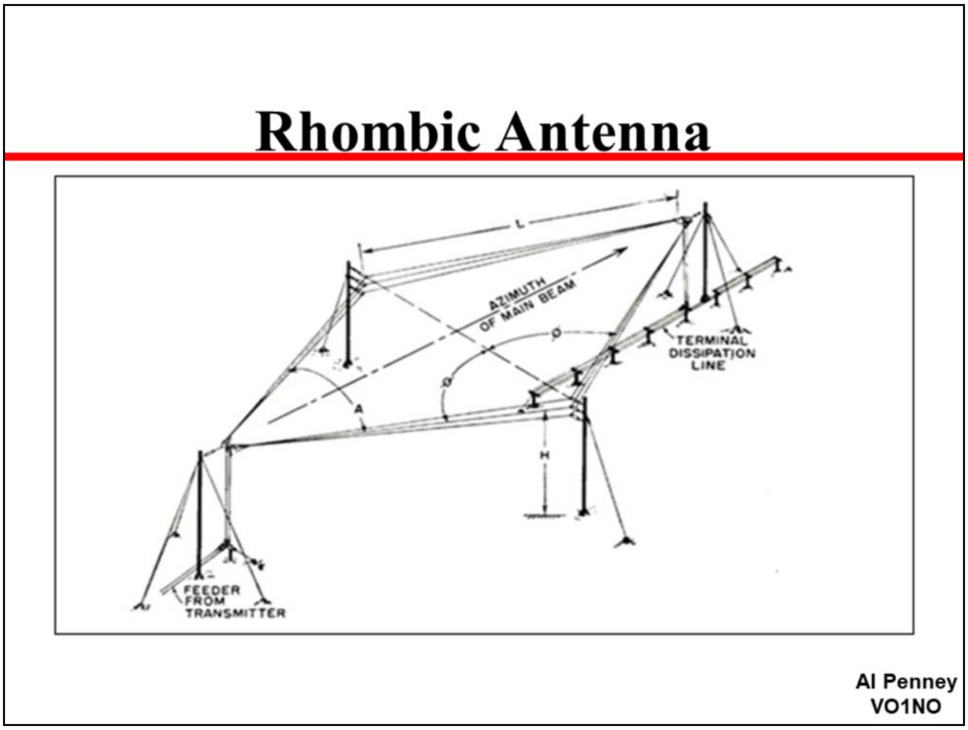
Applications

The following are the applications of Rhombic antenna −

•Used in HF communications

•Used in Long distance sky wave propagations

•Used in point-to-point communications



# Rhombic Antenna

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The terminating resistor must be practically a pure resistance at the operating frequencies; that is, its inductance and capacitance should be negligible. Ordinary wire-wound resistors are not suitable

because they have far too much inductance and distributed capacitance. Small carbon resistors have satisfactory electrical characteristics but will not dissipate more than a few watts and so cannot

be used, except when the transmitter power does not exceed 10 or 20 W or when the antenna is to be used for reception only. The special resistors designed either for use as “dummy” antennas or for

terminating rhombic antennas should be used in other cases. To allow a factor of safety, the total rated power dissipation of the resistor or resistors should be equal to half the power output of the

transmitter.

To reduce the effects of stray capacitance it is desirable to use several units, say three, in series even when one alone will safely dissipate the power. The two end units should be identical and each

should have 1/4 to 1/3 the total resistance, with the center unit making up the difference. The units should be installed in a weatherproof housing at the end of the antenna to protect them and to permit mounting without mechanical strain. The connecting leads should be short so that little extraneous inductance is introduced.

Alternatively, the terminating resistance may be placed at the end of an 800-Ω line connected to the end of the antenna. This will permit placing the resistors and their housing at a point convenient for adjustment rather than at the top of the pole. Resistance wire may be used for this line, so that a portion of the power will be dissipated before it reaches the resistive termination, thus permitting the use of lower-wattage lumped resistors. The line length is not critical, since it operates without standing waves.

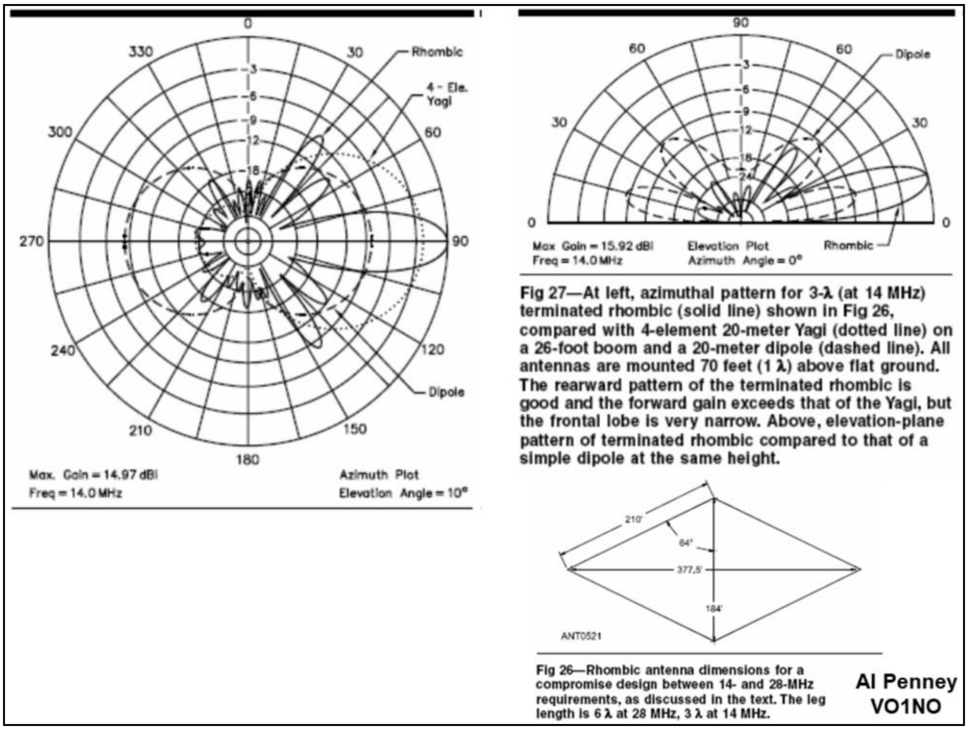

**Fig 27—At left, azimuthal pattern for 3-λ (at 14 MHz) terminated rhombic (solid line) shown in Fig 26, compared with 4-element 20-meter Yagi (dotted line) on a 26-foot boom and a 20-meter dipole (dashed line). All antennas are mounted 70 feet (1 λ) above flat ground. The rearward pattern of the terminated rhombic is good and the forward gain exceeds that of the Yagi, but the frontal lobe is very narrow. Above, elevation-plane pattern of terminated rhombic compared to that of a simple dipole at the same height.**

