# THE MIGHTY DIPOLE (PART I)

COMING SOON: THE MASTER OF DISGUISE (PART II)

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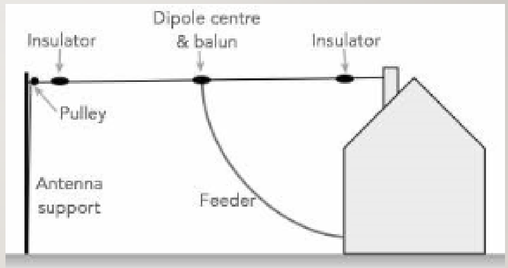
So, thank you for your interest in Part One of… THE MIGHTY DIPOLE. This presentation is centered upon educating the Technician's Class amateur radio operator in preparation for upgrading to a General Class license as it concerns antennas. One who comprehends these "rules of the road" will be able to answer many of the FCC pool questions on antennas with confidence. Further, one who understands and comprehends these "rules of the road" will be very well equipped to understand most ANY electro-magnetic antenna. But fully comprehending is not going to happen from merely viewing the presentation. I recommend that you obtain and view the slides tomorrow or in a few days to review. But even if you are not able to, when you see this material again as you study from other sources for the General Class exam, these things will come back to you.

# WHAT IS A DIPOLE, ANYHOW?

- It's just a couple of pieces of wire stuck together at the middle by an insulator.
- We will see in a later presentation, however, that the dipole hides behind many masks parading as something else.
- If you understand the premises of the dipole you can unmask these imposters.
- Don't be fooled by these imposters!

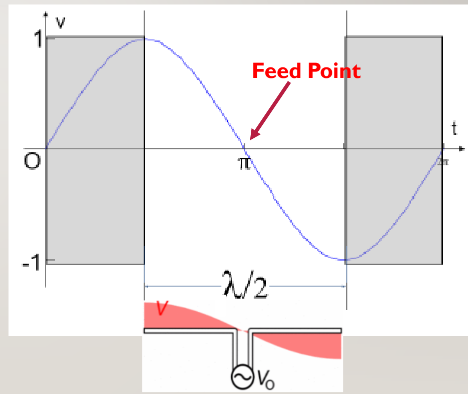


Typical example of an HF band dipole used for amateur radio

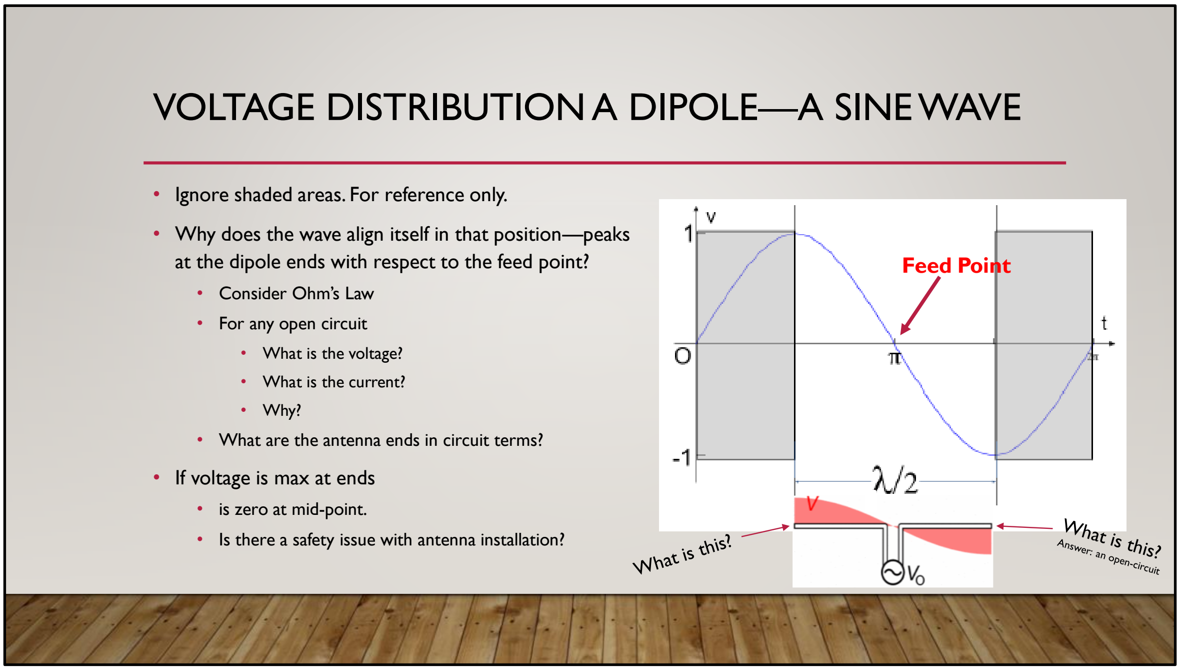
Here is a classic representation of the mighty dipole antenna. All it is, is two wires of equal length held together in the middle by an insulator and suspended at the ends. A balanced feed line connects the dipole to the ham shack transceiver and the host amateur station is happily communicating with the four corners of the globe. But many of us have heard of other antennas such as the log periodic, the bow tie, the Yagi, the loop antenna, and more. Is our friendly neighborhood amateur radio operator going to have to study all new rules for each antenna? I'm going to let YOU decide for yourself, but for now I merely offer a *suggestion* to think about: Is it possible that most all of those antennas are really… dipole antennas in disguise?

# QUICK REVIEW—LAMBDA (λ)

- For this presentation, λ (in meters) and the antenna length (in meters) are inextricably linked.
- The physical antenna length will always be linked to λ by integers or integral fractions.
- Thus to the right
  - The input signal is a constant frequency and therefore wave length (λ).
  - The antenna physical length is proportional to the input signal wave length.




