Just a Dipole

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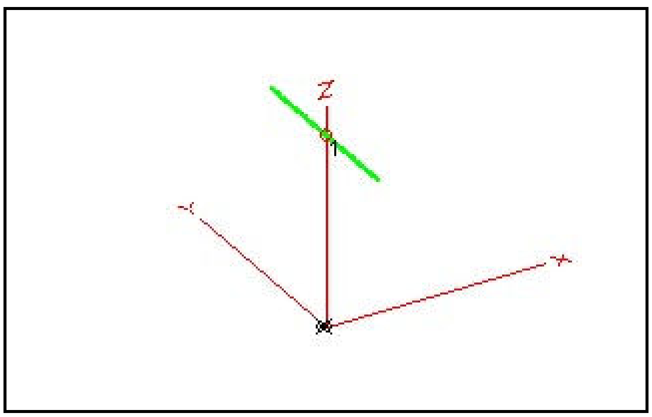
Often we will hear people describing their antennas as 'just a dipole'. After all, a coax cable fed, half wavelength dipole is one of the simplest antennas to construct and install. It must be an antenna only beginners use.

If there is anything we might call a "magic" antenna in amateur radio, it is surely the half wave dipole. A wire cut to about 95% of free space half wavelength at a desired operating frequency and fed in the middle with 50 ohm coax will operate very efficiently.

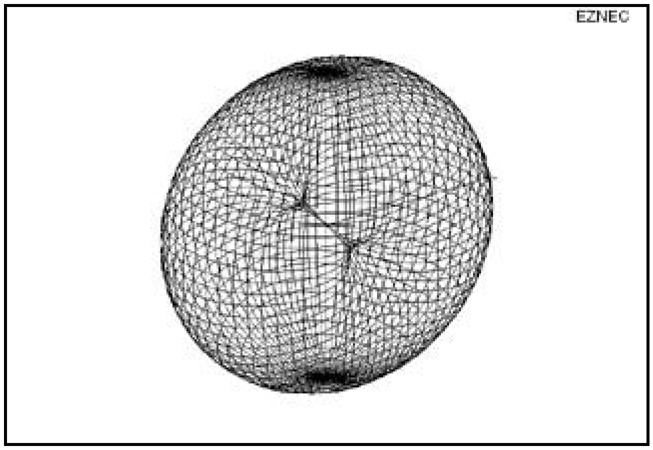
When the length of the wire is adjusted to resonance, a dipole will provide a low feed point SWR. A half wave dipole's radiation pattern is very broad making its installation relatively uncritical. Even the most extensive (and expensive) ham antenna installations will include half wave dipoles cut for various frequencies. This antenna is what other antennas are compared against.



XYZ plot diagram of a dipole antenna. The feed point is the dot in the middle of the wire.

The Half Wavelength Dipole

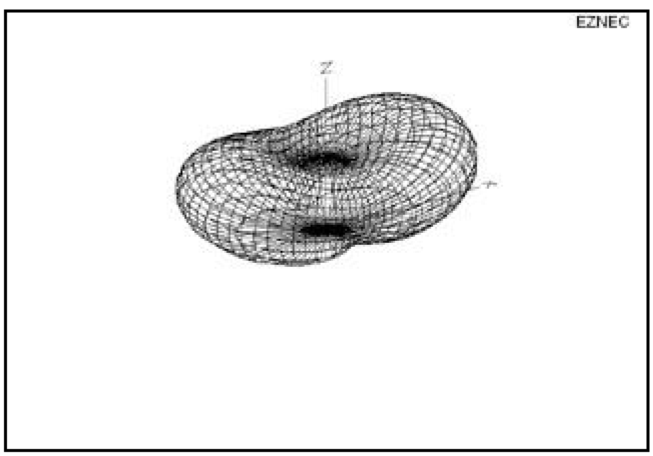
It is fairly easy to picture the radiation pattern of a half wavelength dipole in free space if you simply imagine slipping a bagel over its wire. Maximum radiation is perpendicular to the wire. Little radiation occurs off the ends of the wire.



The bagel on a wire – free space pattern of a half wave dipole.

When we supply an RF signal from a transmitter to the center of the dipole, a standing wave of RF current is created. That RF current generates electrostatic and electromagnetic fields. As the current circulates, some of it is used up in generating RF energy and some of it is simply dissipated as heat. In free space, a resonant half wave dipole will have a feed impedance of about 70 ohms.