**Fig 26—Rhombic antenna dimensions for a compromise design between 14- and 28-MHz requirements, as discussed in the text. The leg length is 6 λ at 28 MHz, 3 λ at 14 MHz.**

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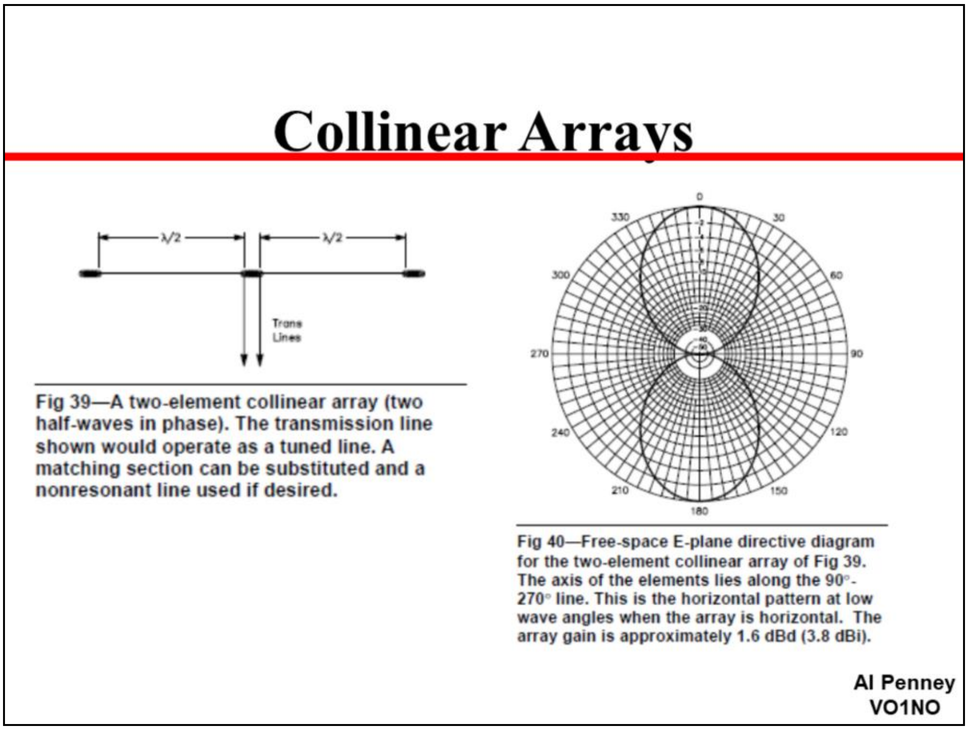

## Collinear Arrays

Fig 39—A two-element collinear array (two half-waves in phase). The transmission line shown would operate as a tuned line. A matching section can be substituted and a nonresonant line used if desired.

Fig 40—Free-space E-plane directive diagram for the two-element collinear array of Fig 39. The axis of the elements lies along the 90°-270° line. This is the horizontal pattern at low wave angles when the array is horizontal. The array gain is approximately 1.6 dBd (3.8 dBi).

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In telecommunications, a **collinear antenna array** is an array of dipole antennas mounted in such a manner that the corresponding elements of each antenna are parallel and collinear, that is they are located along a common line or axis.

Collinear arrays are always operated with the elements in phase. (If alternate elements in such an array are out of phase, the system simply becomes a harmonic type of antenna.) A collinear array is a

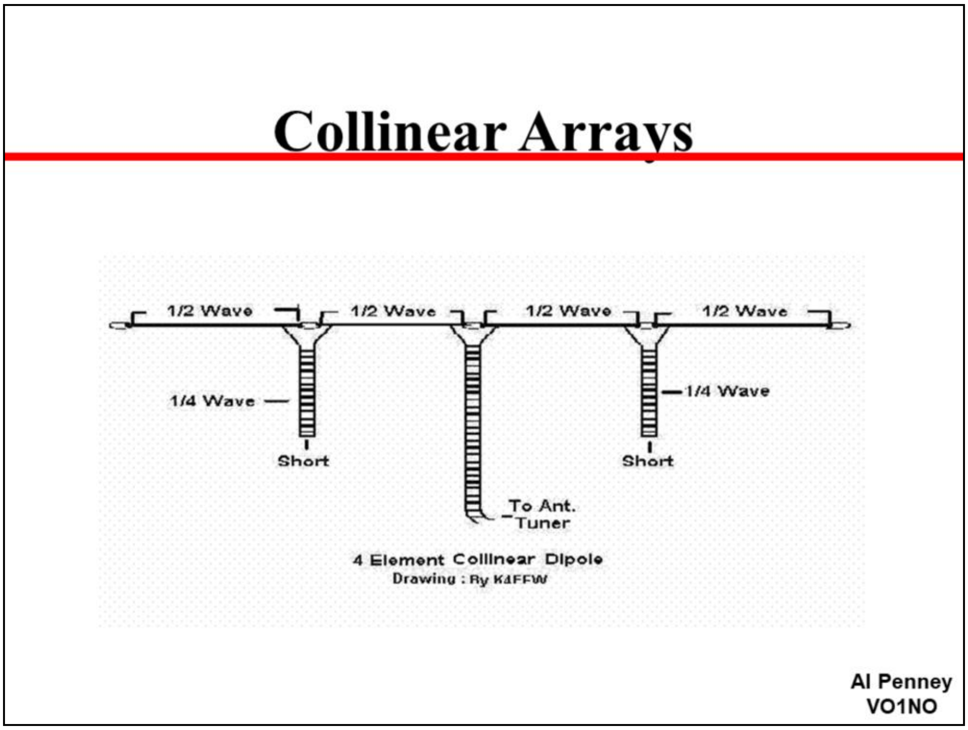
broadside radiator, the direction of maximum radiation being at right angles to the line of the antenna.

### TWO-ELEMENT ARRAY

The simplest and most popular collinear array is one using two elements, as shown in **Fig 39**. This system is commonly known as “two half-waves in phase.” The manner in which the desired current distribution is obtained is described in Chapter 26. The directive pattern in a plane containing the wire axis is shown in **Fig 40**.

Depending on the conductor size, height, and similar factors, the impedance at the feed point can be expected to be in the range from about 4 to 6 kΩ, for wire antennas. If the elements are made of tubing

having a low λ/dia (wavelength to diameter) ratio, values as low as 1 kΩ are representative. The system can be fed through an open-wire tuned line with negligible loss for ordinary line lengths, or a matching section may be used if desired.



