Brass Tacks

An in-depth look at a radio-related topic



Frequencies and wavelengths (introduction to the radio spectrum)

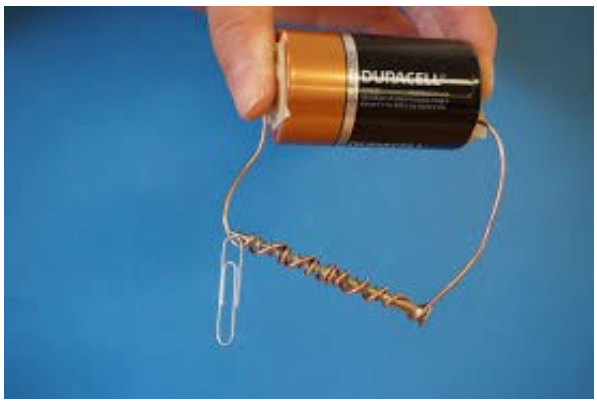
Four years ago we published a one-page summary on the general meaning and definitions of frequencies and bands, but that short article did little to answer the more in-depth questions by the technically curious. This time, let's provide a little more insight on the topic without detracting from the relevant simplicity of the previous article.

To most mortals, the technology of radio is pure magic, enabling one to communicate with another through thin air, as it were. To understand this medium of radio requires some fundamental discussion, which provides the "in-depth" part. But keeping it within the grasp of those who are unfamiliar with the physics is a challenge, due to confining the discussion to within the "introduction" scope as titled.

Start with fields

You've no doubt used a permanent magnet to pick up paper clips or stick notes on a fridge door. It can do so because of an invisible ***magnetic field***. You've also likely seen that magnets not only attract each other, but in certain orientations they repel each other. This means magnets have a ***positive side*** and a ***negative side***, or as we called them in elementary school, a north pole and south pole. You really can't see the magnetic field, but you know it's there, as evidenced by its attraction and repulsion to other magnets.

Another force field that's equally important but not as obvious is the ***electric field***. You can see its effects by rubbing a balloon on a cat, then using the balloon to pick up small bits of paper right afterwards. The balloon collected static electrical charges from the cat, then the balloon's negative electric field attracted the positive electric fields on the paper bits, picking them up.



The permanent magnet is "permanent" because its magnetic field strength doesn't change for a given distance from the magnet. You might also recall that you can create a magnet by winding a wire around a nail, for example, then connecting a battery across the wire. The nail then acts as though it's a permanent magnet while the battery is supplying electrical energy to the wire, and we call that an ***electro-magnet***. In fact, if you reverse the battery across the wire, the nail will still act like a permanent magnet, but with opposite polarity, so that if it attracted one side of a permanent magnet before, it'll now repel that same side of the permanent magnet.

Time for a change

The battery in our magnet experiment produces DC (direct current), meaning that ideally its

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voltage never changes, and electric current from the battery only flows in one direction. This time, let's replace the battery with the wall socket (please don't try this at home!), which supplies AC (alternating current), meaning that its voltage is constantly increasing, then decreasing, reversing, increasing again, then decreasing again, reversing again, and coming full circle, starting the cycle over.

The effect of AC on our little electro-magnet causes its magnetic field strength to increase, decrease, reverse polarity, increase in the opposite direction, decrease, etc. Now's when the magic starts happening. It turns out that a special natural law tells us ***where there is a changing magnetic field, there will always exist a changing electric field that runs along with it***. Furthermore, that changing electric field will change in perfect rhythm with the magnetic field.

Frequency

Using the AC from your wall socket, then, your electro-magnet can now pick up paper clips and drop them many times a second. How many times a second? Well, the American home wall socket electricity is rated for 60 cycles per second, or 60 hertz (Hz) the way we abbreviate it. This means the strength of your electro-magnet connected to the wall socket will increase, decrease, reverse direction, increase in that direction, decrease, reverse direction again, 60 times every second. We refer to the number of these complete cycles every second as the ***frequency***.

The frequency of your wall socket electricity, 60 Hz, is sufficiently high for most household applications, such as refrigerator motors and fluorescent lights, but very low compared with what's needed for radio. The frequencies of AC that's required for most amateur radio transmission and reception is known as ***RF***, or ***radio frequency***, and is summarized in this table:

Frequency range	Abbreviation	Name	Spelled out
3,000,000 Hz to 30,000,000 Hz	3 MHz to 30 MHz	HF	High Frequency
30,000,000 Hz to 300,000,000 Hz	30 MHz to 300 MHz	VHF	Very High Frequency
300,000,000 Hz to 3,000,000,000 Hz	300 MHz to 3000 MHz	UHF	Ultra High Frequency

That's a lot of goings back-and-forth every second, but that's what's been allocated to us amateurs by the FCC. There are a few allocations in other frequencies, but this table covers the great majority of what we use. For example, some repeaters operate on 146.760 MHz or 147.340 MHz, so according to the above table, they are ***VHF repeaters***.