Unless you happen to be an astronaut living on the International Space Station, you probably don't care a lot about how a dipole works in free space. You want to know how it would work in your own back yard. Let's look at that now.



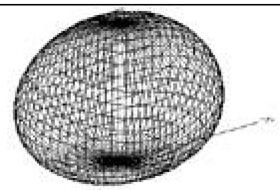
A half wave dipole at one-half wavelength above the ground.

The first parameter we care about is how high the dipole will be installed. Higher is usually better than lower. The antenna and the earth underneath it interact to modify the 'bagel' antenna pattern expected if the antenna were in free space. Downward radiation is reflected upward. Ground reflection interacts with the RF current in the antenna changing the feed impedance, often requiring the wire length be adjusted to bring it back into resonance.

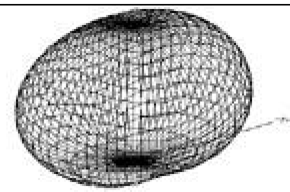
In the case of our half wavelength dipole, ground reflection usually works in our favor, often reducing the feed impedance closer to 50 ohms for a lower SWR on the feedline. Downward radiation is not lost as it is reflected upward adding to the direct upward radiation.

Height Above Ground

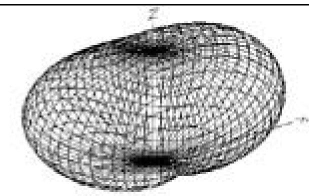
As seen above, the presence of the earth under the antenna effects its radiation pattern. Let's look at how that works. What follows is a sequence of plots. Each is of the same half wavelength dipole but at different heights above ground.



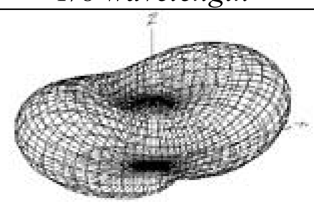
1/8 wavelength



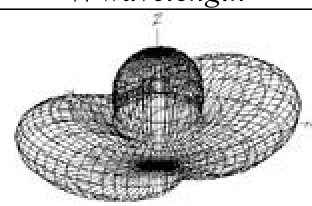
¼ wavelength



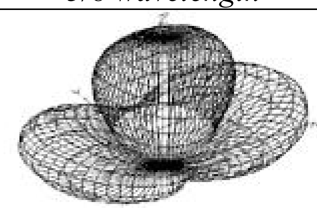
3/8 wavelength



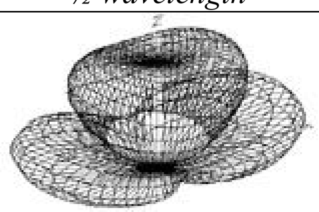
½ wavelength



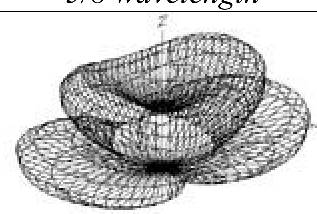
5/8 wavelength



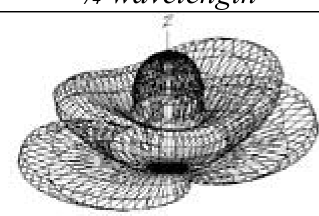
¾ wavelength



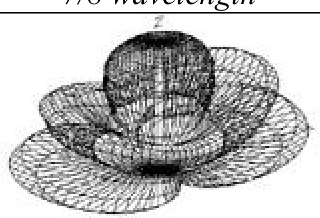
7/8 wavelength



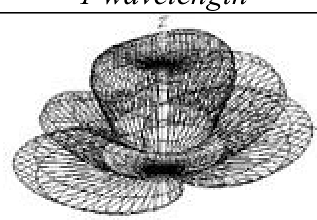
1 wavelength



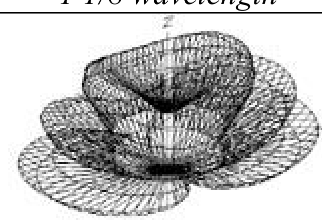
1 1/8 wavelength



1 ¼ wavelength



1 3/8 wavelength



1 ½ wavelength

As can be seen above, half wavelength dipoles at heights below about one quarter wavelength above the ground favor high angle operation. Below about 10 MHz, these lower height antennas work great for communications out to a few hundred miles.

Above about 14 MHz, the Ionosphere typically does not reflect high angle signals well, so lower angles of radiation are best. Notice above that above about one quarter wavelength, vertical radiation decreases and the main radiation lobe shifts lower in angle.

