

Brass Tacks

An in-depth look at a radio-related topic



The antenna

Among all the items making up a complete amateur radio station, the *antenna* is arguably the simplest component with the most complex and perhaps the most important job. To many of us, it's a passive device that converts electrical signals into radio waves, and converts radio waves into electrical signals. This is a discussion about the fundamentals, the rudiments, of how an antenna works, without requiring a college degree.

While proving the existence of radio waves, as predicted by James Clerk Maxwell, *Heinrich Hertz* invented the antenna in 1888, although that's not what he called it. In the summer of 1895, *Guglielmo Marconi* was experimenting with electrical conductors suspended from masts, raised to help increase the reach of his transmitted signals. He made mention of the fact that some of his wires were held up by a tall tent pole, which in Italian is *l'antenna centrale*, the word *l'antenna* having had its origins with ship masts. Soon, the shortened *antenna* spread among researchers, then experimenters, then the world in general.



The term *aerial*, used in the UK for antenna, simply means *of the air*. People have sometimes used *antennae* as an outdated plural for antenna, but today that word refers primarily to the pair of appendages that protrude from the head of an insect.

The physics

Let's start with the basic laws of nature by which an antenna performs its magic, then expand on the various characteristics that identify its properties. Still, a rudimentary (not elementary) discussion cannot take place without mentioning *some* physics, because that's where it all begins. And to help make the explanation a little easier to grasp, let's assume that we're using a perfectly resonant and lossless antenna, whose feed point impedance exactly matches the feed line *characteristic impedance*.

The entire story behind the physics of an antenna begins with *electric charge*, a fundamental property of matter, in which a particle that possesses this influence exhibits electrostatic attraction or repulsion in the presence of another particle possessing the same property. Next is *Coulomb's Law*, which states that the force between two charges (q and q_o) is defined as

$$F = \frac{1}{4\pi\epsilon_o} \frac{qq_o}{r^2}, \text{ but since } E = \frac{F}{q_o} \text{ (definition of the electric field), } E = \frac{1}{4\pi\epsilon_o} \frac{q}{r^2}$$

introducing the concept of an *electric field*, which emanates from each charged particle.

For a moment, let's examine how a *capacitor* works, since an antenna is fundamentally a type of capacitor, and functions like one in some respects. A capacitor has two conductors that are

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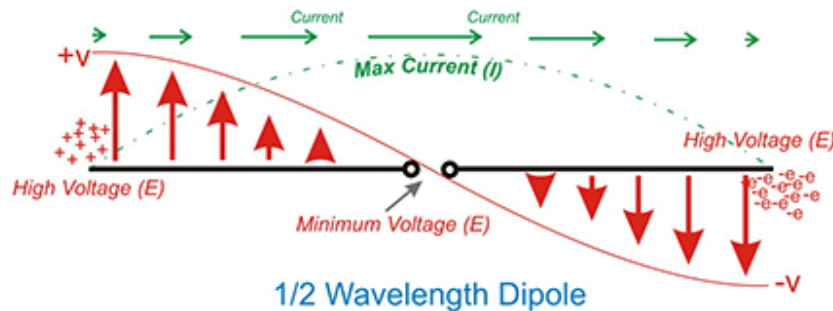


separated by an insulator. At an initially discharged state, the two conductors have equal amounts of opposing charges on both conductors, so the resulting net electric field between the two is zero. These charges are electrons that exist in the conduction band of each metallic atom, and are spread uniformly throughout each conductor.

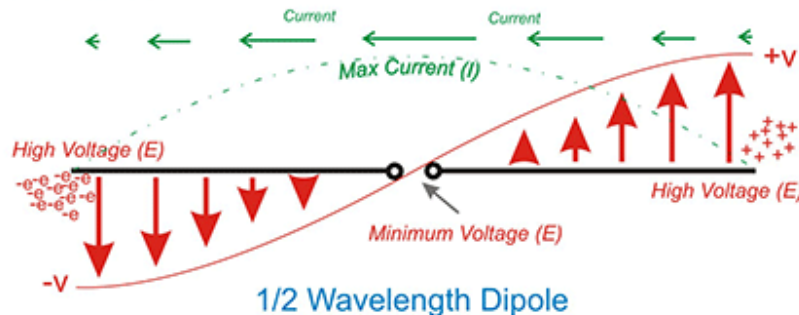
When a voltage potential (battery, for example) is presented across the two conductors of a capacitor, the electric field within the conductors become nonzero, resulting in the momentary migration (flow) of the electrons in the conduction band from one atom to the next, further resulting in a net accumulation of electrons (negatively charged) in one conductor and depletion of electrons (positively charged) in the other.