As this alternating current reaches the antenna, it produces both a constantly changing electric field and a constantly changing magnetic field as we had previously described, The fields increase and decrease at the same rate, and are emitted (sent out) from the antenna ***at nearly the speed of light***. As the fields pass some stationary point, they measure positive, neutral, negative, neutral, positive, etc., just as the signal did in the wire, except now it's moving through the air.

Even though the fields are traveling at nearly the speed of light, their rate of change as measured at the stationary point can be slow or fast. This rate of change reflects the cycles that de-

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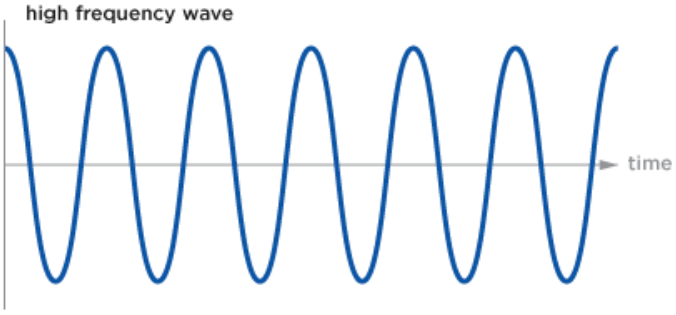
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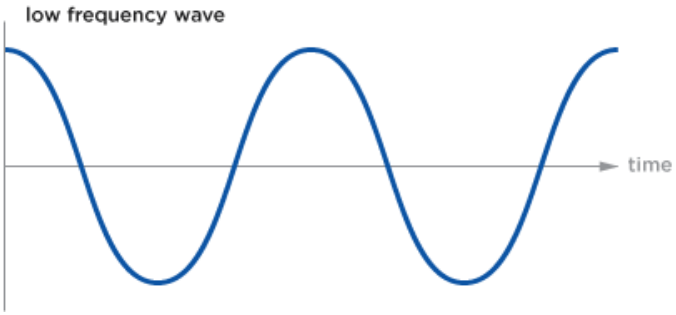
fine the frequency, so it changes at the same frequency. Another name for these tandem traveling fields is a ***radio wave***.

Wavelength

When I was a kid, I used to watch long trains of coal cars go by, and sometimes I would focus on a tall tree on the other side of the train. The tree would appear, then disappear for awhile, then reappear between the coal cars. I recognized that I was seeing the tree appear at a particular rate, or frequency.



A couple of hours later, I would watch a passenger train come by at about the same speed, but because the train was pulling pullman cars, which were longer than coal cars, I would see the same tree less often, or at a slower rate. Even though the speed of both trains was the same, the frequency that I saw the tree was higher with the coal train because the coal cars were smaller. By the same token, the frequency that I saw the tree was lower with the passenger train because the pullman cars were longer.



Each time a high positive point of the radio wave strikes an object, like an antenna, is like the moment I can see the tree between the train cars. This means the higher the radio wave frequency, the closer together the high positive points of the radio wave strikes the object. This "closer together" measurement is known as the wavelength. Just like with the train, the lower the frequency, the greater the wavelength, and vice versa.

As mentioned, radio waves travel through the air at nearly the speed of light, which is about ***300,000,000 meters per second***, continuously cycling positive and negative. As the traveling waves strike an object, it does so at the same frequency it left its source. In fact, we now know that ***the wavelength of a radio wave is the speed of light divided by its frequency***. In other words, the frequency of a radio wave times its wavelength is the speed of light.

frequency times wavelength = speed of light

The problem to be solved

Let's approach the next topic by solving a problem, which in this case is the ability to communicate between point A and point B using radio waves. Radio waves are nothing more than invisible light, kind of like infrared light, except to create infrared light, you only need to connect a battery to an infrared light bulb, and it shines invisible light. But radio waves must be

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generated by more than a mere battery and a light bulb.

The oscillator

To create a radio wave, we first start inside your radio with an electronic circuit known as an ***oscillator***. An oscillator does nothing more than create a steady ***signal***, or AC electricity we discussed previously, only at HF, VHF, or UHF frequency. Another circuit accepts our voice that we speak into a microphone, and turns the voice into another electrical signal.

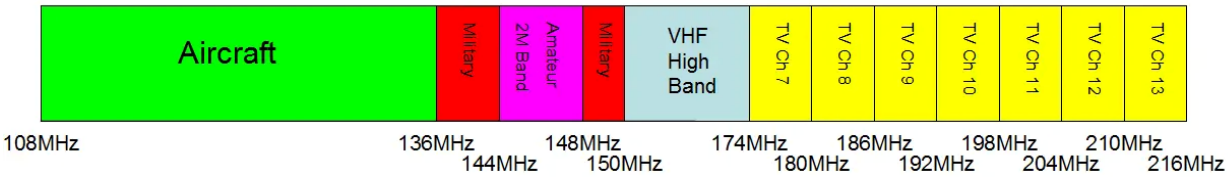
The oscillator signal and the microphone signal combine (a process called ***modulation***) to create a new signal, called the ***modulated signal***. Your radio filters (cleans up) the modulated signal a little, amplifies it (boosts its power), then sends it to an antenna, which converts the electrical signal into radio waves, which are sent through the air in all directions.