Collinear Arrays

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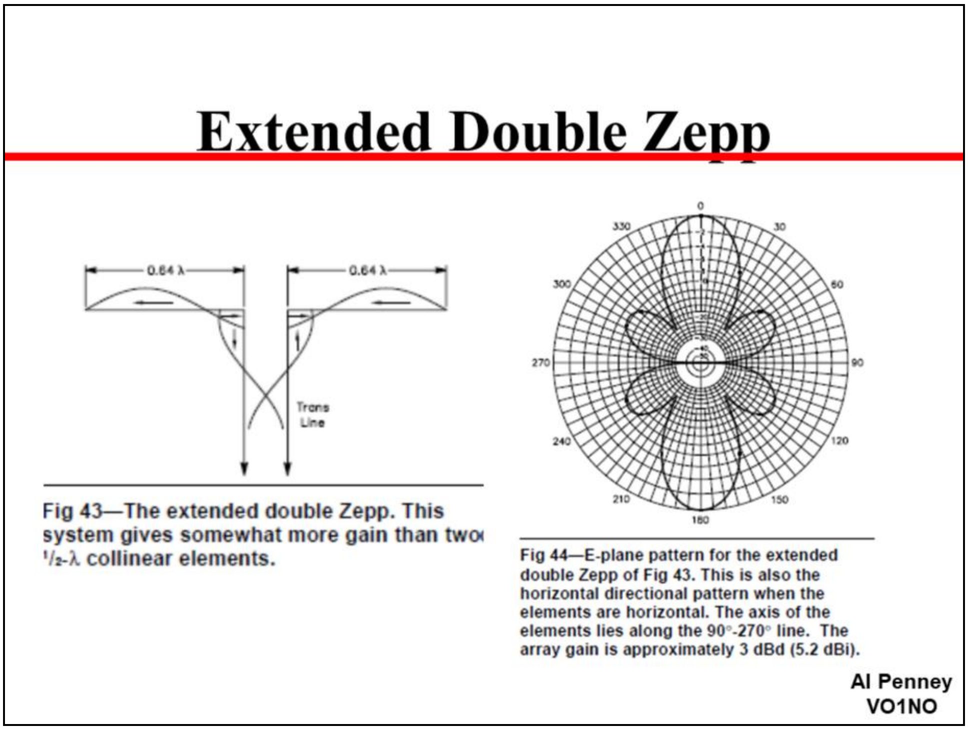
## THREE AND FOUR-ELEMENT ARRAYS

When more than two collinear elements are used it is necessary to connect "phasing" stubs between adjacent elements in order to bring the currents in all elements in phase. In a long wire the direction of

current flow reverses in each ½ wavelength section. Consequently, collinear elements cannot simply be connected end to end; there must be some means for making the current flow in the same direction in all elements. In **Fig 41A** the direction of current flow is correct in the two left-hand elements because the transmission line is connected between them. The phasing stub between the second and third elements makes the instantaneous current direction correct in the third element. This stub may be looked upon simply as the alternate ½ wavelength section of a long-wire antenna folded back on itself to cancel its radiation. In Fig 41A the part to the right of the transmission line has a total length of three half wavelengths, the center half wave being folded back to form a ¼ wavelength phase-reversing stub.



# Extended Double Zepp

Fig 43—The extended double Zepp. This system gives somewhat more gain than two ½-λ collinear elements.

Fig 44—E-plane pattern for the extended double Zepp of Fig 43. This is also the horizontal directional pattern when the elements are horizontal. The axis of the elements lies along the 90°-270° line. The array gain is approximately 3 dBd (5.2 dBi).

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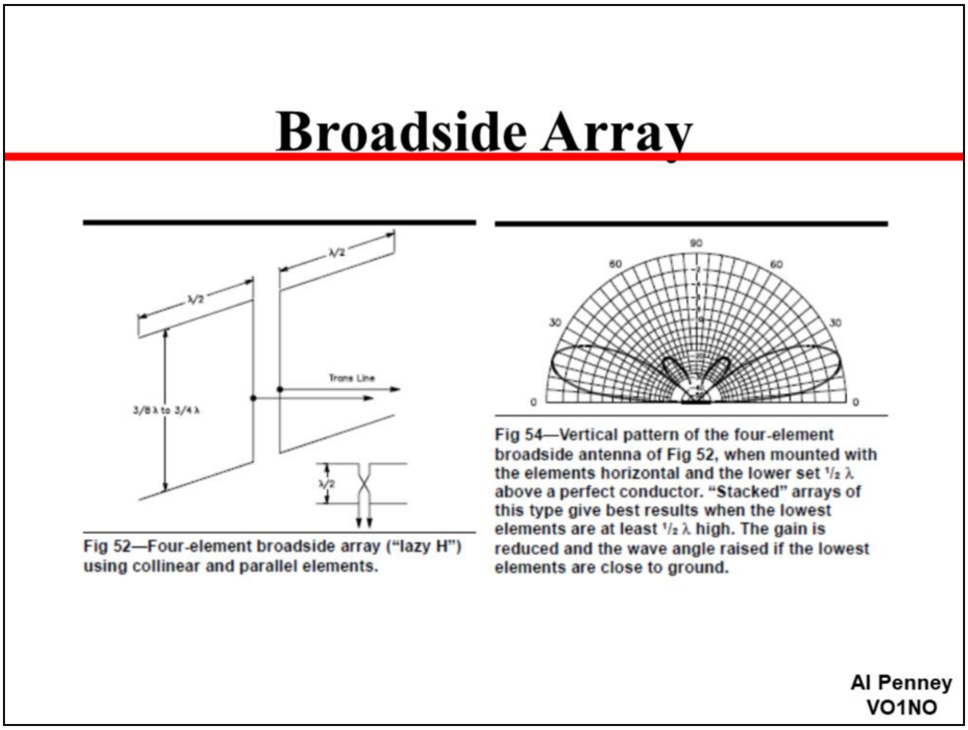
## THE EXTENDED DOUBLE ZEPP

An expedient that may be adopted to obtain the higher gain that goes with wider spacing in a simple system of two collinear elements is to make the elements somewhat longer than 1/2 ωλ. As shown in **Fig 43**, this increases the spacing between the two in-phase 1/2-λ sections at the ends of the wires. The section in the center carries a current of opposite phase, but if this section is short the current will be small; it represents only the outer ends of a 1/2-ωλ antenna section. Because of the small current and short length, the radiation from the center is small. The optimum length for each element is 0.64 wλ.

At greater lengths the system tends to act as a long-wire antenna, and the gain decreases. This system is known as the "extended double Zepp." The gain over a 1/2-wλ dipole is approximately 3 dBd,

as compared with approximately 1.6 dBd for two collinear 1/2-wλ dipoles. The directional pattern in the plane containing the axis of the antenna is shown in **Fig 44**. As in the case of all other collinear arrays, the free-space pattern in the plane at right angles to the antenna elements is the same as that of a 1/2-wλ antenna—circular.