Like the capacitor, this accumulated separation of negatively and positively charged *elements* (radiating sides, also called *radiators*) of a **dipole antenna** results in a nonzero electric field between the two conductors, which of itself is not all that interesting or useful. But, suddenly switch the polarity of the voltage potential, and the electrons now rush to the other end. This reversal of charge migration will reverse the electric field (same field type, but with opposite polarity), because the voltage potential controls that charge accumulation. Reverse the voltage polarity again, and the process re-repeats in the reverse direction, and so on.

AC Cycle A



AC Cycle B



The electric field is an influence that is emitted from the charges at the speed of light, and the alignment of the electric field is what we refer to as the signal **polarization**. The continual reversal of charge polarity therefore results in the continual reversal of (change in) emitted electric field polarity. We say that antenna orientation (physical alignment) determines signal polar-

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ization (electromagnetic field alignment).

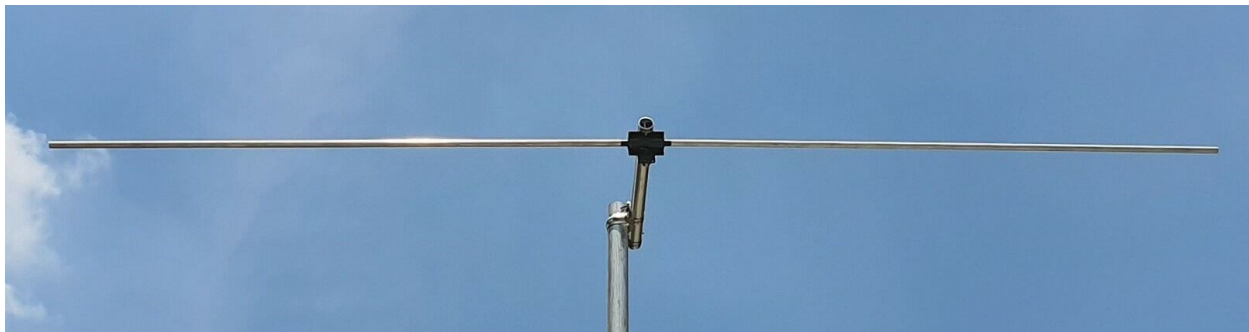
According to [Ampere-Maxwell's Law](#), a changing electric field produces a magnetic field that changes at the same time (same frequency and phase). This combination of the changing electric field and changing magnetic field is what we call *electromagnetic radiation*, or **radio waves**, and it moves out (*propagates*) from the antenna at the speed of light.

Because the electromagnetic radiation produced by an antenna is a composite (observed together) of its continually changing electric and magnetic fields, let's consider them as though they were a single field, which I'll call the *electromagnetic field*. When this electromagnetic radiation (radio wave) strikes a metal object, such as a receiving antenna, its oscillating electromagnetic field causes the electrons in the antenna to accumulate at one side of the dipole antenna and then the other, according to [Faraday's Law of Induction](#).

The electrons begin moving back and forth along the conductor with the same frequency as that of the radio wave. This resulting *alternating current* is then brought into the radio for possible processing to reproduce an intelligent sound, assuming an intelligent signal was received. Whew...we got past the hard part!

The dipole antenna

An ideal antenna that can transmit equally in all possible directions is known as an *isotropic* ("equal turn" or "exhibits the same properties any way you turn it") antenna or radiator, and cannot be realized (made), but is used as a reference tool for textbook and theoretical antenna property discussions. Comparisons with an actual, nearly ideal antenna require the *dipole antenna* to as the reference, because of its simple design and well-known characteristics.

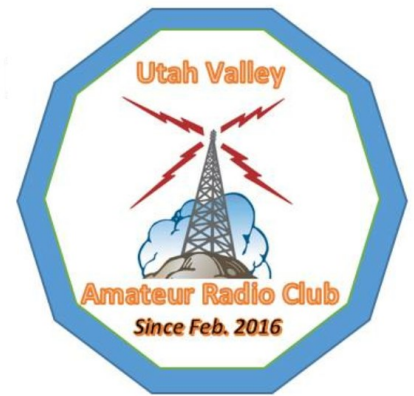


A dipole antenna is a pair of equal-length (and ideally colinear) conductors, each of which is connected to one of the conductors in a feed line, such as coax. In one form or another, nearly every antenna is, or has at its heart, a type of dipole, in that radio waves are emitted from one side of the dipole and received on the other, then the operation is reversed a half-cycle later. The two sides are connected by capacitance, with air or space as the separating dielectric.

