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Let's Talk About Antennas
Part One of Three

What is an Antenna?

They were once known as "aerials," some folks call them "sky wires," they've even been called "antlers," or "signal grabbers," but we all know what we mean when we say "antennas."

Or do we? To be sure, let's begin with a definition of the term "antenna." Basically, an antenna is a device for launching or capturing electromagnetic (EM) waves. EM waves are also called "radio waves," and they are the waves which carry radio broadcasting, television signals, shortwave broadcasting, ham radio signals, radar, radio-teletype, and all other kinds of communications that utilize EM waves for communication.

A radio transmitter, connected to an antenna and then energized, will cause radio-frequency (RF) current to flow in that antenna. When RF current flows in an antenna, this causes EM waves to travel (propagate) outward from the antenna. And, if communication is to be had, somewhere in their travel away from the antenna some of the waves must encounter another antenna.

These incoming waves induce radio-frequency current into any antenna which they encounter. This current is then routed to a receiver and the modulation (music, voice, telegraphy, etc) that was contained in the EM waves is detected by the receiver and made available for our use.

If you are concerned with reliable communication, communicating even when there is interfering noise or signals, or working with weak signals, then it is quite important to select an antenna that will support your communications application. Let's look now at some of the characteristics of antennas that are useful in selecting an antenna.

As you read the following discussions, keep in mind an important characteristic of antennas that is called "reciprocity." Reciprocity means that characteristics of an antenna remain the same whether the antenna is transmitting or receiving. Thus, factors which we will discuss in this series – such as gain and radiation patterns – are the same for an antenna, whether it is transmitting or receiving.

Gain not the most important criterion

Probably the antenna characteristic that many antenna users first think of as important in choosing an antenna is the antenna's gain. A simple definition of gain is an antenna's relative output of radio-frequency current when energized by a passing wave. The higher the gain, the more current the antenna will produce from the wave.

Actually, for most applications, securing a high value of antenna gain is not only unnecessary, it adds to the complexity and cost of an antenna, and in some cases may even cause receiver overload and signal degradation. As we'll discuss later, a large portion of today's radio communication is reliably supported by antennas with modest or even low values of gain.

It's all relative...

To understand the relative value of antenna gain, we must first discuss the effect of electrical noise on reception. Consider that there are electrical noise signals (static, electrical noise incidentally generated by various electrical devices, interfering radio signals) received by the antenna in the same way that it receives the desired signal. In addition, a different kind of electrical noise is produced within the circuitry of your receiver. This is the hissing or rushing sound you hear when the antenna is disconnected and the RF and audio gain are set high, with the squelch control turned off.

A major concern for reception is that any electrical noise, received or produced by the receiver, needs to not be so strong as to mask the reception of the desired signal. When the strength of the desired signal is considerably above the strength of overall noise, reception is usually good.

A measure of the relationship of the strength of the desired-signal strength to the electrical-noise strength is called the "signal-to-noise-ratio," or "S/N." As you can guess, a high S/N leads to good reception and a small value of S/N leads to poor or no useful reception (figs. 1A, 1B& 1C).

What Has That to Do with Antennas?

Obviously, an antenna must have enough gain to produce sufficient signal strength from the desired signal that the receiver output can drive the speaker, video display, or whatever device is used to present that output. Note, however, that many antennas with low or even very-low gain characteristics are capable of producing satisfactory levels of signal strength, and are very useful for a wide variety of applications.

For example, the Beverage antenna and the small table-top loop antennas have much less gain than a half-wave dipole antenna, and yet these antennas can produce good reception of some signals that would be unintelligible due to being buried in noise and/or interference if a dipole antenna were used. We'll see next month what part radiation patterns play in this.