The illustration here may look a little odd but it has a purpose I will explain in the following slides. Any signals delivered to an antenna will have a wave length (lambda) proportional to the physical length of the antenna. These two lengths are inextricably linked. Notice in the lower part of the illustration, a dipole antenna and in the upper part an oscilloscope-like signal <u>input</u> to the antenna. What I want you to see is the relation of the antenna length (which you can see and measure with a tape measure) is directly related to the wavelength which you *cannot* see.

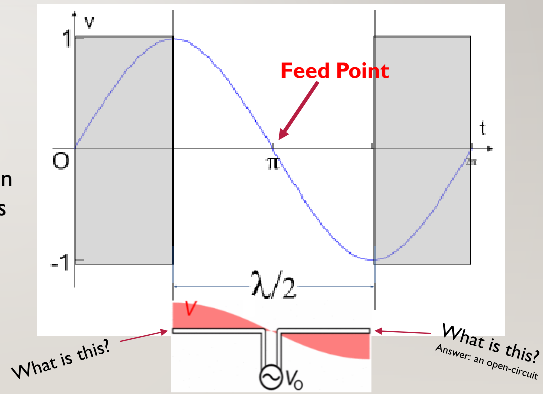



And now… Here is the rule of the road that you **<u>MUST NOT FORGET</u>**. The maximum voltage always appears at the antenna ends. But I want to go a step further. I want you to know WHY the voltage appears thusly. So tell me, has anybody here ever heard of… Ohm's Law? If so, I have some rhetorical questions (nobody please answer). What voltage appears on an open circuit output? Answer: the source voltage or maximum. Okay, next question…What is the current with an open-circuit? Answer: zero. For this next question I would like somebody to answer. What do the ends of a dipole antenna represent? Somebody, please… *(wait for a response)* Okay, if the dipole ends are an open-circuit, what voltage should we expect to see at the ends? Somebody please. *(wait for a response)* Okay, if we see a maximum Voltage at the ends, what Voltage do we see in the middle (which is the feed-point)? *(wait for a response)* This is a principle I want you to take home and remember forever. If you understand why the voltage impresses itself on a resonant antenna in this way you can figure out many aspects of the various dipole imposters such as the Yagi imposter.

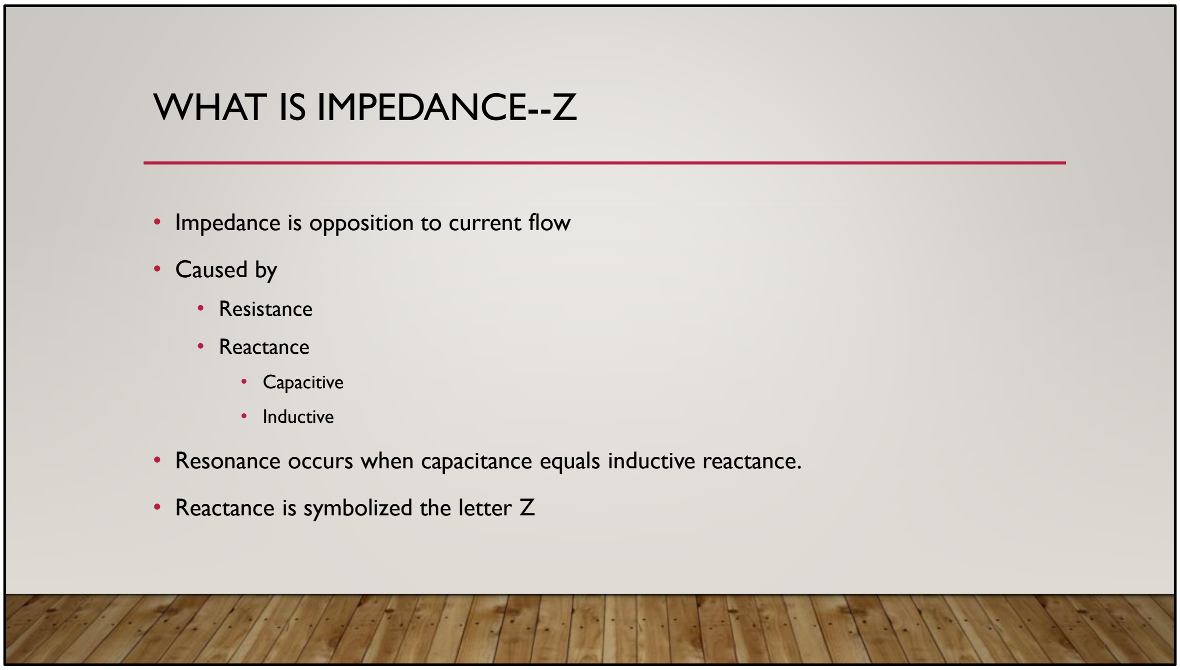
Before leaving this slide I would like to open discussion on a potential safety issue (pun intended). Knowing now that a maximum voltage appears at the ends of a dipole antenna what precautions should be taken when installing a dipole antenna?

# TAKE THIS HOME!

- The voltage
  - at the antenna ends is maximum.
  - At the feed point is zero
- You will see this again and you will need it to answer questions later in this presentation.
- This concept will be critical to recognize when we begin to examine dipole imposters such as the Yagi and J-Pole.