By about one half wavelength above ground, nearly all the vertical radiation is gone with most of the radiation occurring a lower angles. Above one half wavelength, additional higher angle lobes are created. Sometimes these higher angle lobes help by providing higher angle radiation when needed. Other times, the higher angle lobes can introduce multi-path fading by delivering your transmitted signal to the distant station via two or more different paths, sometimes interfering with each other. In general though, higher antennas are better for DX.

That higher HF frequencies work best with antennas at about one half wavelength or higher is not the problem it might appear to be. Remember that as frequency increases, wavelength decreases. A half wavelength on 20 meters (14 MHz) is only a little more than 30 feet. At 10 meters (28 Mhz), it is only about 16 feet.

A question commonly asked is "What is the best height for my antenna?" That, of course, depends upon what you want to do. Do you want to rag-chew with stations within a few hundred miles? Do you want to chase DX? Do you want a combination of both? Nearby communications works best on 40 meters (7 MHz) and lower with dipoles at modest heights – 20 feet is often adequate.

Serious Dxing is best pursued with antennas above one half wavelength above the ground. "Big Gun" Dxers may have antennas up 200 feet or more. Most get by just fine in the 50 to 75 foot height range.

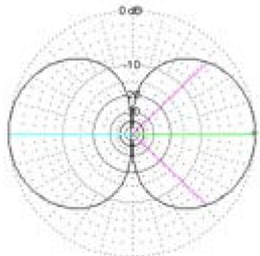
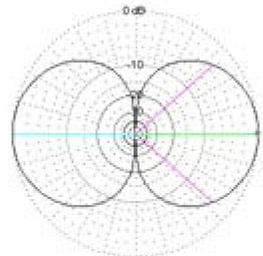
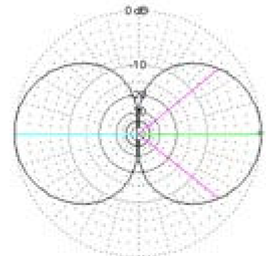
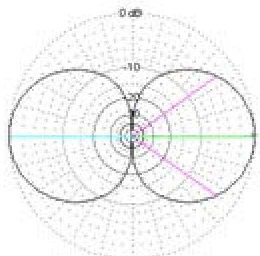
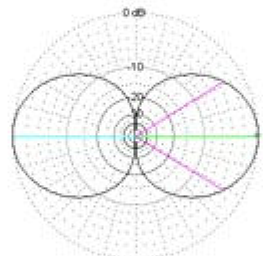
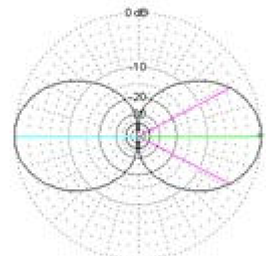
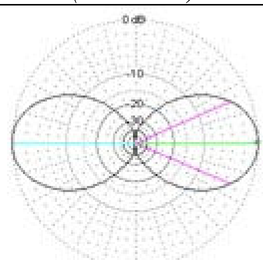
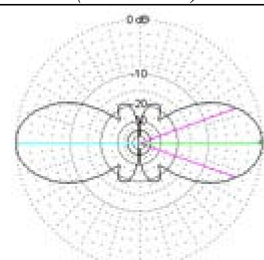
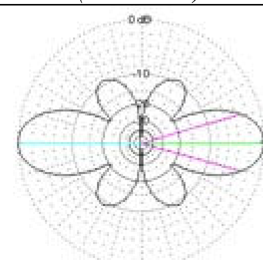
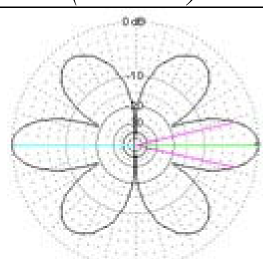
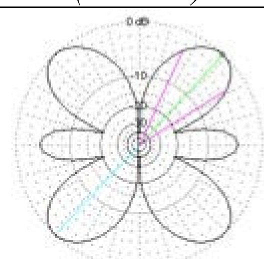
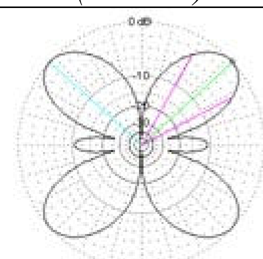
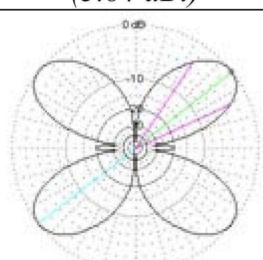
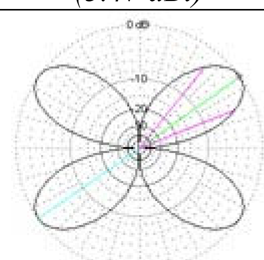
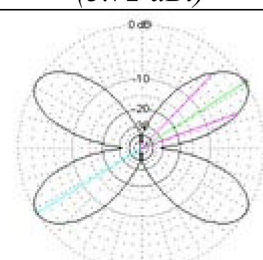
For all around rag-chew, regional network, and DX operation, 50 feet is probably as high as you need to place your antennas. That height provides reasonably low angle operation on 20 meters and above. It also does not produce a deep overhead null on 40 meters and lower.