Still, in terms of gain levels the quarter-wavelength ground plane antenna is a relatively-low gain antenna, and yet it is one of the most useful antennas designs that we have. The fact is, *the major factor determining quality of reception is not the received strength or transmitted*

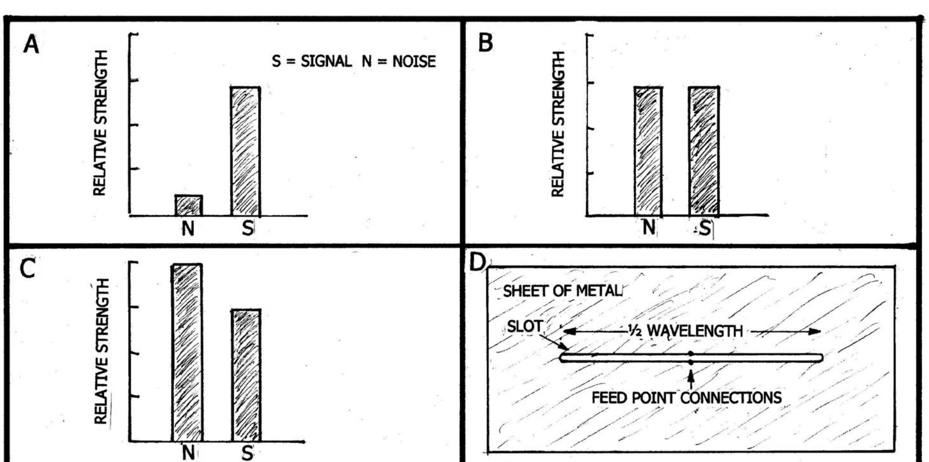

Fig. 1. (A) A low noise level with significantly-higher signal level. This produces good reception. (b) The same signal level as in A, but the noise level is as high as the signal level. Reception is difficult to impossible, depending on the technology used. (c) The signal level is still the same as in A; however, the noise level is now significantly higher than the signal level. This produces no useful reception. (d) A slot antenna.

RADIO RIDDLES

Last Month:

I asked: "Let's say that we have cut a narrow strip a half wavelength long from the center of a large sheet of metal. We could use that metal strip as a half-wavelength antenna. But how about the hole (slot) left in the metal where the strip was removed? A hole is full of nothing, right? Still, it's a half-wavelength long like the strip we removed, so can we then also use the slot as an antenna?"

Well, the answer is "yes." By connecting a feed line to the sides of the slot, we make a half-wavelength slot antenna (fig. 1D). Because they offer no wind resistance, dielectric-filled slot antennas are often employed in the metal skin of aircraft. The slot antenna is said to be "complementary" to an ordinary, half-wavelength dipole made of a metal strip, tube, or wire. One "complementary" factor is that polarization is reversed between the two antennas: a horizontal wire dipole yields horizontal polarization, while a horizontal slot yields vertical polarization.

This Month:

Once there was a very poor train conductor. He seldom had even one dollar in his pocket because he gambled away most of the salary the railway line paid him for collecting tickets from their passengers. He was so poor, hungry, and unhappy that he saw no reason to go on living, and so he decided to kill himself. He thought electrocution would be a good way to leave this world, so he broke into a powerful radio station and placed his hands directly across the high-voltage, output terminals in the radio-frequency power-amplifier stage of the station's 500,000 watt transmitter. However, he was not hurt at all: he received only a tiny shock. Why?

You'll find an answer to this month's riddle, another riddle, another antenna-related web site or so, and much more, in next month's issue of *Monitoring Times*. 'Til then, Peace, DX, and 73.

strength of the desired signal. Rather it is the *relative strength* of that desired signal as compared to the strength of any other electrical noise or interfering signals present at the receiver's early stages (RF amplifier, mixer).

When selecting and installing an antenna system where noise level is a problem, there is much we can do to reduce the amount of noise and interference with which the desired signal must compete.

Next Month:

Next month we'll talk about noise reduction, noise-level variation across the different frequency bands, useful antenna gain, ways to improve poor reception by improving the S/N, and some other important antenna characteristics.

MT READERS ONLY

To access the restricted website for the month of September, go to www.monitoring-times.com, click on the key, and when prompted, enter "mtreader" under the user name. Your password for September is "grayline" – Check in each month for new material!