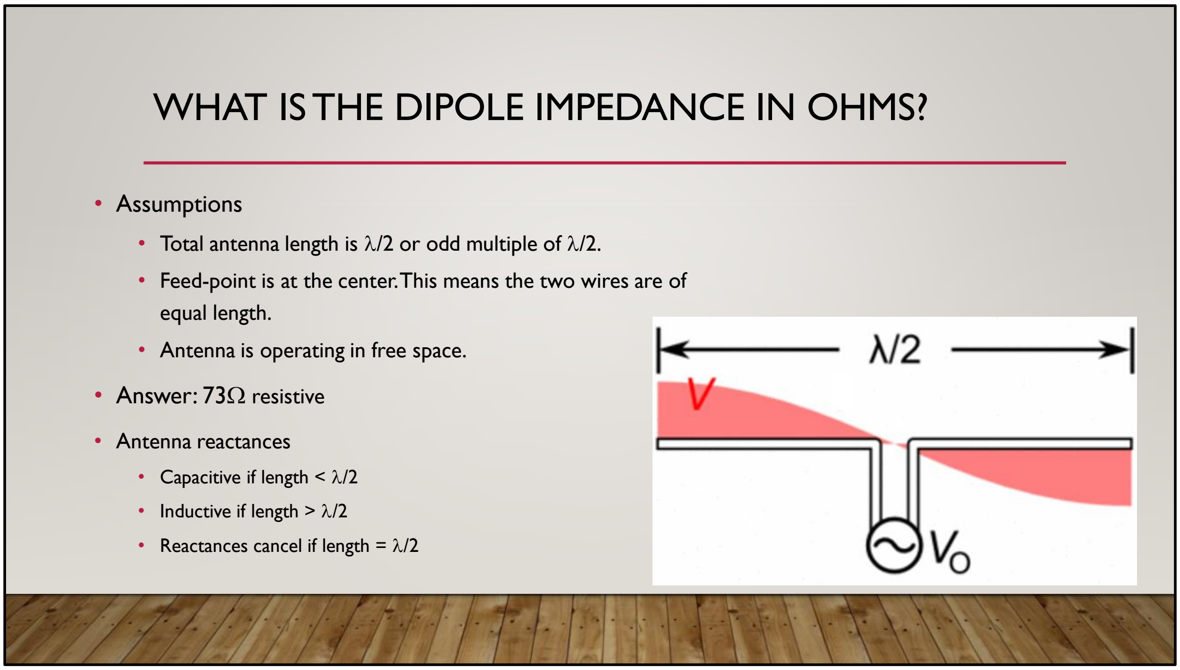

Here is what you must take home with you. When the antenna length is lambda-halves (which means it is resonant for the input signal) the voltage at the antenna ends is a maximum and it is zero at the feed-point if center-fed.




This may seem basic to some but it is covered in the FCC General Class license exam pool questions.

What does just the name “impedance” suggest to you. It is an opposition. An opposition to the flow of current. But there are two forms of impedance. We have a resistive impedance which simply is typically specified as a wire’s Ohms per thousand feet. Resistive impedance has no frequency dependence. This is another way of saying that it pays no attention to frequency or…does not react to it.

The other form of impedance is reactance. Why do you suppose it is called reactance? *(invite discussion)* Yes, the antenna is “reacting” to frequency. Further, reactance can be sub-divided between capacitive and inductive reactance. These two reactances algebraically add so that if the two reactances are equal in an antenna we have a net reactance of zero, the two have canceled each other. When the two cancel for a net zero reactance we have arrived. In an antenna this is our golden state that we like to have which is called “resonance.”



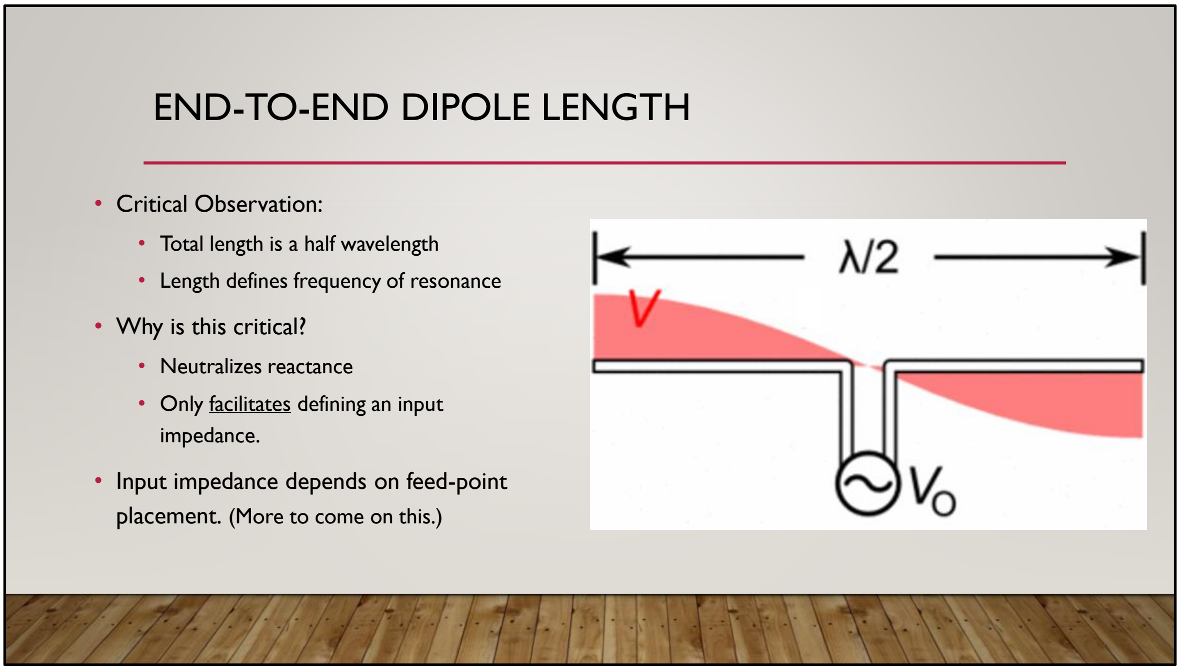

So, now, having blown through the preliminaries, we are ready to finally start talking about the mighty and very great dipole. Let's talk about the dipole input impedance.

When the end-to-end antenna length equals lambda-halves meters, any reactances cancel. That is, the capacitive reactance equals the inductive reactance. With the reactances having canceled each other all that is left is a resistance. The dipole antenna input impedance is therefore 73 Ohms resistive. But 73 Ohms assumes three conditions.

First, the end-to-end antenna length must be lambda-halves or an odd multiple of it. We are allowed one λ-halves, three λ-halves, five λ-halves, but not two λ-halves.