If your radio is point A and the radio of your friend is point B, your friend's radio will receive the radio waves that your radio just sent everywhere. Its antenna will convert the radio waves into an electrical signal, your friend's radio will ***demodulate*** the electrical signal, reproduce the voice electrical signal, present it to your friend's radio speaker, and your friend will hear your voice.

Bands

Referring to a radio wave frequency grouping as "VHF" is rather ambiguous because it covers the 300 MHz through 3000 MHz range, as was mentioned. It's also a little cryptic, because it has little relevance to our daily experience. To help identify which sub-range of frequencies our radios are using within VHF, people have decided to divide the VHF range by names called roughly by wavelength.

The frequency range supported by most handheld radios is between 144 MHz and 148 MHz, and we call that range a ***band***, because it looks a little like a horizontal strip resembling a headband:



Recall that the wavelength of a radio wave is the speed of light divided by its frequency. This way, the wavelength of a 150,000,000 Hz (150 MHz) radio wave is

300,000,000 ÷ 150,000,000 = 2 meters

and because the range of frequencies used by most of our handheld radios is between 144 MHz and 148 MHz, which is close to 150 MHz, we call that range the ***2-meter Band***. Many of our handheld radios also support the frequency range from 420 MHz to 450 MHz, and since

300,000,000 ÷ 428,000,000 = 0.7 meters = 70 centimeters

we call that range the ***70-cm band***.

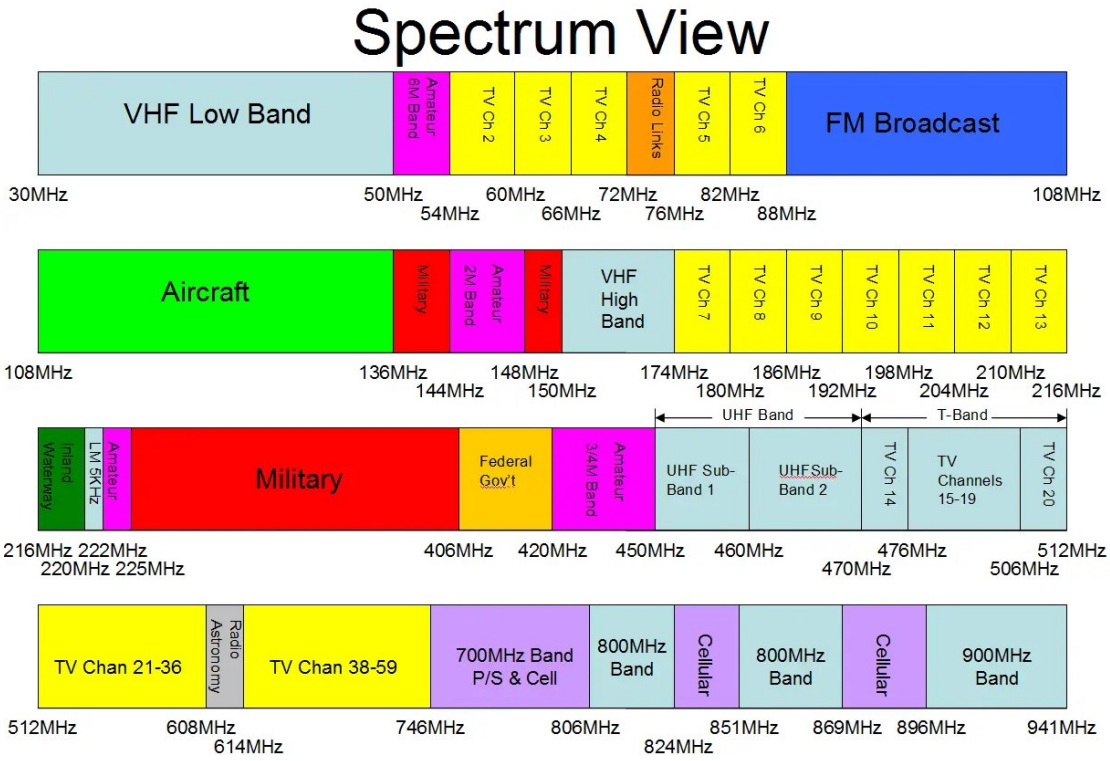
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The radio spectrum

If we combine all the radio frequency bands into a single grouping, we refer to that collective range the radio ***spectrum*** because of how it appears on a chart if all the different bands were represented by colors. It's a visualization of multiple ranges on a single graphic:



In general, when people refer to the *radio spectrum*, however, they tend to mean *all* the frequencies, not just HF, VHF, and UHF ranges.

Summary

Starting with the concepts of a magnetic field and an electric field as fundamentals, if we use alternating current to generate a changing magnetic field, natural laws state that it results in a similarly changing electric field. Frequency is the number of complete cycles per second the field is changing. Given the speed of a wave, the wavelength is the length between periodically recurring points on a wave, such that the wavelength is the speed of the wave divided by its frequency. Because radio waves travel the speed of light, its wavelength is the speed of light divided by its frequency. Bands are named for their relative wavelengths.

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