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Let's Talk About Antennas
Part Two of Three

Last month, in discussing the effect of received noise on reception, we found that, in general, the higher the strength of a desired signal in relation to the strength of the received-noise (signal-to-noise ratio, or S/N) the better the reception. So this month we consider how to increase the S/N by our choice of antenna, and how we install our antenna system. We'll also introduce the idea of antenna radiation patterns, and their effect on wave propagation and reception. We'll also continue our examination of the value of antenna gain in radio communication.

As you read the discussion below, don't forget to keep in mind the reciprocity principle: characteristics of an antenna, including gain and radiation patterns, remain the same whether the antenna is used for transmitting or receiving.

❖ Reducing Received Noise:

Proximity:

Electrical noise is more intense close to its source. Noise fields, such as those common around electrical machinery and many other electrical devices, can be detected with a portable receiver. Once located, you can then locate your antenna away from noisy areas. Also avoid running antenna lead-in cable through such fields. Coaxial cable shields the signal it carries. So, if for practical reasons it is necessary to run the lead-in through the noise field, use coaxial-cable lead-in.

Polarization:

Signals and antennas both have a characteristic "polarization." Antennas with horizontal elements usually have horizontally-oriented electrical fields, and thus produce horizontal polarization. For reception, they also respond best to signals with horizontal polarization. Vertical antennas generally produce vertically-polarized signals, and respond best to signals with vertical polarization.

Electrical noise tends to be vertically polarized. Thus, horizontally-polarized antennas generally capture less electrical noise than do vertically-polarized antennas. Television broadcast stations in the USA transmit horizontally-polarized signals for this reason.

Radiation Patterns:

Antenna response, both in transmitting and receiving, is generally not distributed evenly in space. Even the so-called non-directional antennas have at least some unevenness in how they respond in different compass directions and at different vertical angles. By appropriate design, we can produce antennas which have very significant differences in how they respond in different compass directions (horizontal radiation patterns, fig. 1A) or at different vertical angles (vertical radiation patterns, fig. 1B).

The compass directions or the vertical angles at which an antenna directs a major part of its functioning are called "lobes" (fig. 1A, and fig. 1B). Compass directions or vertical angles where minimal responding is directed are called "nulls" (fig. 1A, and fig. 1B).

Antennas that have very sharp nulls in their horizontal radiation patterns can often be oriented such that problematic noise signals arriving at the antenna arrive at a position on the pattern where there is a null. Thus, the strength of the noise can be reduced or eliminated. Small table-top loops have such nulls and are useful for medium-wave reception where they can be rotated to orient their sharp nulls toward the direction of arrival of interference. The Beverage or wave antenna has both sharp lobes and sharp nulls. It is useful for reducing interference using the nulls and emphasizing the desired signal via the main lobe in medium and low frequency receiving.

The small loops and Beverage antennas just mentioned both have low gain. However, given their reduction of noise and consequently improved S/N, they can sometimes provide good reception when other, higher-gain antennas with less-discriminating radiation patterns cannot support useful reception.

Vertical-angle radiation patterns are also important in both transmitting and receiving. In the HF and MF bands the vertical-radiation angle can determine whether the waves launched are more likely to propagate to far-away places or to locations closer in the transmitting antenna.

For reception on these same bands, the complement of this is true: the vertical-radiation pattern of the antenna determines whether it responds maximally to high-angle waves from closer-in stations, or more to lower-angle signals from more distant stations. For VHF and higher frequencies, low-vertical angles are usually desirable, allowing signals to reach as far toward the horizon as possible, or even a bit beyond.