The second condition is that the feed-point must be at the center. What does this mean then about the two wire lengths? *(somebody please answer—they are equal)*.

Third, the antenna must be operating in free space. What is free space? Amateur extras out there, help us. *(somebody please address)*.

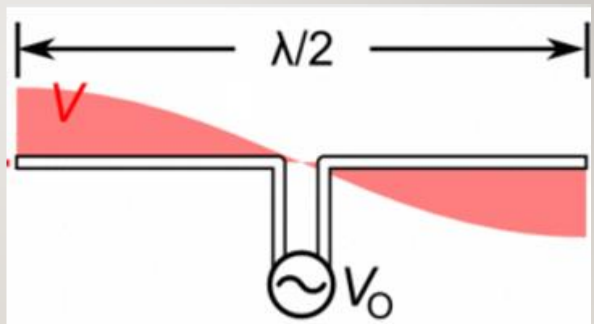



As we saw earlier, there are two components to the dipole input impedance: the resistive impedance and the reactive impedance. Further, the reactance has two components: capacitive reactance and inductive reactance, both measured in Ohms. In a sense, therefore, you could say that there are three components to the dipole impedance: 1. the resistance in Ohms; 2. the capacitive reactance in Ohms; and 3. the inductive reactance in Ohms. All three components are measured in Ohms. Together they define a NET vector quantity input impedance. This is beginning to sound complicated and is why you saw a preview slide earlier but please bear with me. It gets simple, I promise. Assuming free space, a $\lambda$-halves length, and a center-feed, the dipole impedance will always be 73 Ohms. As we have already learned, the reactances have canceled leaving only a 73 Ohms resistance.

Before we leave this slide please consider some food for thought which we will address in a few slides. What happens to the impedance if we move the feed point in either direction so that the two wires are no longer equal in length although the SUM of the two is still $\lambda$-halves? This new configuration would be called an "off-center-fed dipole." I haven't presented enough information yet to solve this but think about it for now. *Are there any comments from Technician Class licensees?*

## IMPEDANCE AT CENTER AND AT ENDS

- Consider 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
- Voltage at feed is zero and therefore results in the minimum $Z_{in}$ of 73.13Ω (assuming free space).
- Voltage at ends maximum. Resulting in roughly 2kΩ < $Z_{in}$ < 5kΩ

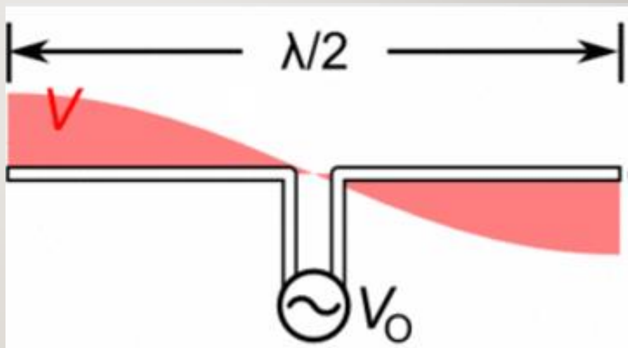



A properly configured center-fed dipole antenna input impedance is 73 Ohms. Further, 73 Ohms is a minimum assuming free space. But what is it that defines this minimum? Ohm's Law tells us that the resistance or impedance is equal to the voltage divided by the current. Since the voltage at the feed point is zero, the center-fed dipole input impedance is the minimum 73 Ohms which is as close to zero as we can get. We might be inclined to expect a zero input impedance but this is simply an attribute of the dipole antenna. It has a minimum input impedance of 73 Ohms, again assuming free space.

What then is the impedance at the antenna ends where the voltage is high and the current is zero? (talk to me).

## CRITICAL OBSERVATIONS – INPUT IMPEDANCE ($Z_{IN}$)

- $Z_{in}$ can not be less than 73.13Ω (assuming free space).
- 73.13Ω occurs only when the two wires are of equal length (center fed dipole).
- $Z_{in}$ increases when feed point is off center in either direction.
- When the two wires are of unequal length
  - $Z_{in}$ > 73.13Ω.
  - But total length still defines resonance.



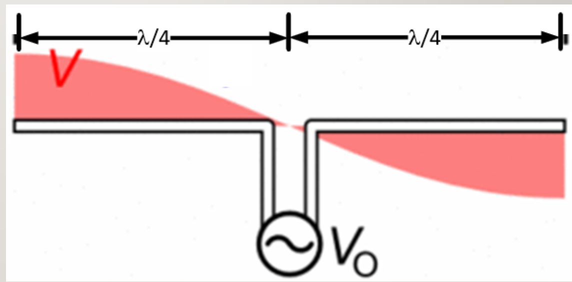

The minimum dipole impedance is 73 Ohms. It can never be less than this assuming free space. Please don't forget those words "free space" because we shall see in a future slide that when we LEAVE free space we can begin to see less than 73 Ohms.

When the feed point is moved to either end the impedance becomes a maximum. Since the current is zero at both ends the impedance in theory at either end would be infinite but in practice is usually less than 5k Ohms. As we will see in a future presentation, dipole imposters rely on these types of attributes to beguile their audiences.

When the two wires are of UNequal length the antenna is no longer center-fed. What should we expect to then see for an input impedance when fed off-center but the end-to-end length is kept to lambda-halves? (*talk to me*)

## NOBODY TOLD THE DIPOLE

- In a sense, the dipole doesn't know there is a gap. (Over simplified but true.)
- The width of the gap is mostly irrelevant for practical purposes. (Over simplified but true.)
- The signal passes through the gap as if it were butter. Really! No joke.
- Why do we know the signal is continuous?
  - Any discontinuity would produce odd harmonics of the fundamental. (Fourier Theorem)
  - Harmonics would render the dipole ineffective.