## Broadside Array

Fig 52—Four-element broadside array ("lazy H") using collinear and parallel elements.

Fig 54—Vertical pattern of the four-element broadside antenna of Fig 52, when mounted with the elements horizontal and the lower set ½ λ above a perfect conductor. "Stacked" arrays of this type give best results when the lowest elements are at least ½ λ high. The gain is reduced and the wave angle raised if the lowest elements are close to ground.

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### FOUR-ELEMENT BROADSIDE ARRAY

The four-element array shown in **Fig 52** is commonly known as the "lazy H." It consists of a set of two collinear elements and a set of two parallel elements, all operated in phase to give broadside

directivity. The gain and directivity will depend on the spacing, as in the case of a simple parallel element broadside array. The spacing may be chosen between the limits shown on the drawing, but

spacings below 3/8 λ are not worthwhile because the gain is small. Estimated gains are as follows

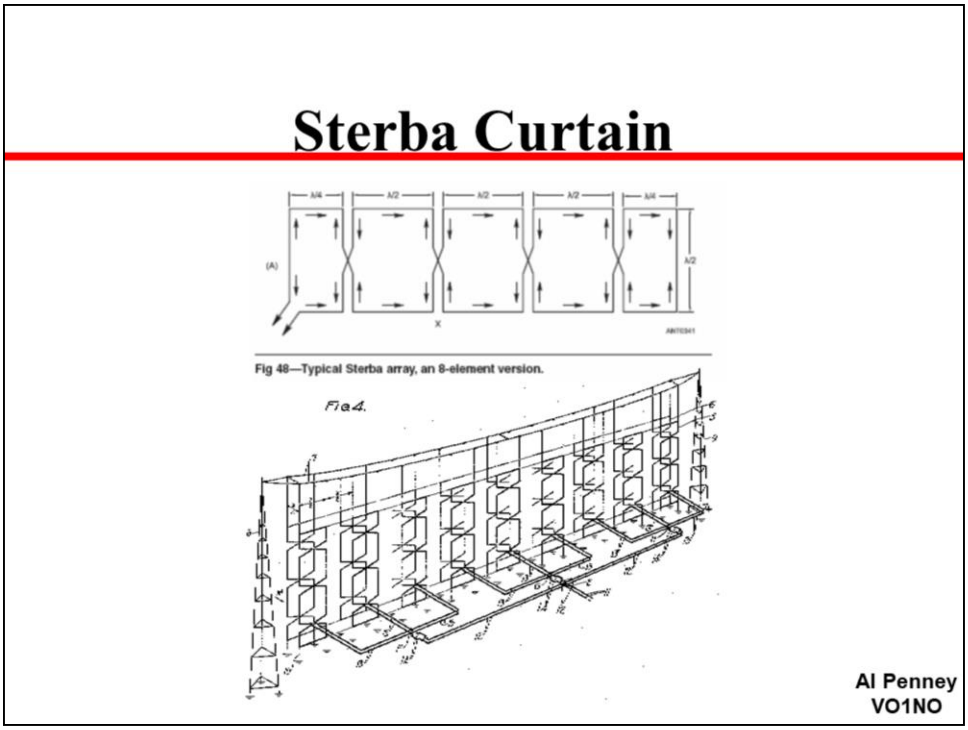
3/8-λ spacing—4.4 dBd (6.6 dBi)

1/2-λ spacing—5.9 dBd (8.1 dBi)

5/8-λ spacing—6.7 dBd (8.9 dBi)

3/4-λ spacing—6.6 dBd (8.8 dBi)

Half-wave spacing is generally used.



# Sterba Curtain

Fig 48—Typical Sterba array, an 8-element version.

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The Sterba array, shown at A in **Fig 61**, is a broadside radiator consisting of both collinear and parallel elements with 1/2-λ spacing between the latter. Its distinctive feature is the

method of closing the ends of the system. For direct current and low-frequency ac, the system forms a closed loop, which is advantageous in that heating currents can be sent through the wires to melt the

ice that forms in cold climates. There is comparatively little radiation from the vertical connecting wires at the ends because the currents are relatively small and are flowing in opposite directions with

respect to the center (the voltage loops are marked with dots in this drawing).

The system obviously can be extended as far as desired. The approximate gain is the sum of the gains of one set of collinear elements and one set of broadside elements, counting the two 1/4-λ

sections at the ends as one element. The antenna shown, for example, is about equivalent to one set of four collinear elements and one set of two

parallel broadside elements, so the total gain is approximately 4.3 + 4.0 = 8.3 dBd. Horizontal polarization is the only practicable type at the lower frequencies, and the lower set of

elements should be at least 1/ 2 wλ above ground for best results.

When fed at the point shown, the impedance is of the order of 600 Ω. Alternatively, this point can be closed and the system fed between any two elements, as at X.

In this case a point near the center should be chosen so the power distribution among the elements will be as uniform as possible. The impedance at any such point will be 1 kΩ or less in systems with six or more elements.

Three bay Sterba Curtain for 6m

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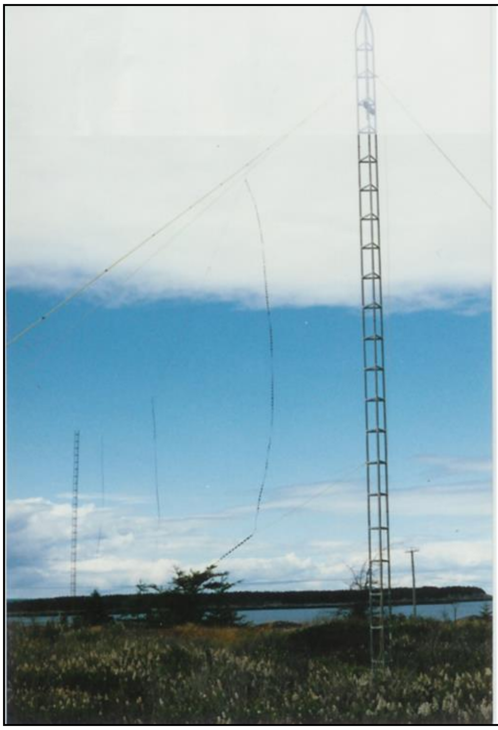