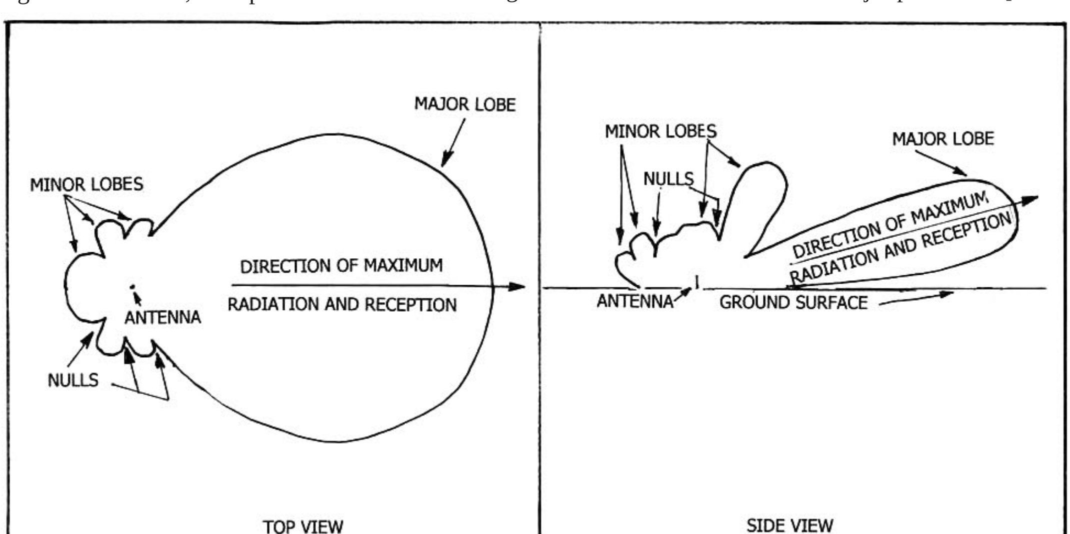

Fig. 1. THE HORIZONTAL-RADIATION PATTERN FOR A CERTAIN BEAM ANTENNA (A), AND THE VERTICAL RADIATION PATTERN FOR THE SAME ANTENNA (B)

❖ Antenna Gain Can be Useful

Earlier we discussed why high antenna-gain levels are often not necessarily useful or even desirable. But in some situations, having high antenna gain is important. When received-noise level is low, then antenna gain can often bring a weak signal level up to provide good reception. Note that

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this refers to "weak" signal reception. For strong signals, the S/N will be favorable without need for extra antenna gain.

To understand the "why" of the last paragraph, consider that when received noise is low, then the noise generated within the circuits of the receiver itself becomes the dominant noise that interferes (competes) with the desired signal. So, in a low received-noise situation, the received-noise level increase due to antenna gain is inconsequential compared to the noise from the receiver's circuits. So, with increased antenna gain, the increased strength of the desired signal yields an increased S/N, and reception improves.

Received-noise levels tend to decrease as frequency increases. So we find that antenna gain often becomes useful for weak-signal reception at frequencies above 10 MHz or so, depending on conditions at your location. Antenna gain is almost always useful for improving weak-signal reception at VHF and higher frequencies.

When an antenna is used for transmitting, the more gain it has in the direction of the distant station with which it is communicating, the more signal it puts into that distant antenna. For the transmitting antenna, noise is not a concern, so gain in a transmitting antenna – for any frequency – generally leads to an improved S/N at the receiving antenna. In addition, if antenna gain is increased, then the amount of transmitted power required for successful communication is reduced.

Next Month

In our last segment, we'll consider some other factors important in selecting an antenna for your application and for getting good performance from the antenna once it is in operation.

RADIO RIDDLES

Last Month:

I wrote: "Once there was a very poor train conductor. He seldom had even one dollar in his pocket because he gambled away most of the salary the railway line paid him for collecting tickets from their passengers. He was so poor, hungry, and unhappy that he saw no reason to go on living, and so he decided to kill himself.

"He thought electrocution would be a good way to leave this world, and so he broke into a powerful radio station, and placed his hands directly across the high-voltage, output terminals in the radio-frequency power-amplifier stage of the station's 500,000 watt transmitter. However, he was not hurt at all: he received only a tiny shock. Why?"

Well, electrical current will flow only through a conductor. The better the conductor, the more current will flow. In a poor conductor less current will flow. So, because he was such a poor conductor, only a tiny amount of electrical current could flow through him. [*All together now: Groan - ed.*]

This Month:

Since the unhappy man in last month's riddle performed so poorly as a conductor, perhaps his title should be changed from "conductor" to something different. But what?

You'll find an answer to this month's riddle, another riddle, another antenna-related web site or so, and much more, in next month's issue of *Monitoring Times*. 'Til then Peace, DX, and 73.