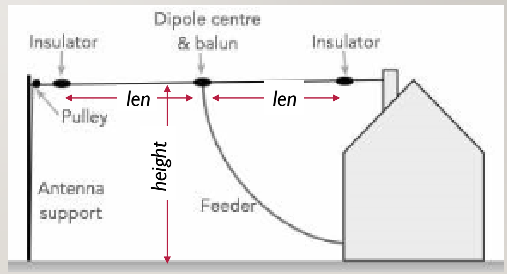



Did you ever stop to think about what is happening inside the gap? There is no electrical connection between the two wires for the configuration we have thus far described. Remember there is an insulator that connects the two wires yet I am telling you that the signal travels through the gap in a continuous fashion. So, how can we be certain of this? The easy way to explain this is by observing that any discontinuity in a signal generates harmonics. We know that the dipole antenna does not generate harmonics, else it would not work.

Another consideration is that the signal source, $V_o$, provides a shunt path through the gap.

## HANDS ON: LET'S MAKE US A DIPOLE

- Identify a frequency to resonate at: $f_o$ = 7 MHz corresponding to $\lambda_o/2$ = 21.43 meters.
  - $\lambda_o = 300/f_o$ = 42.86 meters
- Measure the dipole gap: gap = 0.27 meters (27 cm).
- Solve for the required length for each wire.
  - If $\lambda_o/2 = [2\,len + gap]$
  - then $len = \frac{\lambda_o/2 - gap}{2} = \frac{1}{2}(21.43 - 0.27) = 10.58\ meters$
- Our antenna should resonate nicely at 7 MHz with zero reactance for a net 73 Ohms input impedance.
- We were able to mount the dipole at a height above the ground plane of 23 feet which is 7.0 meters.

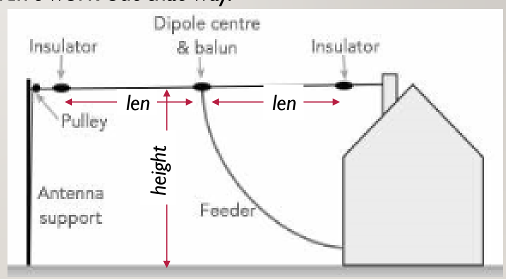



We have decided to make a dipole antenna that will allow us to operate on the 40 meter amateur allocation at 7.00 MHz which corresponds to a wave length of 43 meters. The insulator used for our gap that ties the two wires together measures 27 centimeters. Let's write an equation for the dipole from what we know. We know that the end-to-end length is Lambda-halves. We also know that the dipole consists of two equal length wires plus an insulator. Therefore, two of those lengths plus a gap IS the end-to-end length or lambda-halves. We can then algebraically rearrange that equation to solve for the length of each wire. Doing so we find that each wire must be ten and a half meters. After mounting the dipole we measured its height above ground at 23 feet. We should now be able to confidently measure 73 Ohms resistive with a 7.00 MHz input signal. Or can we…

You amateur extras… talk to me. Do you see anything unaccounted for?

# MEASUREMENTS OF OUR HOME-MADE DIPOLE

- Measurements are indicating that our home-made dipole is
  - $f_o$ = 6.75 MHz, not 7.0 MHz
- We were off on the resonant frequency but you would think that with an input signal at 6.75 MHz we would have 73 Ohms input impedance. It didn't work out that way.
  - $Z_{in}$ = 48 Ohms, not 73 Ohms
- Our dipole is too long leaving it with a net inductive reactance at our intended 7.0 MHz.
- What went wrong?



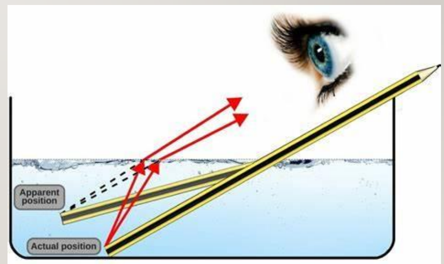

Taking measurements on our home-brew we found that the antenna was resonating at a lower frequency than what we had designed for. But to make matters worse, you would think that if we then put in that resonating frequency of 6.75 MHz that we would see our input impedance of 73 Ohms. However, we measured 48 Ohms, not 73 Ohms.

Talk to me you amateur extras. Where might we look to account for these discrepancies? First, why 6.75 MHz instead of 7?

Second, why 48 Ohms at 6.75 MHz in stead of 73 Ohms?

## WOULD SOMEBODY EXPLAIN THE SPEED OF LIGHT

- What do you see when you put a pencil in a glass of water?
- There is an illusion that the pencil sharply bends at the water interface.
- Why is that?
- The speed of light in
  - free space: 299.79e6 m/sec
  - Earth's atmosphere: 299.70e6 m/sec
  - Water: 225.00e6 m/sec
- Introducing the "velocity factor."




We all remember in grade school when we stuck a pencil in a glass of water and observed the illusion of the pencil bending. We learned in the 4th grade that this is because the speed of light in water is slower than the speed of light in air. So also is the case with electrical wire such as we used with our home-made dipole antenna. Electricity always flows at the speed of light. In free space it is one thing, but in an electrical wire the speed of light is slightly less. The difference in the speed of light between air and electrical conductors is slight but significant nevertheless. We account for the difference with a convenience we call the "velocity factor." While the velocity factor sounds complicated, it turns out that it makes life simple, really.

## WHAT IS THE "VELOCITY FACTOR," ANYHOW?

- Velocity factor is merely a convenient way to express the speed of light relative to its speed in free space.
- If the velocity factor of a given wire is 0.92 it means electricity travels down that wire at 299.79e6 x 0.92 = 275.81e6 meters per second.
- Velocity factor is specified as a ratio from zero to unity or as a percentage from zero to 100%.
  - $0 < vf < 1.0$ or $0 < vf < 100\%$

All that the velocity factor is supposed to do is relate the ratio difference in the speed of light in free space to the speed of light in a medium such as electrical wire. In so doing we skip the complicated numbers. A velocity factor can never be greater than unity since the speed of light can never travel faster than it does in free space.

