THE MIGHTY DIPOLE

THE MASTER OF DISGUISE – THE CHELSEA AMATEUR RADIO CLUB

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Welcome to tonight's presentation of THE MIGHT DIPOLE ANTENNA, the master of disguise. It is sad that many amateurs are intimidated by the dipole antenna when its underlying principles are quite simple. But what is more important is that the dipole is the fundamental element of radio frequency communication. All others antennas are formulated upon it. If you understand the simple elements of the dipole antenna, you can explain any other antenna.

For tonight's presentation I am going to read from a script that I have written. I'll try to make it sound spontaneous but sooner or later I will hit upon a bad choice of words and the jig will be up. I will try to wade through it when that happens. The presentation will be less than 30 minutes.

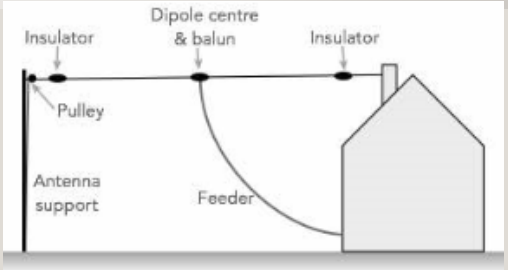
WHY LEARN ABOUT THE DIPOLE?

- The dipole antenna is the fundamental element of all antennas.
- Understanding the dipole enables you to explain all other antennas.

Many ask, “Why learn about the dipole? Let’s just use it.” Does the dipole antenna intimidate you? There is no reason for this since if you know Ohms Law you know the dipole antenna. You just have to learn of the analogies between Ohms Law and the dipole which we shall do in this lesson.

WHAT IS A DIPOLE, ANYHOW?

- It's just a couple of pieces of wire stuck together at the middle by an insulator.
- Each wire is cut to exacting lengths.
  - Generally equal lengths
  - Different lengths for special conditions
- An insulator mechanically connects the two wires.
- A feedline connects the antenna to the transmitter.
- Best results are obtained when using a "bal-un" to mate the feedline to the antenna.

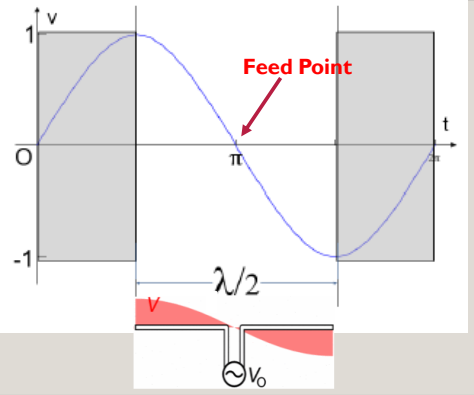


Typical example of an HF band dipole used for amateur radio

The dipole antenna is a familiar sight to all amateur radio operators. It is just two pieces of wire (cut to exacting lengths I might add), with an insulator in between and at both ends. A feed-line connects the center to the transmitter output. Best results are obtained when the feedline is "balanced" into the dipole antenna. We are talking twin lead as opposed to coax. More will be said about this later.

VOLTAGE DISTRIBUTION A DIPOLE—A SINE WAVE

- Ignore shaded areas. For reference only.
- Why does the wave align itself in that position—peaks at the dipole ends with respect to the feed point?
  - Consider Ohm's Law
  - For any open circuit
    - What is the voltage?
    - What is the current?
    - Why?
  - What are the antenna ends?
- If voltage is max at ends
  - is zero at mid-point.
  - Is there a safety issue with antenna installation?



This is the meat of tonight's presentation. Here is an illustration showing what happens electrically to an antenna when a resonant signal is fed to it. In this case the feed point is at the center of the antenna where you see the Greek symbol pie. Again, this is assuming a resonant signal is being fed to the antenna. To review, we have an assigned frequency to operate at. Our transmitter will therefore put out its signal using that assigned frequency. In order for the antenna to work, it has been cut to dimensions such that this illustration works. That assigned signal frequency has a length in meters. One wave is the measure so we speak of "wavelengths." The antenna will resonate when there is one half of a wavelength or any number of precise wavelengths, both odd and even. However, for the antenna to work there must be an ODD number of wavelengths. We will talk about why even wavelengths don't work later but for now our interest is in exactly one half wavelength, no more, no less.