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Let's Talk About Antennas
Part Three of Three

In this three-part series, the first two parts covered a definition of the term "antenna," why increasing antenna gain is only sometimes useful, the meaning of signal-to-noise ratio (S/N), the effect of received noise and of receiver noise on reception, antenna radiation patterns, and ways to reduce noise for improving weak-signal reception.

This month we finish the series by considering some effects on communication of both vertical and horizontal radiation patterns, and the effect of antenna height above earth on vertical-radiation patterns.

As mentioned in the other parts of this series, it is always good to keep in mind the reciprocity principle: characteristics of an antenna including gain and radiation patterns remain the same, whether the antenna is used for transmitting or for receiving.

❖ Utilizing Antenna Radiation Patterns

Last month we discussed the value of radiation-patterns for attenuating (nulls), or maximizing (lobes) an antenna's responding. Now let's consider how we can design and orient an antenna system to take advantage of some factors in the way that signals travel from transmitting antenna to receiving antenna (signal propagation).

At VHF and higher:

At VHF and higher frequencies we generally want our signals to leave the transmitting antenna at low-vertical angles (fig. 1B), and thus travel relatively parallel to the earth, or at least not at high angles. Signals at low angles will propagate toward, and go somewhat beyond the horizon. Thus we typically want antennas with low-angle, vertical-radiation patterns for VHF and higher frequencies.

Of course, communications with aircraft, space craft, and satellites require higher vertical-angle patterns. Vertically-polarized antennas such as ground planes and discones are useful at these frequencies for their non-directional, low vertical-angle performance.

Higher-gain vertical antennas give a lower vertical-angle radiation pattern than do the lower-gain ones. Beam antennas offer both lower-angle radiation as well as increased gain.

For Shortwave:

For shortwave (the HF band) and even medium-wave signals, short-range, local communications are often supported by ground waves from antennas with low vertical-angle radiation (fig. 1A). Vertical antennas are best for this ground-wave work.

For another kind of close-in communication using horizontal antennas at these frequencies, see NVIS propagation later in this discussion.

For longer-range (DX) communication on these bands, low vertical-angle radiation is also desirable, but here the waves leave the antenna at a low angle, travel to the ionosphere, and refract there, and return to earth far from the transmitting antenna (fig. 1A). Sometimes there are several of these "skips" or "hops," so that the signals reach far beyond the horizon, even completely around the world when conditions are right for it. Both vertical and horizontally-oriented antennas are useful here.

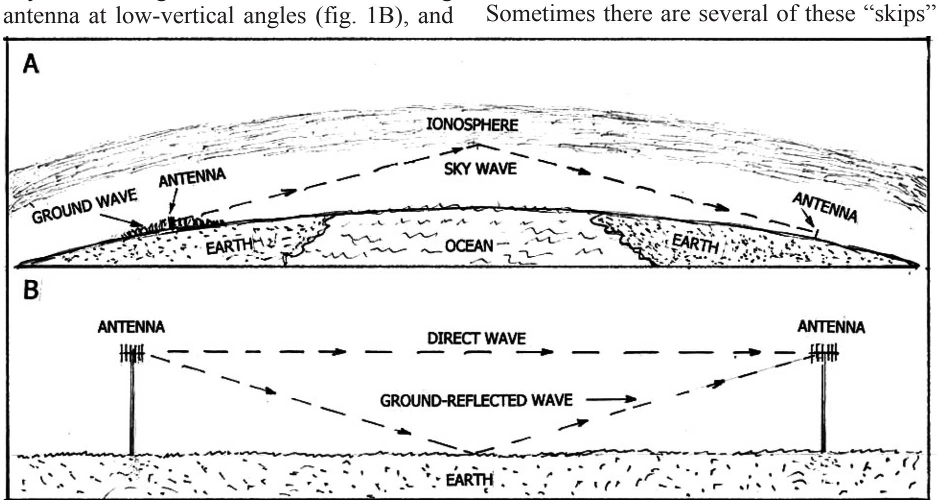

Fig. 1. HIGH-FREQUENCY ANTENNAS SHOWING GROUND WAVES, AND SKY WAVES (A), UHF ANTENNAS COMMUNCATING VIA A COMBINATION OF DIRECT WAVES, AND GROUND-REFLECTED WAVES (B).