An antenna that's built using *only one* of these two halves (known as a [monopole](#)) still requires the missing counterpart, or *counterpoise*, for proper operation. In this case, an antenna will often make use of other conductors that can return the signal to the radio, such as the chassis of an HT (handheld transceiver) or the shield of the coax (coaxial cable), if one's attached.

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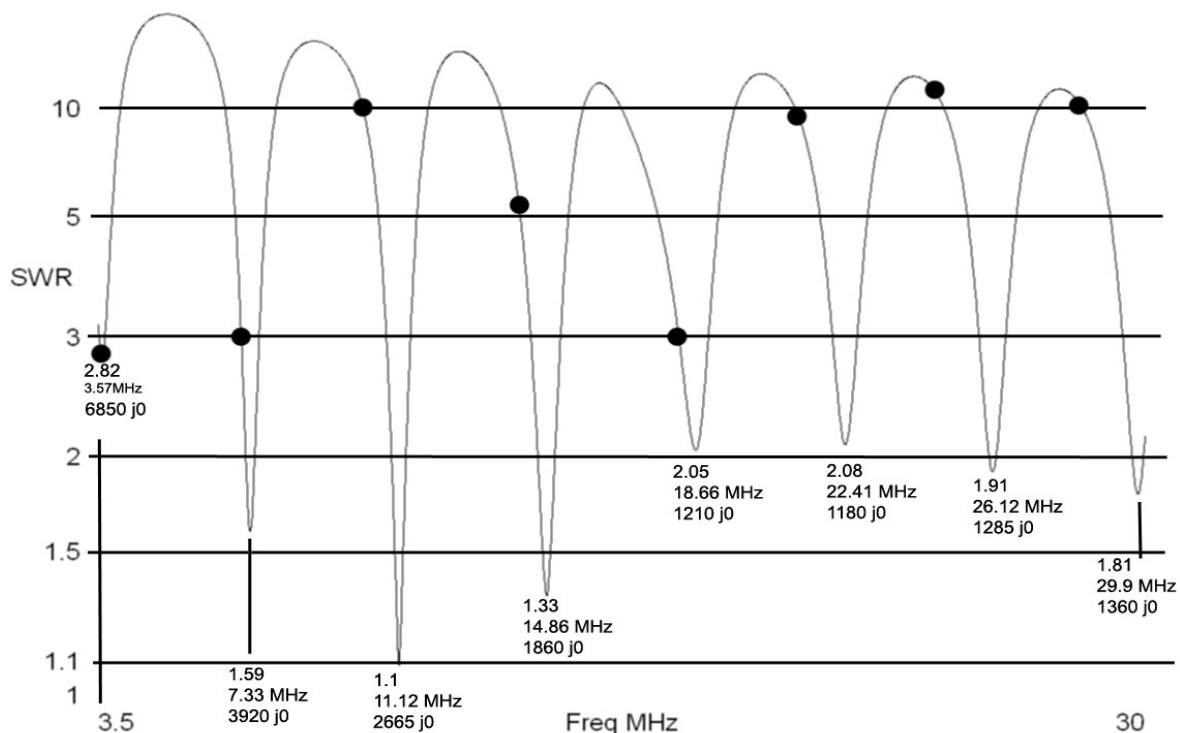
Antenna resonance

But isn't the antenna being bombarded by radio waves of a jillion different frequencies at any given moment? Yes, it is, so which frequency of radio wave gets "picked up" best by the antenna? In the case of the dipole antenna, it's the frequency that will result in the greatest difference in voltage between the feed point of the dipole and that of the end of the element.

During any frequency cycle, the moving charges accumulate at one end of the antenna, then the other. If the conductor is precisely the size (due to geometry and medium, which controls the velocity factor) at which the accumulated charges reach a maximum accumulation at one end and a minimum accumulation at the middle (feed point) of the dipole at the same time, the voltage displacement (potential difference) is at maximum, resulting in maximum current flow at that frequency.

This is known as **antenna resonance**, and the frequency of maximum current flow is called the **resonant antenna frequency**. A signal whose frequency that does not produce this maximum displacement will cancel some of the effect, resulting in non-maximum current flow. Resonance means that the antenna feed point impedance is **real**, since any portion of the signal power that is **imaginary** is not radiated, but is reflected back, and so contributes to SWR.