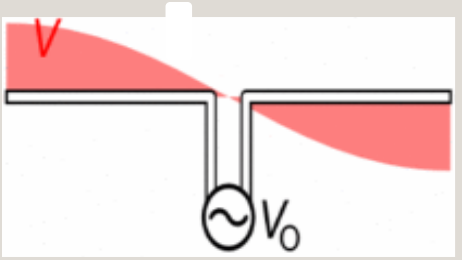
I now ask the question: What is the voltage output for an open circuit otherwise called "no-load"? If you were to attach a voltmeter to an open circuit, you would measure the source voltage (which is the maximum) because the circuit is open and therefore no current can flow. If there were current flowing, the voltage at the output would be shared and therefore the voltage out would be less than the source. The dipole antenna (and all other antennas) is an open circuit since the two ends don't connect to

anything but the feedline. What should you therefore expect to see voltage-wise at the ends of a dipole antenna wire? Like with the open circuit, you will see a maximum voltage. Thus in the illustration you see the sine wave is a maximum (positive and negative) at each end. This is a critical point to take home with you if you take nothing else home tonight. Because we know that the voltage is a maximum at the ends, we therefore know that the voltage is a minimum at the middle which is the feed point.

Up to this point we have referenced the antenna as an open circuit which is fine for the applications we have been studying. This is a special case in that the dipole antenna (and all antennas) do conduct current even though we have spoken of an open-circuit where there can be no current flow. For now (and likely the forever future) just know that there is such a thing as a "characteristic impedance" as opposed to a simple impedance. Characteristic impedance is for another discussion but for now just know that there is in fact a characteristic impedance which DOES allow for a transient very low current flow. This current flow is opposed to the voltage following Ohms Law. Where the voltage is maximum the circuit is "most open" and there is a minimum current flow. On the other hand, where the voltage is a minimum (the center), the current is a maximum. For those of you for whom this is new information, you cannot understand it at this point. Yet I introduce if for you as a concept that you can nevertheless work with to understand the dipole. We will be coming back to this again, and again, and again so just keep it in the back of your mind for now.

TIP-TO-TIP DIPOLE LENGTH IGNORING VELOCITY FACTOR

- Voltage at feed point is near zero
  and therefore results in the minimum Z_{in} of 73.13Ω (assuming free space).
- Voltage at ends maximum. Resulting in roughly $2k\Omega < Z_{in} < 5k\Omega$
- Return to Ohms Law
  - R = V / I
  - What is R if V = 0 ?
    - Answer: R = Minimum (73.13Ω)
  - What is R if V > 0 ?
    - Answer: R > Minimum

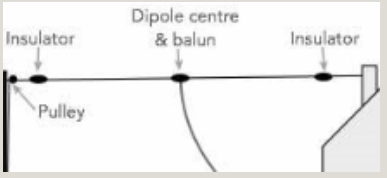


From the last slide we found out that the voltage at the ends of an antenna is a maximum and the voltage at the middle is zero or a minimum. Have you ever heard of the word “impedance” before? What is Ohms Law? Ohms Law is the fundamental building block of all electronics. It says that the impedance (or more specifically the resistance) is equal to the voltage divided by the current. We also learned of a current flow in the dipole antenna due to its “characteristic impedance.” So, we know about a voltage and roughly how much it is relatively and we know about a current and roughly about how much it is relatively and we also know about Ohm’s Law. Voltage divided by current is resistance or an impedance including a characteristic impedance. We learned that the voltage is maximum at the ends while current at the ends is a minimum. Since impedance is the voltage divided by the current, thinking back to your high school algebra, what is the quotient of a large number divided by a small know. It is a VERY large number. Therefore the impedance at the ends of an antenna is a maximum, though we only roughly know how much. It might typically be between 2k to 10k Ohms. But we are not (at this time at least) doing anything with the ends of the antenna. However, we ARE doing something with the middle of the antenna. That is our feed point. Because we all have been doing amateur radio for some number of years, we all know that 50 Ohms is the magic number. Just about all transceivers have an output impedance of 50 Ohms. When we use coax feedline (which is most all the time)