## THE SPEED OF LIGHT DID IT! TIME TO FIX THINGS

- We must modify the equation to account for the decreased speed of light. We introduce the "velocity factor," vf.
- A corrected lambda therefore becomes: $\lambda_c = \frac{300}{f_o} vf$
- Assuming vf = 0.94 for the wire we used
  - $\lambda_c = \frac{300}{7} 0.94 = 40.23\ meters\ \ \cancel{42.86\ meters}$
  - $len = \frac{\lambda_c/_2 - gap}{2} = \frac{1}{2}(20.14 - 0.27) = 9.94\ meters\ \ \ 10.58\ \cancel{meters}$
- We shortened both wires and took our measurement again. Our resonant frequency is now right on at 7.00 MHz.
- But the input impedance is 48 Ohms again.

| VF (%) | Transmission line |
|---|---|
| 95–99 | Open-wire "Ladder" Line |
| 82 | RG-8X Belden 9258 coaxial cable (foamed polyethylene dielectric) |
| 77 | RG-8/U generic (foamed polyethylene) |
| 66 | RG-213 CXP213 (solid polyethylene dielectric) |

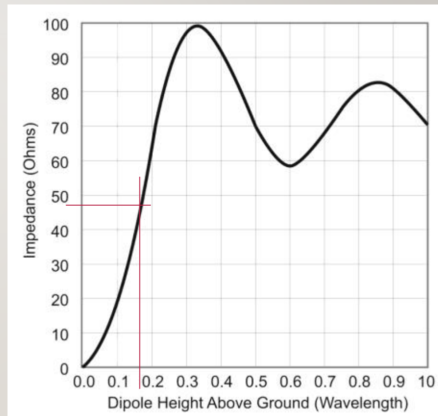
Recognizing that we need to allow for a decreased speed of light we can then solve for a new length. The wire we are using is specified to have a velocity factor of 0.94 resulting in a corrected wave length of 40.23 meters. A corrected wire segment length is then solved for as 9.94 meters.

Having adjusted the two wire lengths and put the adjusted dipole back up at 23 feet again we made our measurement again and now finally realize resonance at the designated frequency of 7.00 MHz.

But there is still something wrong. We are still measuring an input impedance of 48 Ohms when we know that a dipole cannot have an impedance less than 73 Ohms. I'm calling on you amateur extras again who already know all human knowledge. Speak to us. Help us understand where we went wrong.

## HEIGHT ABOVE THE GROUND PLANE

- We mounted our antenna at 23 feet above ground which is 7.0 meters.
- The curve plots input impedance as a function of the height above ground plane relative to the resonant wave length, $\lambda_o$ = 40.29 meters
- The relative height above ground is therefore
  7.0/40.29 = 0.17
- 0.17 on the chart corresponds to 48 Ohms.



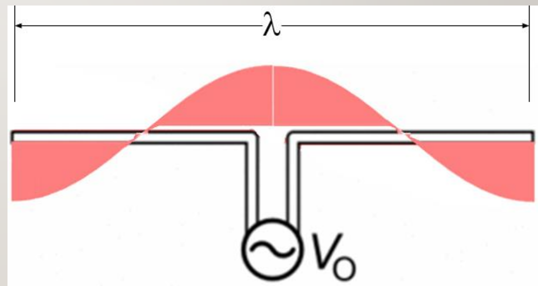

It is usually not practical to operate a dipole in free space. The dipole needs some distance between its feed point and the ground plane. It can only realize 73 Ohms in free space and our dipole is mounted only 23 feet (or 7 meters) above ground.

To understand the chart, the horizontal axis represents a “number of wavelengths” relative to the antenna’s resonant wavelength. Relating it to our home-brew antenna, if we had mounted the feed-point at a height equal to the resonant wave length which is 40 meters or 131 feet, the impedance would be about 70 Ohms. If we had mounted the feed point at 0.33 wavelengths which is 43 feet, the impedance would be 100 Ohms.

So since our actual mount height was 23 feet which is 7.0 meters and therefore only 0.17 wavelengths, the chart indicates that we should expect to see 48 Ohms which corresponds to our observations.

## UP INPUT FREQUENCY TO 2X FUNDAMENTAL

- When we double the frequency, our home-brew dipole now becomes 2 $\lambda/2$ (which is $\lambda$) wavelengths. Twice as many half-waves fit on our dipole contraption.
- This new frequency is a harmonic of the original. What harmonic?
- What happens to the input impedance?
- What happens to the resonance?




Let’s pull a fancy trick on our home-brew dipole antenna. We double the frequency input from 7 to 14 MHz. This then allows a second half-wave to impress itself on the antenna. The antenna now assumes a new name. We can call it a “full-wave center-fed dipole.” But remember that we didn’t make any changes to the physical makeup of the antenna, all we did is dial up the input frequency. When we doubled the input frequency we presented to the antenna its…second harmonic.

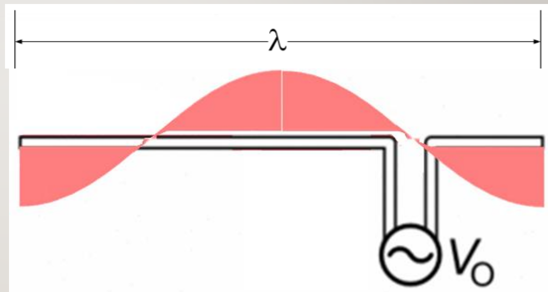
Why do we know that the voltage maximums still appear at the antenna ends with a full-wave dipole? *You amateur extras keep quiet.*

If a voltage maximum is appearing at the input, what is the resulting input impedance given this second harmonic input?

What happens to resonance?
As long as there are x half-wavelengths the reactances will cancel leaving only a pure resistance. The antenna can resonate nicely. But that doesn’t mean it can RADIATE. There is a major problem we have not discussed. Amateur extras…please help me.