It's important to note that signals of frequencies near but not exactly the same as the resonant frequency will also be received. But their induced current strengths will be attenuated



Display of "long wire" antenna resonance points

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(reduced) compared with what might otherwise have been realized at the resonant frequency. On the other hand, if you extend the antenna element far enough to where another half-wave of the signal is producing another maximum displacement, you can see that an element that's 3/4 wavelength is also resonant. In fact, every odd-quarter-wavelength multiple of the element size is also resonant, since the impedances at those points are also real.

Antenna size

The actual size of the dipole that is resonant for the signal of a required frequency can be calculated by considering that one half-cycle of the signal will result in a maximum voltage difference (from the smallest to the largest positive) on one element of the dipole, and the reverse maximum difference (from the smallest to the largest negative) on the other. This translates into the highest to the lowest peak of the radio wave, which amounts to a *half-wavelength*.

Calculating the half-wave dipole size requires knowing the VF (*velocity factor*) of the material being used for the wire. The VF is the speed of electrical energy in the material, and is expressed as a fraction of the speed of light in a vacuum. For example, the VF of copper at room temperature is 0.95, meaning that electrical energy can travel $0.95 \times 300 \text{ Mm/s} \approx 285 \text{ Mm/s}$ in bare copper.

Let's say we want to design a half-wave dipole antenna for 20 meters, at about 14.175 MHz, using bare copper wire. The entire length of the dipole should be a half-wavelength, making it $300 \text{ Mm/s} \div 14.175 \text{ MHz} = 21.164 \text{ m}$ for one wavelength (symbol λ), and $21.164 \text{ m} \div 2 = 10.58 \text{ m}$ for a half-wavelength. But that's how far one half-wave travels (per $1/14.175 \text{ MHz}/2$ seconds) in a vacuum, yet the electrical energy in the bare copper wire travels a bit slower. In fact, it travels 0.95 times the distance, or $10.58 \text{ m} \times 0.95 = 10.05 \text{ m}$ in the same amount of time. Converting meters to feet gives us

$$10.05 \text{ m} \times 39.37 \text{ in/m} \div 1 \text{ ft}/12 \text{ in} = 33.0 \text{ ft}$$

A convenient "tool" for us Americans, to calculate dipole lengths is the number **468**, which is nothing more than a conversion factor that a) converts MHz to feet and b) includes the 0.95 VF by assuming the half-wave dipole elements are made of copper. This way,

$$468 \div 14.175 \text{ MHz} = 33.0 \text{ ft}$$

The value "468" is derived from converting from MHz into feet, then multiplying by the VF of copper

$$\left(\frac{1}{2}\lambda\right) \left(\frac{300 \text{ Mm/s}}{1 \text{ MHz}}\right) \left(\frac{39.37 \text{ in}}{1 \text{ m}}\right) \left(\frac{1 \text{ ft}}{12 \text{ in}}\right) \times 0.95 \approx 468$$

then, further divide that by 2 for the length of each (dipole element) side.

One more antenna property you might want to be aware of is known as *aperture*. This is the amount of conductive surface an antenna can present or expose to an electromagnetic field. Typically related more to receiving antennas than transmitting ones, essentially, the more of your antenna you can expose to the field, the more signal it can collect. Many microwave, tele-

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vision, and other antennas use parabolic dishes to maximize their aperture, to collect the most signal at the frequency in question.

To make an effective shortwave radio antenna, for example, simply purchase a 500-foot roll of wire from your favorite hardware store, and string the wire all over your trees, bushes, and even over your house. You might be amazed how well your radio can receive signals with this wire, even if the wire isn't cut precisely for a particular resonant frequency.

Antenna efficiency

An antenna property that's often misunderstood is *efficiency*. The classic definition informs us that the efficiency of an antenna is the ratio between the amount of power radiated from an antenna to the power that's absorbed by the antenna. On the surface, this sounds clear and simple, but once we examine the details of that power, its story is no longer so innocent-sounding.

For example, let's say we send 100 watts PEP from our transceiver to the antenna, and ignore transmission line losses for now. Due to a mismatch, say 3.0:1 SWR, 25%, or 25 watts will be reflected back from the antenna to the transceiver. We can conclude that 75 watts was absorbed by the antenna, and we'd be correct. But what did the antenna do with that 75 watts of power?