we use 50-Ohm coax. And we know that our antennas are all 50 Ohm input impedance. What do you suppose is the impedance of a dipole antenna at its center (assuming equal two lengths of its two wires)? We know that the voltage at the center is a minimum and that the current at the center is a maximum. Think back to your high school algebra again and Ohm's Law. What is a SMALL number divided by a large number. The answer of course is a VERY small number. Thus, a dipole antenna will typically have an input impedance of 90 Ohms to 25 Ohms which is close enough for a rudimentary match of 50 Ohms. In practice however, only the coax has a precise 50 Ohm characteristic impedance. The antenna might be 40 to 60 Ohms and even the transmitter might be 40 to 60 Ohms of output impedance.

THE FEEDLINE AND BALUN

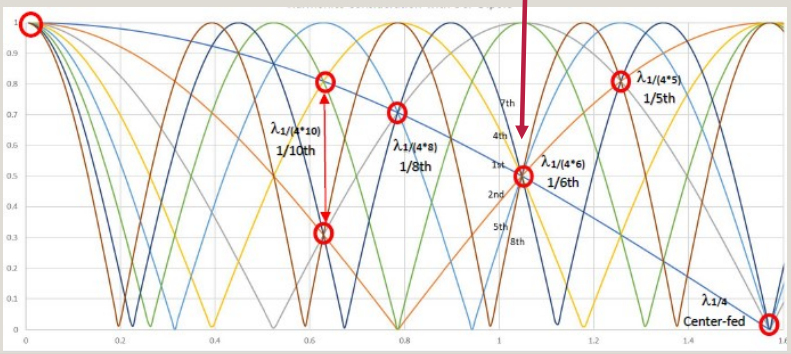
- Feedlines
  - Balanced – (i.e. ladder line_
  - Unbalanced – (i.e. coax
- The dipole has a balanced input.
- For proper operation must feed balanced
- A "balun" (balanced-Unbalanced) transforms an unbalanced line to balanced.



Let's talk a little bit about the feed line, now. There are two uttermost basic types of feedlines: balanced and unbalanced. Balanced lines are ladder lines which might otherwise be called "twinlead." We don't need to concern ourselves for this application of what makes a balanced transmission line balanced. All we need to know for now is that they exist. Balanced feed lines are ideal to use for feedlines to your dipole antenna since you can connect them directly to the dipole antenna without any fancy stuff. The only thing is that you have to guide the twinlead to the transmitter avoiding any ferrous material such as when entering the house. Twinlead transmission lines have very low loss as well which speaks well of them. By contrast, coax is rugged and is relatively impervious to its path from transmitter to the antenna feed point. But if unbalanced is being used (coax), you will need to use a balun for optimal results. Let's not talk about baluns tonight.

ONE EXCEPTION—THE WINDOM OCF DIPOLE

- The Windom is off center by precisely 1/3.
- Works a strange pattern of harmonics
  - 1st or fundamental
  - 2nd
  - ~~3rd~~
  - 4th
  - 5th
  - ~~6th~~
  - 7th
  - 8th
  - ~~9th~~
  - 10th
  - 11th
  - ~~12th~~



I'm throwing in this slide as a zinger to tantalize the taste buds to the highly experienced engineering amateur in the audience. Much has been said about the so-called Windom or 1/3rd dipole antenna. Its wires are cut at 1/3rd and the other at 2.3rds of a half-wave. So, the feed point is NOT at the center. We learned what the impedance is with a regular dipole having its input at the center. What will the impedance be in this case? Let's just talk about it and see if we can reach a consensus.

SO ENDS TONIGHT'S PRESENTATION--QUESTIONS