Three-bay Sterba Curtain for 40m, Whitehead Island, Bay of Fundy

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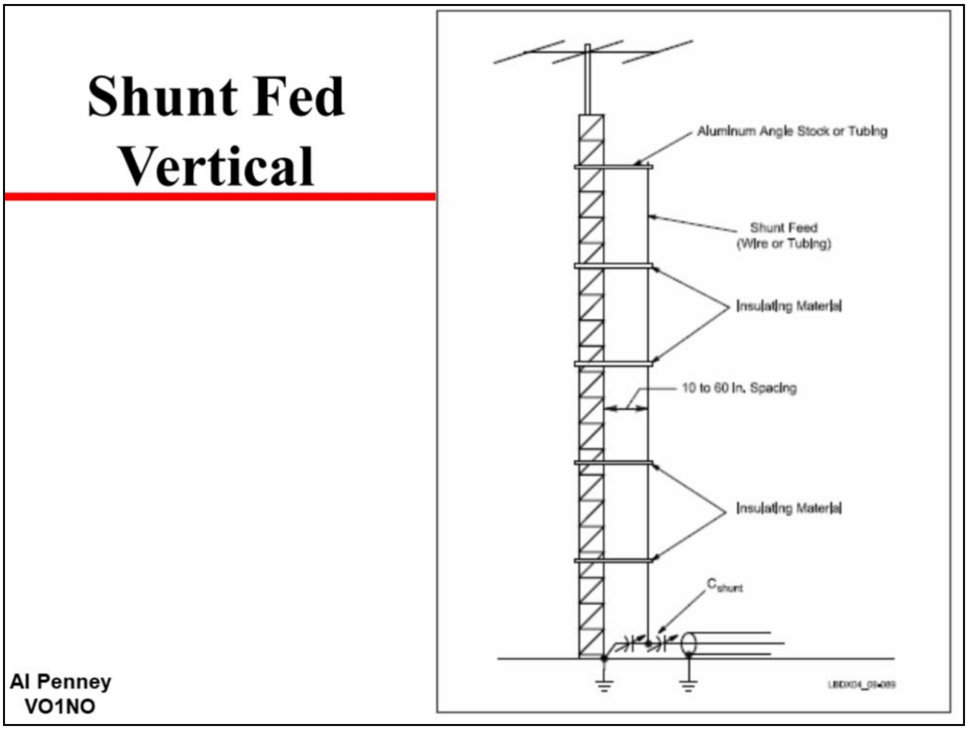

# Shunt Fed Vertical

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A tower can be used as a vertical antenna, provided that a good ground system is available. The shunt-fed tower is at its best on 1.8 MHz, where a full λ/4 vertical antenna is rarely possible. Almost any

tower height can be used. If the beam structure provides some top loading, so much the better, but anything can be made to radiate—if it is fed properly. W5RTQ uses a self-supporting, aluminum, crank-up,

tilt-over tower, with a TH6DXX tribander mounted at 70 feet. Measurements showed that the entire structure has about the same properties as a 125-foot vertical. It thus works quite well as an antenna on

1.8 and 3.5 MHz for DX work requiring low-angle radiation.

Gamma match – one capacitor

Omega Match – two capacitors

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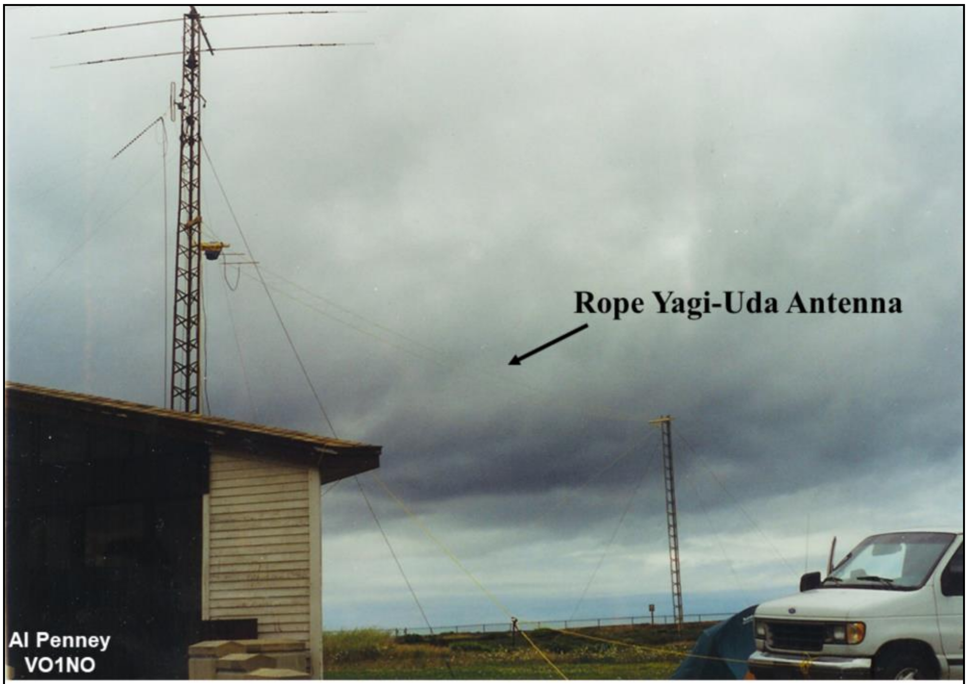
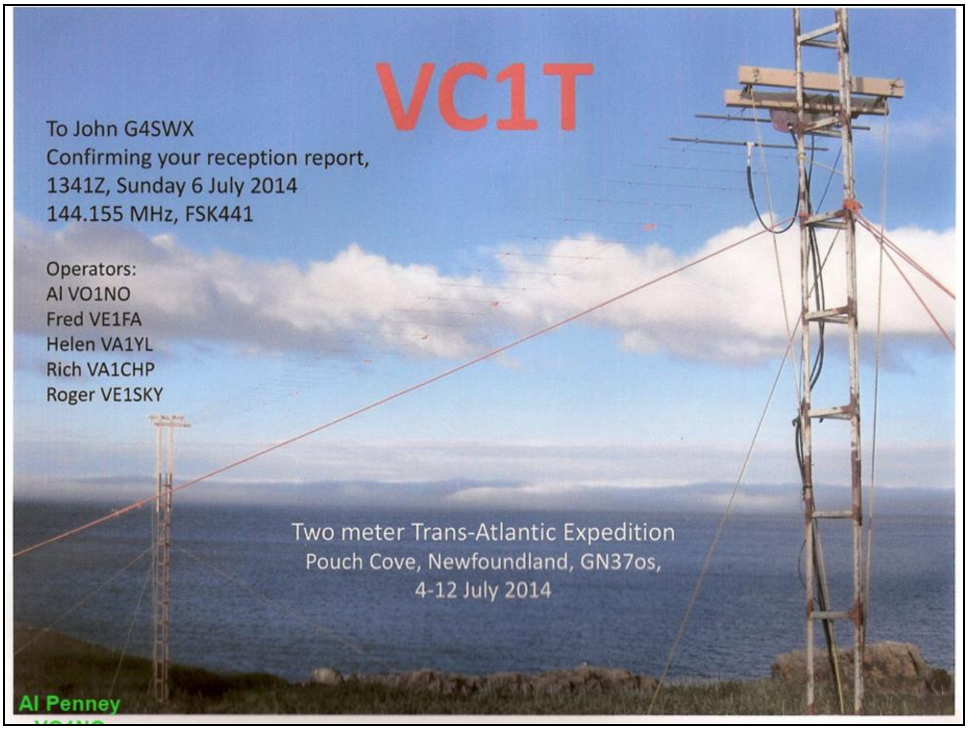
VO1NO