Part of the power is radiated out into space, but part of it ("ohmic" power) is emitted as heat. The applicable equation for power is $P = I^2R$, and because this circuit possesses two power-consuming entities, $P_T = P_{rad} + P_o$ (power absorbed equals radiated power plus ohmic power), and so $P_T = I^2R_{rad} + I^2R_o$ (current times radiation resistance and ohmic resistance). Therefore, $R_T = R_{rad} + R_o$ (total resistance equals radiation resistance plus ohmic resistance).

Returning to the definition of antenna efficiency, therefore, the efficiency of the antenna is the ratio of the power radiated to the power absorbed, or $\eta = P_{rad}/P_T = P_{rad}/(P_{rad} + P_o)$. Canceling the currents, we have

$$\eta = R_{rad}/(R_{rad} + R_o)$$

or the efficiency η is equal to the radiation resistance divided by the total (radiation plus ohmic) resistance.

Therefore, antenna efficiency has nothing to do with SWR, reflections, feed line losses, or how well matched an antenna is. Furthermore, by reciprocity, the efficiency of a receiving antenna is identical to its efficiency as a transmitting antenna.

Antenna gain

Antenna *gain* is one of the most misunderstood and misused properties of an antenna, yet is used to compare one antenna with another, often without regard to more important attributes, such as radiation pattern or feed point impedance. Antenna gain is the *direction of its strongest signal*, whether that signal is transmitted or received. The degree to which the antenna signal vectors are concentrated in one direction more than in others is called its *directivity*.

Gain, therefore, is a measure of antenna directivity and is equal to $G = \eta D$, in which η is the

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antenna efficiency and D is its directivity. The quantity of signal strength in a particular direction is known as **power density**, and is measured in W/m^2 , or watts per square meter. Power density is calculated as

$$P_D = \frac{P_{\text{rad}} G}{4\pi d^2}$$

in which P_D is the power density, P_{rad} is the antenna output radiated power, G is the antenna gain, and d is the distance between the antenna and the measurement point.

The gain direction is usually accompanied by a value that compares the antenna's maximum potential strength with that of a reference antenna, which is traditionally either an isotropic radiator or a half-wave dipole. Antenna gain listed in **dBi** indicates that it's being compared with that of an isotropic radiator. Gain listed in **dBd** indicates a comparison with that of a half-wave dipole.

Antenna gains listed simply as **dB** have an indeterminate meaning, so we must assume the worst case, which is dBi. Some advertisers will list a gain in dB in an effort to mislead the unsuspecting buyer into a more attractive purchase. To convert a dBi value to a dBd value, simply subtract 2.15 (free space), so that an antenna listed as 9 dBi or even 9 dB is actually 9 dBi – 2.15 = 6.85 dBd in free space.

The dBd value is useful in calculating the **ERP** (**effective radiated power**) output of a station, since ERP is relative to a half-wave dipole. For example, say your radio is set to transmit on 20 meters at 100 watts maximum, your antenna gain is listed at 9 dBd, and you're using 50 feet of RG-58 coax. What is the resulting ERP from your antenna? The calculation is basically

$$\text{ERP} = \text{PEP} + \text{gains} - \text{losses}$$

The 'PEP' value is the amount of power that your rig is transmitting. Next, your transmission line is RG-58 coax. Looking at the [coax chart](#), you can see that for 20 meters RG-58 exhibits 1.7 dB loss per 100 feet. This means for 50 feet, or half that length, your coax loss is $1.7 \text{ dB} \div 2 = 0.85 \text{ dB}$ loss at 20 meters. So, your total ERP is now

$$\begin{aligned} \text{ERP} &= 100 \text{ watts} + 9 \text{ dBd} - 0.85 \text{ dB} \\ &= 100 \text{ watts} + 8.15 \text{ dB} \\ &= 100 \text{ watts} \times 10^{(8.15/10)} \\ &= 100 \text{ watts} \times 6.53 = 653 \text{ watts} \end{aligned}$$

Which means your station is putting out 653 watts of power! Wait a minute...how can you get more power out of your station than you've put into it? Is your station somehow violating the laws of physics, or maybe generating extra power? Remember that antenna gain is the direction at which the maximum signal power is directed. In other words, just like with a flashlight, the reflector dish doesn't magically generate more light, it only focuses the light that it does have, more in one direction than in others. So, **it appears** that your station is putting out 653 watts in a particular direction (actually W/m^2), and that appearance is ERP.