Don't get discouraged if you are not able to operate with antennas at optimum heights. You can still work plenty of DX with low antennas. You can still make close in contacts with high antennas. You may not have the strongest signal possible for the path you are trying to operate on but often that is not necessary for successful communications.

It's Really A Family Of Antennas

When a ham says he is using a 'dipole', he usually means a center fed, half wavelength antenna. The term 'dipole' actually has a much broader meaning. A dipole is actually any single conductor cut and fed in the middle. Examples of alternatives to a dipole are loops, multi-element arrays, and end fed conductors such as ground-mounted verticals.

The table below illustrates the various patterns produced by different dipole lengths. These plots are simple two dimensional free space horizontal azimuth patterns.

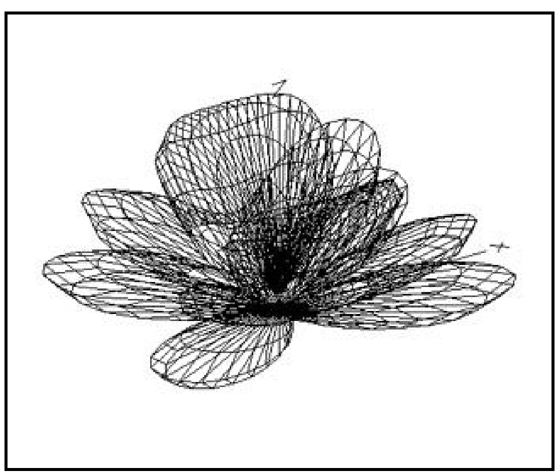
 *1/4 wavelength* *(1.76 dBi)*	 *3/8 wavelength* *(1.92 dBi)*	 *½ wavelength* *(2.12 dBi)*
 *5/8 wavelength* *(2.39 dBi)*	 *¾ wavelength* *(2.76 dBi)*	 *7/8 wavelength* *(3.24 dBi)*
 *1 wavelength* *(3.86 dBi)*	 *1 1/8 wavelength* *(4.58 dBi)*	 *1 1/4 wavelength* *(5.03 dBi)*
 *1 3/8 wavelength* *(3.84 dBi)*	 *1 ½ wavelength* *(3.47 dBi)*	 *1 5/8 wavelength* *(3.72 dBi)*
 *1 ¾ wavelength* *(3.72 dBi)*	 *1 7/8 wavelength* *(3.73 dBi)*	 *2 wavelengths* *(3.99 dBi)*

The radiation pattern, feed impedance, and SWR bandwidth vary with dipole length. Shorter dipoles exhibit the same broad radiation pattern as their resonant half wavelength cousins but exhibit lower radiation resistance and high reactive impedance. The reactive impedance can be canceled by installing inductors, known as loading coils, in the dipole wires. Unfortunately, the lower radiation resistance means that higher RF current must flow in the dipole wires to radiate the same power increasing power loss in the conductors. The loading coils introduce their own problems in that their conductors dissipate additional power as heat and cause resonance to be narrower than for full size antennas, reducing the SWR bandwidth.

Dipoles longer than one half wavelength can exhibit increased gain. That occurs because the current peaks on the dipole wires remain an electrical one quarter wavelength from their outside ends. Spreading the current peaks narrows the main beam, increasing its strength while decreasing it in directions off the main beam. This gain increase continues up to about one and a quarter wavelength (1.25 wavelength) total dipole length. A dipole of that length is call a "Double Extended Zepp" and is popular as a simple gain antenna for fixed point-to-point operation.