**Al Penney**
**VO1NO**



2m Trans-Atlantic attempt, Marconi National Historic Site, Nova Scotia



# VC1T

To John G4SWX
Confirming your reception report,
1341Z, Sunday 6 July 2014
144.155 MHz, FSK441

Operators:
Al VO1NO
Fred VE1FA
Helen VA1YL
Rich VA1CHP
Roger VE1SKY

Two meter Trans-Atlantic Expedition
Pouch Cove, Newfoundland, GN37os,
4-12 July 2014

Al Penney

# Practical Antenna Construction

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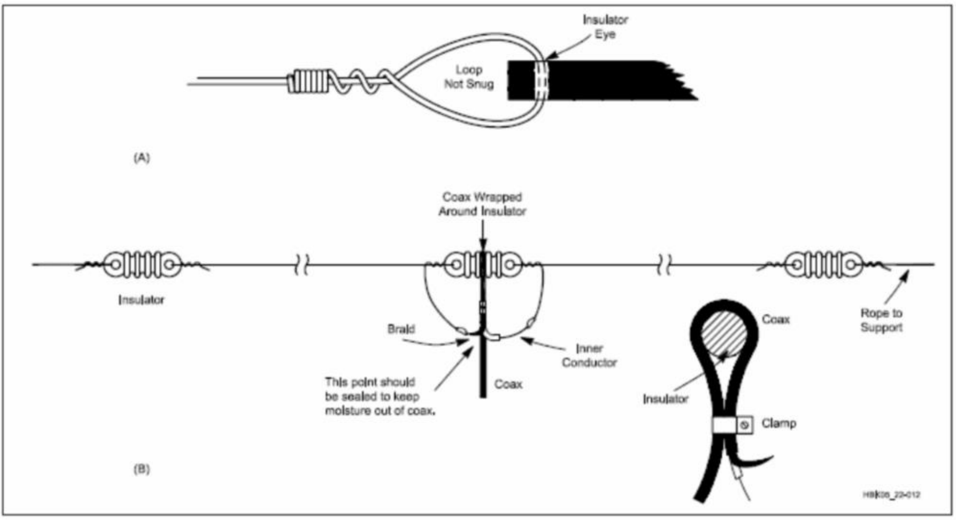

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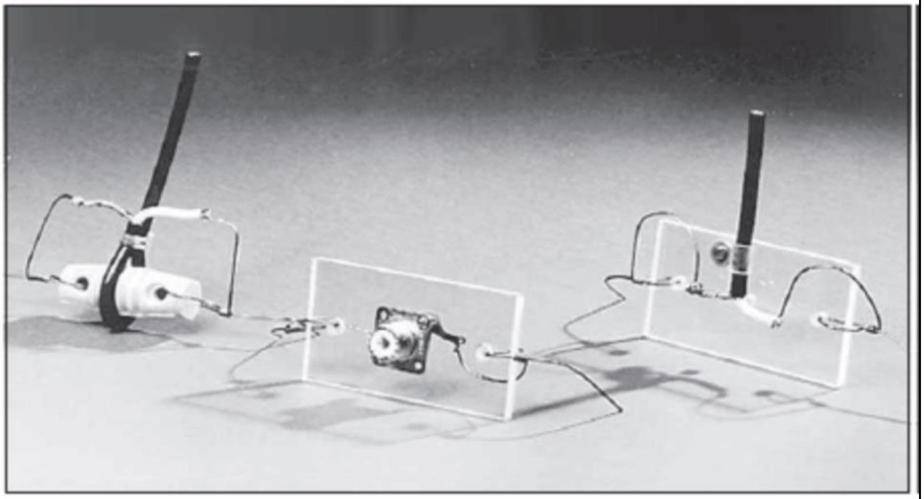

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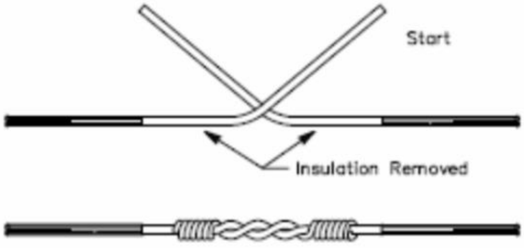

Fig 3—Correct method of splicing antenna wire. Solder should be flowed into the wraps after the connection is completed. After cooling, the joint should be sprayed with acrylic to prevent oxidation and corrosion.

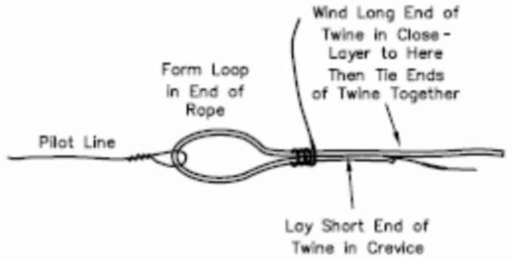

**Fig 2—In connecting the halyard to the pilot line, a large knot that might snag in the crotch of a tree should be avoided, as shown.**

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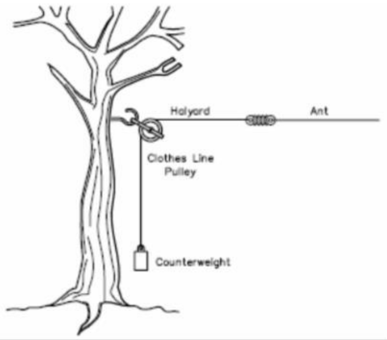

Fig 1—A method of counter weighting to minimize antenna movement and avoid its breaking from tree movement in the wind. The antenna may be lowered without climbing the tree by removing the counterweight and tying additional rope at the bottom end of the halyard. Excess rope may be left at the counterweight for this purpose, as the knot at the lower end of the halyard will not pass through the pulley.

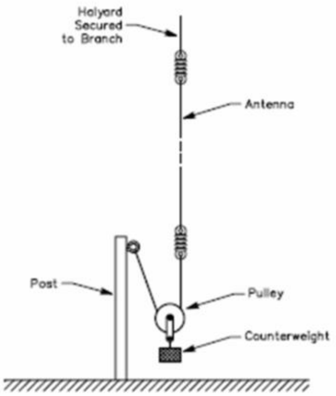

Fig 5—Counterweight for a vertical antenna suspended from an overhanging tree branch.