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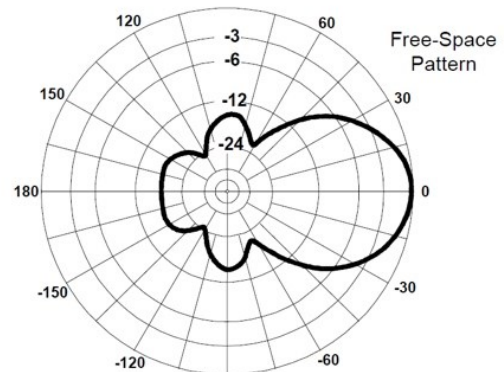
The dBi value can also be useful for when the *EIRP* (effective isotropic radiated power) is requested. The newest amateur bands, the 630-meter band and 2200-meter band, for example, list the maximum allowable output in EIRP. To calculate that value, first convert your antenna gain into dBi, and repeat the steps.

A physical principle known as *reciprocity* states that the receiving characteristics (gain, radiation pattern, bandwidth, resonant frequency, efficiency, etc.) of an antenna are identical to its transmitting characteristics. This means that if an antenna exhibits gain in a particular direction, both its receiving and transmitting ability are strongest in that same direction.

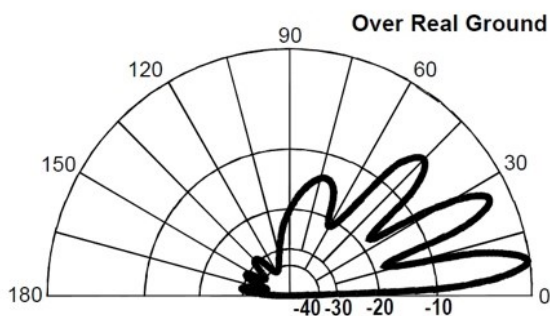
Antenna radiation patterns

If we were to shrink the antenna down to a dot, and examine the radio waves emanating from it, we call that examination the *far field*. This kind of approach allows us to determine antenna and field properties independent of close-range anomalies that are not relevant to the discussion. Next, let's draw a line from that dot in any direction, such that the length of that line is proportional to the transmitted signal strength in that direction, without regard to where on the antenna the signal originated. Let's then draw another line from the dot in any other direction, and with the same requirement.

Once we draw enough of these lines, we begin to see the formation of a three-dimensional shape, which displays what we call the *antenna radiation pattern*. This visual model gives us an idea of not only the gain direction, but the relative peaks (high points) of the transmitted signals in other directions as well. The resulting balloon-like figures are called *lobes*, with special attention drawn to the front (front lobe), back (back lobe), and sides (side lobes), especially if the antenna exhibits significant directivity.



Azimuthal view of a Yagi pattern



Elevation view of a Yagi pattern

Although antenna gain is defined as the direction of maximum radiated strength, it doesn't tell the whole story. An antenna might also exhibit a strong signal in a slightly different direction, and maybe another, and another, which is very common among actual antennas. The pattern lobe of the gain is called the *main lobe*, and all other lobes are measured relative to the main lobe.

Because of our reliance on two-dimensional displays, we typically draw antenna patterns from either a side (*elevation*) view or top (*azimuthal*) view. There are certainly three-dimensional drawings that display a more complete model at once, but a two-dimensional picture tends to be easier to draw. The side, or elevation view can display wasted radiated power and the antenna's takeoff angle, which we'll discuss shortly.

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The top, or azimuthal view helps us understand the lateral (compass N-S-E-W) directions of the lobes, the nulls, and the antenna beamwidth. Combined, they can easily display antenna directivity.

Beamwidth

Examining the azimuthal pattern, if the antenna exhibits some directivity, we surround the pattern with a circle, using the antenna dot as the center of the far-field and the main lobe as the radius. We then label that outer circle “0 dB” because it’s our reference, since all other points are relative to the main lobe. We then draw a second circle 3 dB (half the maximum main lobe signal power) closer to the center, and mark where the major lobe crosses the –3 dB circle. The angle created by those two intersections is known as the **half-power beamwidth**. This graphically displays how much *effective* sweep angle an antenna covers.

From the azimuthal pattern on the previous page, you can see that the antenna beamwidth is the difference between the positive angle where the main lobe intersects the –3 dB circle and the negative angle where they intersect again. It appears that the two angles are approximately $+25^\circ$ and -25° , and the difference is the beamwidth, or $BW = (+25^\circ) - (-25^\circ) \approx 50^\circ$.

Takeoff angle

Examining the elevation pattern, let’s again focus on the gain, the direction at which the strongest signal radiates. The main lobe angle over flat ground is known as its **takeoff angle**, because it looks as though the signal is “taking off” from the antenna dot into space. Understanding the takeoff angle of an antenna can be important if you’re trying to target a distant (DX) land or some place nearby (NVIS).