## BUT WHAT IF WE MOVE THE FEED-POINT?

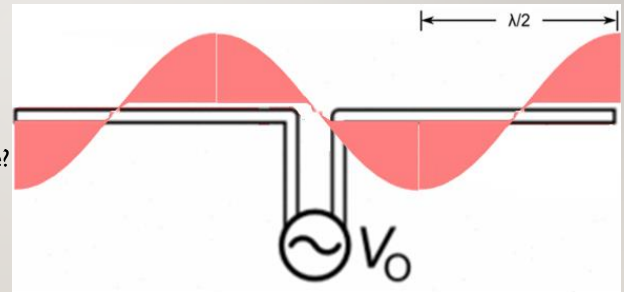
- This is still a full-wave dipole, nobody cut nut'n.
- $Z_{in}$ can now assume 73 Ohms.
- Two positions for feed exist which will give low $Z_{in}$.
- **But it still won't work**—transfer RF energy for propagation. Why?




We can move the feed point off-center corresponding to the middle of one of the half-waves. Here the voltage is a minimum and our theoretical 73 Ohms can be realized. But we are still left with the problem of the two half waves canceling each other such that although the antenna resonates, no RF is radiated. In another presentation we will look at how the J-Pole imposter utilizes this effect with great advantage.

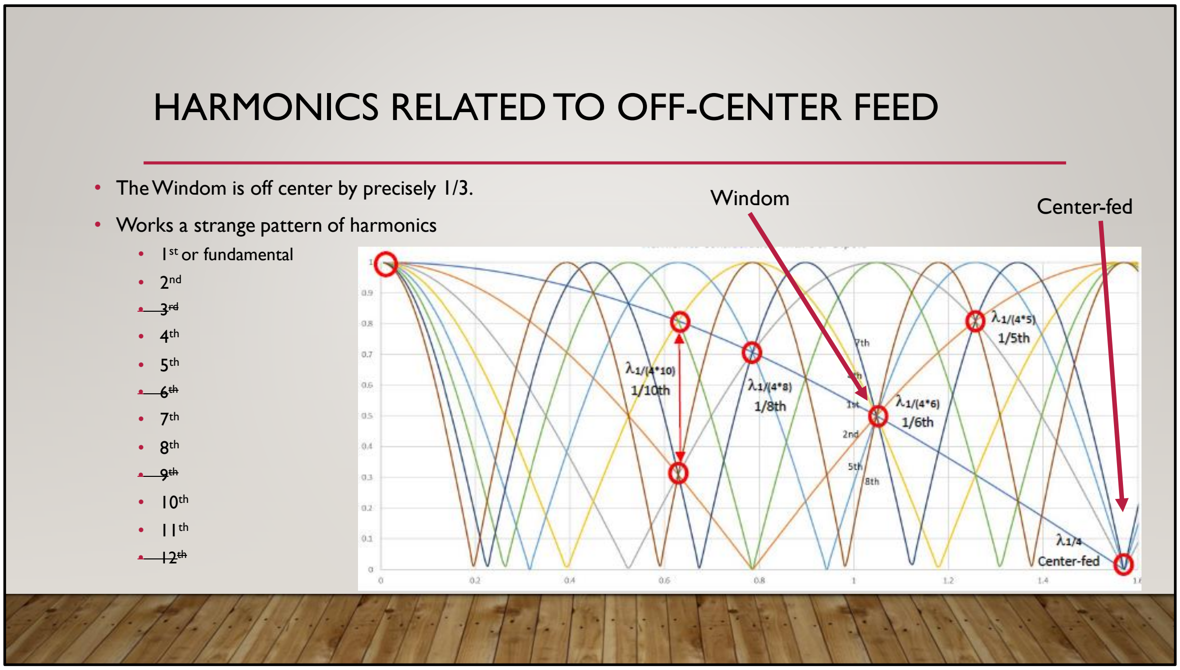
## UP INPUT FREQUENCY TO 3X FUNDAMENTAL

- Dial up the input frequency 3x the fundamental – from 7 MHz to 21 MHz.
- What is another name for this new signal?
- There are now three positions for feed which will give low $Z_{in}$.
- **Now it will work**—Why?
- What would happen if we dialed up the input frequency to 4x, then 5x, and more?
- How many odd x'es can you go?




If we add a third half-wave by tripling the fundamental input frequency we remain resonant but now we can radiate since there are an odd number of half-waves avoiding cancelation.

We have now shown that the dipole will in theory work for not only the fundamental but its odd harmonics. But let's go beyond that. How many harmonics CAN it accommodate? How about 11x, 21x, 101x, 1001x? You amateur extras… talk to me.




Warning. The information now being discussed is not covered in any way by the FCC pool questions for the general (or any) class exam. This is being presented purely for the interest of those advanced amateurs who have not hung up yet on the conference. It could easily the subject of an entire presentation but ONLY for committed theoreticians. I will only discuss it briefly here. The illustration is my own invention and admittedly it is very hard to follow. It is a screen capture of an Excel worksheet so the numerical resolution is weak.

The dipole does nicely with odd harmonics but ONLY WHEN CENTER-FED! When you move the feed point anywhere from the center in either direction the whole ball game collapses and harmonics are the big loser. BUT…and this is the big but…such a dipole is good at harmonic rejection making it improved for the fundamental frequency.

In the illustration, the horizontal represents a relative distance from the dipole center. The extreme right IS the dipole center. Each curve represents a harmonic from 1 to 8. The blue curve is the fundamental or harmonic #1, the brown is the second harmonic #2, and so on. At many various places some of the curves converge, sometimes 2, sometimes 4 signals and so on. Not all convergences are circled, only the notable ones. Notice that there are no cases of a near-miss. When signals converge it is with mathematical precision. So, where any two or more signals converge, a dipole off-center fed by that corresponding distance will accommodate those harmonics.

Notice that at the center-fed position on the extreme right, all of the odd harmonics converge corresponding with what we learned about the dipole. Then notice the famous Windom dipole which is off-center fed at one third. Look at its very interesting and rich harmonic coverage.

I will entertain questions but only briefly. This thing is way too complicated to spend much time on.