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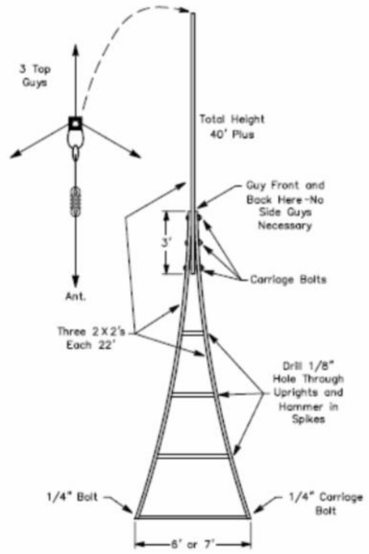

Fig 7—The A-frame mast is lightweight and easily constructed and erected.

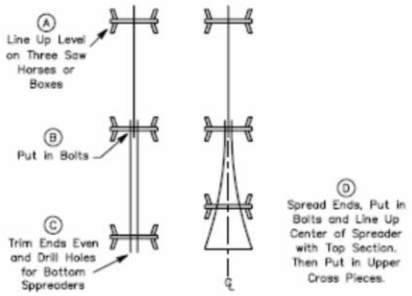

Fig 8—Method of assembling the A-frame mast on sawhorses.

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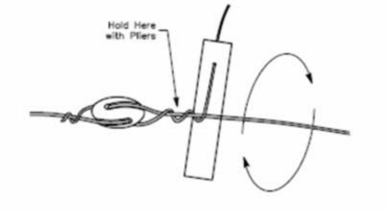

Fig 9—Simple lever for twisting solid guy wires when attaching strain insulators.

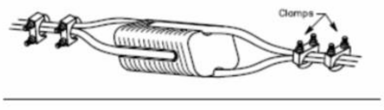

Fig 10—Stranded guy wire should be attached to strain insulators by means of standard cable clamps made to fit the size of wire used.

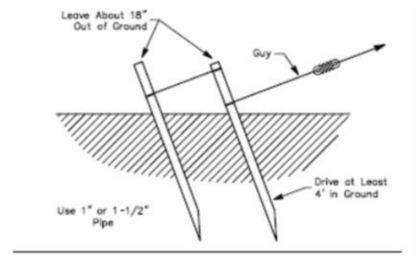

Fig 11—Driven guy anchors. One pipe is usually sufficient for a small mast. For added strength, a second pipe may be added, as shown.

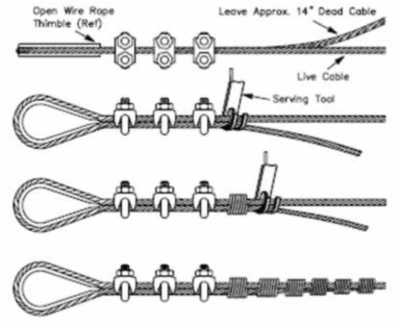

Fig 25—Traditional method for securing the end of a guy wire.

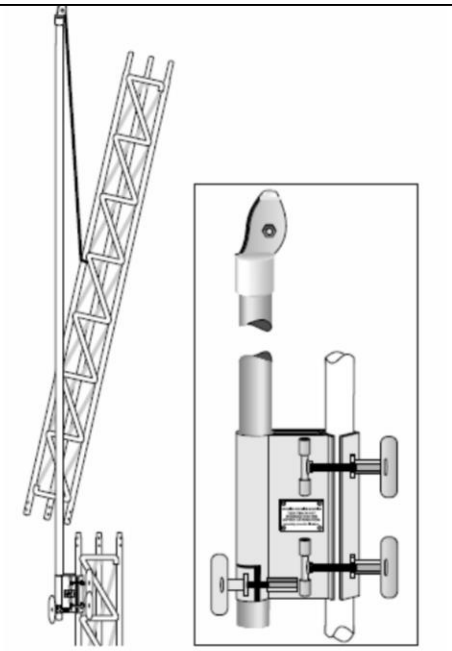

Fig 21—Drawing of Rohn “Erection Fixture” EF2545, also known commonly as a “gin pole.”

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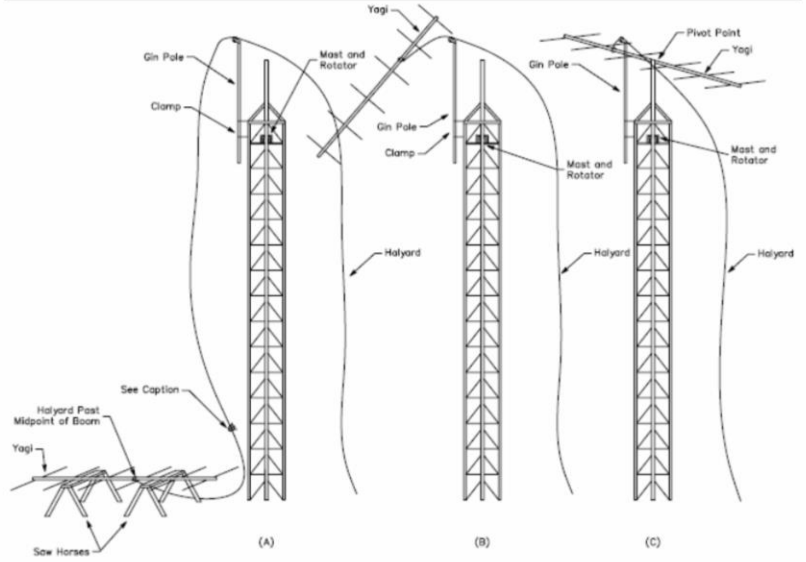

**Fig 33—Raising a Yagi antenna alongside the tower. At A the Yagi is placed in a clear area, with the boom pointing toward the tower. The halyard is passed under the elements, then is secured to the boom beyond the midpoint. B shows the antenna approaching the top of the mast. The person on the tower guides it after the lifting rope has been untied from the front of the antenna. At C the antenna is pulled into a horizontal position by the ground crew. The tower worker inserts the pivot bolt and secures it. Note: A short piece of rope is tied around the halyard and the boom at the front of the antenna to stabilize the beam as it is being raised. The tower worker removes it when the boom reaches him at the top of the tower.**