If your antenna’s takeoff angle is very low, say, 10 degrees, it’s set to strike the ionosphere very far away, and can reach a distant station with fewer hops (bounces of refractions off the sky and reflections off the Earth) than can one whose takeoff angle is higher. Fewer hops between stations means less signal loss, assuming ionospheric conditions are favorable. If your antenna’s takeoff angle is very high, say, 80 degrees, it’s better suited for NVIS (near-vertical incidence skywave) contacts within 200 to 500 miles, an area that could otherwise end up in the **skip zone** for one with a lower takeoff angle.

From the elevation pattern on the previous page, you can see that the antenna takeoff angle is the angle made by the main lobe over real ground. In this case, it appears to be approximately 8° , which is pretty low for a Yagi antenna, unless it’s been mounted fairly high up. Judging by its pattern alone, I’d say that this high-gain antenna can easily be used for making DX and domestic contacts alike.

Takeoff angle can be controlled by antenna type and antenna height. Vertical and other monopole-type antennas tend to exhibit a very low takeoff angle, and are typically better suited for DX. On the other hand, vertical antennas tend to be noisier, because of their lack of signal rejection in any direction. A Yagi beam antenna tends to exhibit a higher takeoff angle, making them more suitable for continental (within our own continent) contacting. But increasing the height of a Yagi can reduce its takeoff angle, and allow for much farther propagation.

Reciprocity

In the world of amateur radio, antennas have two basic arenas of function, transmitting and

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receiving. And because of reciprocity, each antenna's receive pattern is identical to its transmitting pattern, although experience doesn't always make that seem obvious. That pattern determines in what direction the antenna gain is pointed, as well as the directions of its relative signal strengths or sensitivities. And different antenna shapes, sizes (lengths), and especially its height over ground, affect that pattern, for both transmitting and receiving.

Antenna impedance, SWR, and matching

Because an antenna is an electrical component, it exhibits *impedance*, which is the opposition to current flow through it. To function ideally as an effective signal radiator, an antenna must convert all of the electrical signal sent to it, into radio waves. This can only occur if the antenna is completely lossless and its *feed point impedance* (impedance measured at the point where the feed line connects to the antenna) perfectly matches that of the feed line.

But even in the lossless antenna case, if the feed point impedance does not match that of the feed line, a portion of the signal sent to the antenna will be *reflected* back to the transceiver. The measure of this relative quantity of signal reflection is called the *SWR* (standing wave ratio), and is a function of the difference between antenna (load) impedance Z_L and feed line (characteristic) impedance Z_0 , as follows (Γ is known as the *reflection coefficient*):

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} \quad \text{and} \quad SWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

Because of the reactive (opposed to the resistive) nature of the transceiver output, the entire signal that was reflected by the mismatched antenna will be re-reflected by the transceiver to the antenna again. Therefore, if the feed line is completely lossless, all of the transceiver signal will eventually be sent out through the antenna, regardless how badly matched they are. The lower the feed line attenuation (loss), therefore, the less of a concern SWR is.

If you're using coax (coaxial cable) as your feed line, then keeping your SWR down can reduce the signal power lost through your coax. To reduce SWR, either construct your antenna geometry to more closely manage the signal of a given frequency, or use an impedance matching device. One such device is an *impedance transformer*, which you can easily make, but often only covers a limited frequency range. Another is a *tuner* (ATU, or antenna tuning unit), which can often cover a much larger range.

Antenna types

This section alone can serve as its own book. We've already covered the dipole antenna, because it's a reference antenna that's very effective, easily constructed, and is the foundation of most other antennas. Without listing every antenna ever made, there are a few important ones that are worth mentioning.

The monopole

An antenna constructed from a single radiating / receiving element is known as a *monopole antenna*, and is simply half of a dipole antenna, using an Earth connection for the other half. You've no doubt seen examples of this common type of antenna on vehicles, HTs (handheld transceivers), AM broadcast station towers, and portable FM broadcast receivers. Invented in

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1896 by Marconi, the monopole antenna was once called the *Marconi antenna*.

A monopole antenna emits its signals omnidirectionally from an azimuthal point of view. From an elevation perspective, it radiates its signals primarily outward from (perpendicular to) the antenna, plus a lesser percentage of the signals at a slightly upward angle and some at a slightly downward angle. The downward signals are reflected by the Earth and sent back upward, adding to the upward-angle signals.