## IN REVIEW

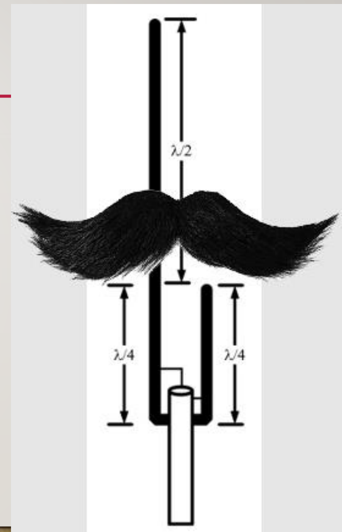
- Voltage is
  - Minimum or zero at center
  - Maximum at ends
- Dipole length is $\lambda/2$ or integer odd multiples of it end-to-end including gap.
- Input impedance
  - 73 Ohms minimum assuming free space and a center feed
  - Increased when fed off center.
  - Reduced with proximity to ground
- Velocity factor accounts for reduced speed of electricity in conducting media relative to free space affecting the required antenna end-to-end length.

Here is what I want you to take home. If you understand these things you can make sense out of what was presented and you will be well established in analyzing most any dipole imposter that comes your way.

Concerning the voltage: it is maximum at the ends, minimum at the center where half-waves are concerned. The dipole end-to-end length is lambda halves or odd integer multiples of it. The input impedance for a center-fed dipole is 73 Ohms in free space. However, since it is not usually possible to operate a dipole in free space, the distance to the ground plane must be considered. When you shift the feed point in either direction, while keeping the end-to-end length unchanged, the input impedance increases. The velocity factor provides an easy way to correct for antenna end-to-end lengths depending on the type of wire used.

## IN A FUTURE PRESENTATION:

- In a future presentation we will critically examine the J-Pole imposter.
- We will rip off his moustache to reveal his TRUE identity.
- But this will only be possible if you first understand why a dipole
  - does what it does and
  - Why it does what it does.
- See you in a follow up presentation!




In a future presentation we will be looking at the J-Pole imposter. We are going to see that it is really just a dipole in disguise but with some clever quirks.

# THE MIGHTY DIPOLE (PART I)

QUESTIONS

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## GENERAL CLASS EXAM POOL QUESTIONS

- This presentation has covered upwards of a dozen amateur General Class exam questions.
- If you understand this presentation you will answer those questions with confidence.

## GENERAL CLASS ANTENNA – G9A04

- What might cause reflected power at the point where a feed line connects to an antenna?
  - Operating an antenna at its resonant frequency
  - Using more transmitter power than the antenna can handle
  - A difference between feed-line impedance and antenna feed-point impedance
  - Feeding the antenna with unbalanced feed line

## GENERAL CLASS ANTENNA – G9A07

- What must be done to prevent standing waves on the antenna feed line?
  - The antenna feed point must be at DC ground potential
  - The feedline must be cut to a length equal to an odd number of electrical quarter wavelengths
  - The feed line must be cut to a length equal to an even number of physical half wavelengths
  - The antenna feed point impedance must be matched to the characteristic impedance of the feed line.

## GENERAL CLASS ANTENNA – G9A09

- What standing wave ratio will result when connecting a 50 Ohm feed line to a non-reactive load having 200 Ohm impedance?
  - 4:1
  - 1:4
  - 2:1
  - 1:2

# GENERAL CLASS ANTENNA – G9A10

- What standing wave ratio will result when connecting a 50 Ohm feed line to a non-reactive load having a 10 Ohm impedance?
  - 2:1
  - 50:1
  - 1:5
  - 5:1

# GENERAL CLASS ANTENNA – G9A11

- What standing wave ratio will result when connecting a 50 Ohm feed line to a non-reactive load having a 50 Ohm impedance?
  - 2:1
  - 50:50
  - 1:1
  - 0:0

## GENERAL CLASS ANTENNA – G9B07

- How does the feed-point impedance of a ½ wave dipole antenna change as the antenna is lowered below ¼ wave above ground?

## GENERAL CLASS ANTENNA – G9B08

- How does the feed point impedance of a ½ wave dipole change as the feed point is moved from the center toward either end?

## GENERAL CLASS ANTENNA – G9B10

- What is the approximate length for a ½ wave dipole antenna cut for 14.25 MHz?

## GENERAL CLASS ANTENNA – G9B11

- What is the approximate length for a ½ wave dipole antenna cut for 3.550 MHz?

# GENERAL CLASS ANTENNA – G9B12

- What is the approximate length for a ½ wave dipole antenna cut for 28.5 MHz?

# GENERAL CLASS ANTENNA – G9D02

- What is the feed-point impedance of an end-fed half-wave antenna?

# GENERAL CLASS ANTENNA – G9D11

- Which of the following is a disadvantage of multiband antennas?
  - They present low impedance on all design frequencies
  - They must be used with an antenna tuner
  - They must be fed with open wire line
  - They have poor harmonic rejection

## GENERAL CLASS ANTENNA – G0A06

- What precaution should be taken when installing a ground-mounted antenna?
  - It should not be installed higher than you can reach
  - It should not be installed in a wet area
  - It should be limited to 10 feet in height
  - It should be installed such that it is protected against unauthorized access.

# GENERAL CLASS ANTENNA – G4B11

- Which of the following must be connected to an antenna analyzer when it is being used for SWR measurements?
  - Receiver
  - Transmitter
  - Antenna and feed line
  - All these choices are correct

# GENERAL CLASS ANTENNA – G4B13

- What is a use for an antenna analyzer other than measuring the SWR of an antenna?
  - Measuring the front-to-back ratio of an antenna
  - Measuring the turns ratio of a power transformer.
  - Determining the impedance of coaxial cable
  - Determining the gain of a directional antenna.

## GENERAL CLASS ANTENNA – G5A07

- What happens when the impedance of an electrical load is equal to the output impedance of a power source, assuming both impedances are resistive?