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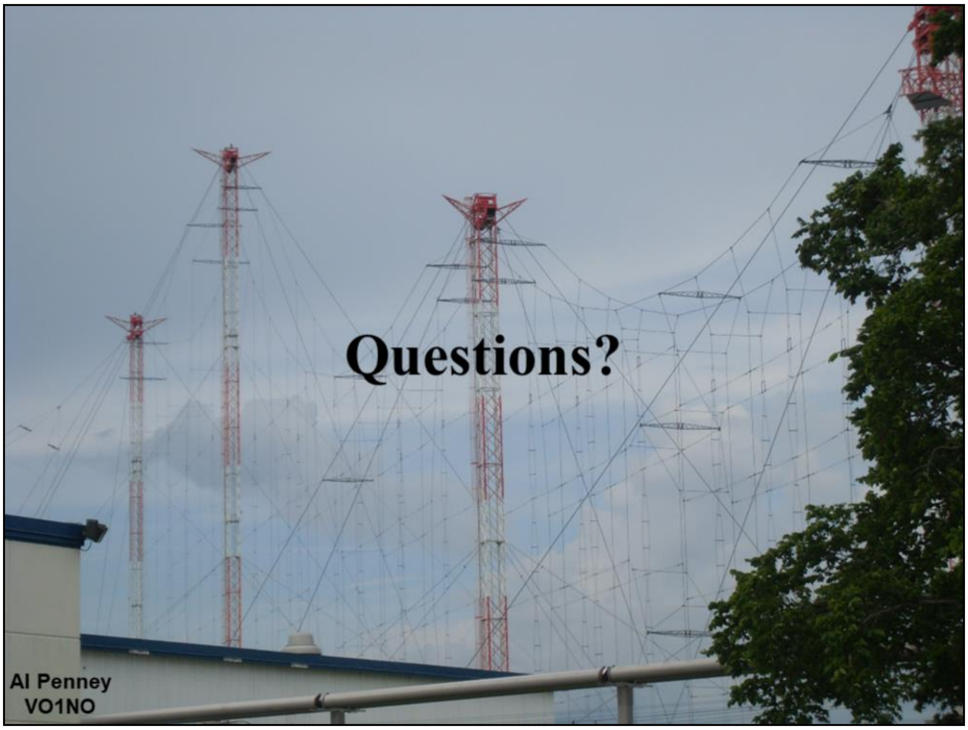

## Questions?

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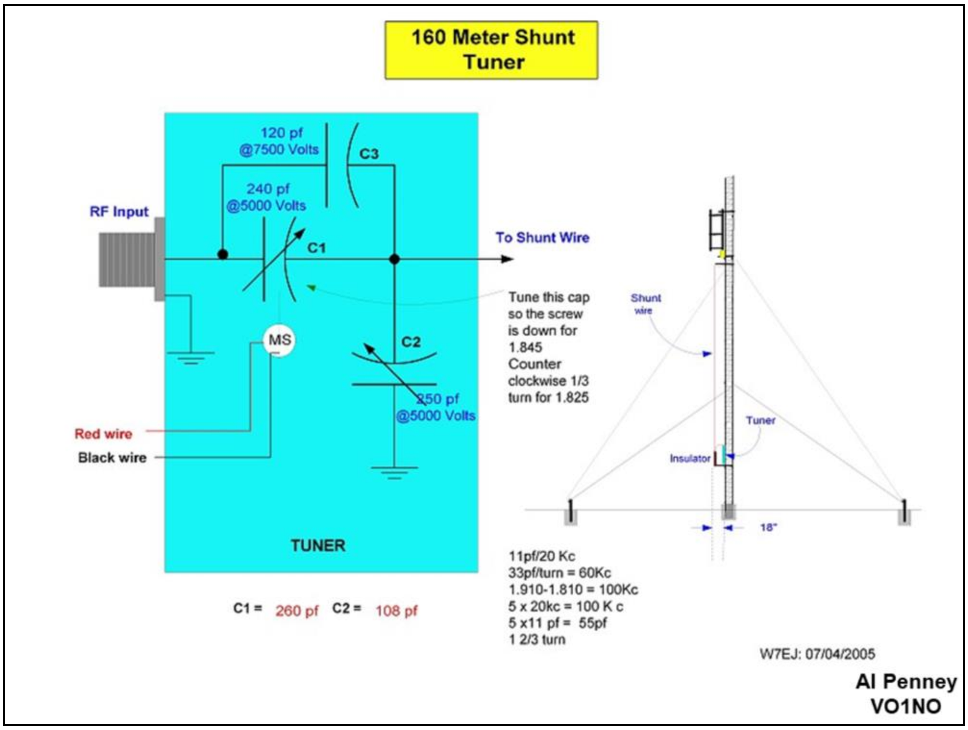

## 160 Meter Shunt Tuner

Tune this cap so the screw is down for 1.845 Counter clockwise 1/3 turn for 1.825

C1 = 260 pf C2 = 108 pf

11pf/20 Kc
33pf/turn = 60Kc
1.910-1.810 = 100Kc
5 x 20kc = 100 K c
5 x11 pf = 55pf
1 2/3 turn

W7EJ: 07/04/2005

**Al Penney
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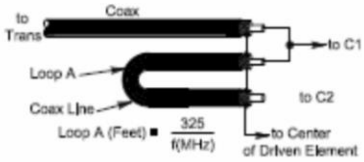
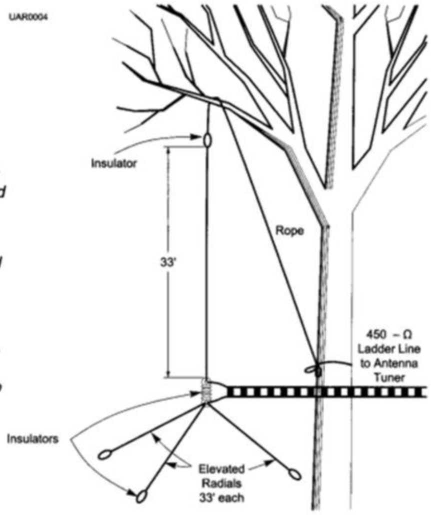


4; 1 Coax Balun

*Figure 18 — The W1AB Killer Antenna is an elevated ground plane sized as a 40-meter antenna, but fed with ladder line and an antenna tuner for use on all HF bands and 160 meters. The radials for the elevated counterpoise are 6 to 10 feet above the ground, and are not connected to earth ground. For low-profile use, you can run the 33-foot vertical wire up the side of the tree.*



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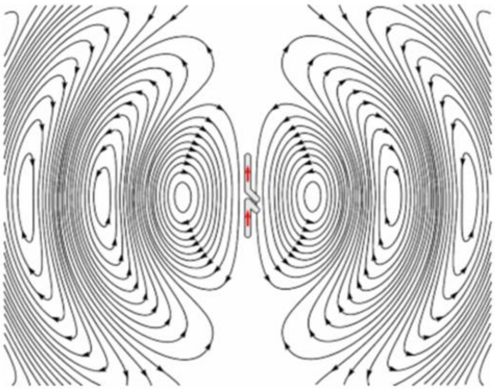
**VO1NO**



Electric field of a half-wave dipole transmitting antenna.