Lower Medium Frequencies and Below:

For the lower medium frequencies and the bands below that, communication is almost always by ground waves. Here, various vertical antenna designs with low vertical-angle radiation patterns are the antennas of choice for transmitting. Ferrite-core loop antennas, air-wound loops, active antennas, Beverage (wave), and even random-length wire antennas are common choices for reception at these frequencies.

❖ Effect of Height above Ground

Generally speaking, the higher an antenna is mounted, the better it performs. However, there may be certain heights at which an antenna will perform maximally or minimally. At VHF and higher frequencies, antennas are often several wavelengths above the earth.

Often a combination of direct and ground-reflected waves (fig. 1B) from the same transmitting antenna will arrive together at the receiving antenna and combine there to produce the received signal. Varying the antenna's height above ground will vary the distance travelled by the wave reflected up to the antenna from the ground. Varying this distance varies the phase of that wave when it arrives at the antenna.

When the phases of the direct and ground reflected waves are the same, the waves add together to give maximum reception. When the phases of the two waves are different, there is less output from the antenna. So, there are best heights and worst heights for the antenna in such situations. This is not generally a concern below the VHF band.

At HF or lower frequencies, the antennas of most radio hobbyists are mounted less than a wavelength above the earth's surface. When transmitting, some of the waves leaving the antenna will reach the ground and reflect upwards. And during reception, some of the waves reaching the antenna will have been first reflected from the ground before reaching the antenna.

Depending on the conductivity of the earth and the height of the antenna above the

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earth, these earth-reflected rays of the signal will interact with other rays of the signal. The result is a modified vertical-radiation pattern as compared to the shape that the pattern would have had if the antenna were suspended in outer space, for example.

On the HF band, horizontal antennas a quarter wavelength above earth produce a beam-antenna effect with the earth acting as a reflector. A majority of this antenna's radiation is thus directed upward. This is known as "near-vertical-incidence-radiation" or "NVIS." Here the radiation is relatively straight up to the ionosphere. This is reflected back to earth and scattered very broadly around the transmitting antenna. Thus, NVIS is useful for situations where signals from stations relatively close to one another are blocked by a mountain range or other obstacle between the stations.

If that same horizontal antenna were to be raised to a half wavelength above ground, then its radiation pattern will have predominately lower-angle radiation, and it will then be useful for long-distance sky-wave skip communication as described earlier.

The lower end of the popular Marconi quarter-wavelength vertical antenna must be at ground level for that antenna to function properly. Similarly, on vertical antennas with a so-called "ground plane," the lower end of their vertical element must be on the same level as the ground-plane elements.

Nevertheless, the height above earth has some effect on ground-plane antennas, too. The wavelengths are so long in the lower portion of the medium frequency band that it is difficult to mount the antenna even a quarter wavelength above ground. On longwave frequencies, it is impossible. At these frequencies transmitting antennas are almost always short (in terms of wavelength), loaded verticals, mounted with their lower ends at ground level.

At these frequencies communication is essentially all by vertically-polarized waves. These waves hug the earth and, with very-high power, can even travel completely around the earth.

❖ And So:

We've now finished the three-part "Let's Talk About Antennas" series, but there's more to an antenna system than the antenna itself. In the near future we'll have columns on such things as antenna feed lines, antenna tuners, and even have a bit to say about the environment in which the antenna system is immersed.

RADIO RIDDLES

Last Month:

I asked: "Since the unhappy man in last month's riddle performed so poorly as a conductor, perhaps his title should be changed from 'conductor' to something different. But what?"

Well, since very little current would flow through him, he could be called a "very high value resistor," or a "leaky insulator." But let's be obstinate and call him a "low-mho conductor."

A what?! See this month's riddle below.

This Month:

In reference to the above paragraph, what is a "mho" anyhow? We'll have mho on this subject next month.

You'll find an answer to this month's riddle, another riddle, another antenna-related web site or so, and much mho, in next month's issue of *Monitoring Times*. 'Til then, Peace, DX, and 73.