Beyond a length of one and a quarter wavelength, the main beam begins decreasing and additional side lobes begin building. Provided these side lobes are pointed in a direction helpful for your desired operation, they may be an advantage. As an example, the G5RV antenna was intended for 20 meter DX operation from Louis Varney's back yard. The lobes produced matched desirable DX beam headings. Of course, that was only true for that one band, from that one location, and in the one direction he hung it.

Longer dipoles can have many lobes in many different directions. In case you are wondering why I switched to two-dimensional plots for this section of the article, check the diagram below. There are often so many lobes that the plot is often useless.



2 wavelengths long at 1.5 wavelengths above the ground

Care Feeding Of Dipoles

As mentioned in the opening paragraphs, one of the magical features of resonant half wave dipoles is that they provide a good match with popular 50-ohm impedance coaxial cable. Installed clear of nearby objects, they seldom show an SWR greater than about 1.5 to 1 at resonance. Installing a balun at the feed point eliminates the imbalance that occurs with direct coaxial cable feed.

A resonant half wave dipole is probably the easiest antenna type to keep on the air. After installation and tune-up, write down the resonant frequency and the SWR measured there. You can use those numbers later to verify that it is still properly connected and working. If a discrepancy is noticed, a quick visual inspection will usually allow you to spot the reason for the problem. Broken wires, bad feed line connections, and broken support lines are the main failures.

The feed line magic disappears as soon as we consider dipoles other than the resonant half wavelength kind. Feed point impedance can vary widely, with values into the thousands of ohms seen at some lengths. Low loss open wire RF transmission line is typically used for feeding non-resonant dipoles. A wide range antenna tuner is usually necessary to match the transmission line to the transmitter's specified antenna port impedance.

An open wire transmission line fed dipole and antenna tuner combination has the advantage that it can usually be used on all bands where the dipole's overall length is greater than about three eighths of a wavelength. As you will have noted above, it will have multiple lobes on those bands where it's significantly longer than a full wavelength. It will still radiate efficiently but there will be nulls in some, often difficult to predict, directions.

All The Different Kinds

So far only the simplest and most common kind dipole antennas has been discussed. There are many variations on the dipole theme, each with its own particular purpose. What follows is a list of some of them.

1. **Trap Dipole:** A dipole that includes tuned circuits strategically placed to create an antenna that resonates on multiple frequencies.
2. **Multiple Dipole:** Two or more separate dipoles connected to the same feed point to provide multi-band operation on the same feed line.
3. **Open-Sleeve Dipole:** One or more additional closely spaced wires placed parallel with but with no electrical to a simple dipole to create multiple resonant frequencies.
4. **G5RV:** A simple 20-meter dipole 102 feet long using a short length of open wire transmission line to provide a match to 50-ohm coaxial cable. It is also popular as a multiband antenna but suffers high loss in the 50-ohm cable on some bands.
5. **Double Extended Zepp:** A 1 ¼ wavelength long dipole. It provides about 3 dB gain over a half wavelength dipole by narrowing the main beam perpendicular to the dipole wires.

6. **Cage Dipole:** A dipole built for broader SWR bandwidth than a standard dipole by using multiple wires spaced apart with circular spreaders to create a thick radiator.
7. **Double Bazooka:** This dipole uses two quarter-wavelength coaxial cable stubs as part of the dipole wires. The stubs provide some small SWR bandwidth improvement.
8. **Folded Dipole:** This dipole utilizes two parallel and end connected half wavelength wires. The feedline connects to only one of the wires. Because of the antenna current distribution, the feed impedance is increased, typically by a factor of four. This antenna is used to provide a low SWR match to an open wire feedline at the dipole's resonant frequency.
9. **Sloping Dipole:** This is any kind of dipole installed so the dipole wires slope from one end to the other. Often created when one end of the dipole is attached high on a tower and the other to some lower support.
10. **Bent Dipole:** A dipole installed with its wires bent so a longer antenna fits into a shorter space.
11. **Inverted Vee:** This is any kind of dipole installed so its center is higher than its ends. This is probably the most common way dipoles are installed today.

Just A Dipole

As you have seen above, a half wavelength resonant dipole is an important part of the ham antenna arsenal. It is the standard to which all other ham antennas are compared. That is for good reason. Its efficiency is usually very close to 100%. Its radiation pattern is very predictable. These would be important attributes for any antenna. They are easily and repeatably achieved with a half wavelength dipole using simple construction and inexpensive material.

There are many variations on the dipole antenna theme. Each has its own purpose. The resonant half wavelength dipole, though, remains king of the magic antennas.