At a quarter-wavelength, a monopole antenna is resonant, meaning its feed point impedance is purely resistive. At lengths shorter than a half-wavelength, the monopole impedance will exhibit capacitive reactance, and between a quarter-wavelength and half-wavelength, it'll exhibit inductive reactance.

While it's possible to mount a vertical monopole above ground, like on your roof, it's also possible to mount one right on the ground, often a convenience advantage of monopole antennas over other types. But to maintain the feed point impedance at its optimum, it needs a **counterpoise**, to compensate for the bottom half of the dipole, especially if it has a poor connection to Earth ground. This counterpoise is often achieved by the use of radials, which are nothing more than wires that are connected to the non-radiating side of the antenna, spread out radially (hence the name) from its base.



My own monopoles

The Yagi antenna

The one highly performing antenna sought for by most serious hobbyist and contester hams is the **Yagi-Uda antenna**, which we tend to abbreviate as Yagi, pictured at the start of this discussion. The Yagi antenna is known for its high gain and high noise rejection. Similar to narrowing a flashlight beam, to concentrate its light to a smaller area, a Yagi antenna can be made with high directivity, providing more focus of the signal "beam" in a particular direction, and leading us to refer to such a Yagi antenna by the nickname **beam** antenna.



And in the receiving case, due to reciprocity, because more focus is placed in the gain direction, the Yagi beam antenna receives signals from other angles much more poorly, allowing for high passive noise reduction from sources other than those in the forward heading. This is possibly the biggest performance difference between a vertical antenna and a beam antenna.

Perhaps the biggest downside to the Yagi beam is the fact that you'll need to rotate the antenna toward your signal to communicate well with a contact in that direction, requiring you to install an *antenna rotator* that you can control from within your shack. Then again, a few amateurs who live away from metropolitan areas do install their Yagi antennas permanently trained in a particular direction, possibly at a favorite repeater or group of repeaters.

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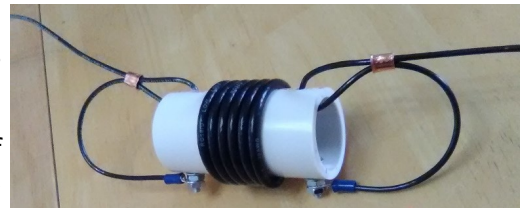
Electrically short antennas

Due to resonance, an antenna ideally possesses a geometry (specific length or other dimensions) that's defined by its operating frequency. Yet, that often leads to excessively long wires or height for antenna elements, making the antenna cumbersome and maybe even a bit dangerous in some circumstances. It's possible to shorten this same antenna, while retaining its effectiveness at the target frequencies, by using a **loading coil**, either at the base of the antenna, or near the middle of it.

A loading coil allows the antenna to retain its optimal length through all the wire that's coiled up in it. But, the coil often adds serious inductance to the antenna, requiring added capacitance to bring the antenna back to resonance at the frequency of interest. For this reason, a capacitance hat or other methods are often used on a vertical antenna that has been shortened below its quarter-wavelength height.

Trap antennas

One way to create an antenna from a single wire that is resonant on two or more different bands is through an antenna **trap**. A trap is (typically) a passive device that, through a simple tuning circuit, can allow for signals of one supported band to pass through it, while it filters out ("traps") those of the other band.



20/40 antenna trap

Finally

Antennas seem like such simple, innocent devices. Yet, explaining how they work can get really complicated really fast, so in spite of how long it is, our discussion has scaled down much of the detail to the level of a club newsletter.

If you'd like to pursue the ultimate education on antennas, a degree in RF Engineering would definitely help you achieve your goal. To focus only on antennas, you can study the *de facto* standard antenna reference, *Antenna Theory Analysis and Design*, by Constantine Balanis, the undisputed authority on antennas. But caution: advanced calculus and physics are required, without which, brain damage or partial blindness can easily result. :-)

Another recommended work that's more down to an amateur level is the **ARRL Antenna Book**, which can be purchased from [Amazon](#) or from [ARRL directly](#). The *ARRL Antenna Book* not only covers basic antenna theory, but also discusses performance and design characteristics.

Summary

An antenna is a non-trivial device that converts electrical signals into radio waves, and/or collects radio waves and converts them into electrical signals. Properties such as impedance, geometry (size and aperture), gain, radiation pattern, and resonant frequency, must be taken into account for effective antenna use. There are several categories of antennas, yet nearly every antenna can be thought of as a dipole in one respect or another. Efficiency, gain, and SWR are widely misunderstood antenna properties that might deserve some homework time if you plan to discuss them intelligently.

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