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VHF and UHF Propagation

by
W3IHM

One thing led to another with my last fox hunt article. Some seemed to be hungry for more knowledge on how RF signals could “do that”. So, I thought it would do us all some good to expand a bit on RF propagation, especially where most foxes are found, in the VHF and UHF frequencies.

Let’s say you are a fresh licensee. You just got your license, and were hungry to get on the air. So you bought a VHF/UHF handy talkie, thought about some sort of antenna, and hooked up your microphone. Let’s say you also spent some time on the WWW, set up and used Chirp, and loaded all sorts of repeater frequencies and PL tones into your new U/VHF rig. You didn’t put too much thought into your antenna, though, but maybe you just used whatever came with the HT for now, as you are somewhat reticent about drilling holes, erecting towers, or whatever around the house.

So how far can this thing hear and send? That’s usually what we hams think about first. What do we expect to hear from this setup? How will the signals come and go from this radio? What repeaters can we hit with it?

Let’s introduce some basics. I could just launch in to a diatribe about how well an HT will do while sitting in your easy chair, but let me try to teach you some generalities instead. Lots of past people before us have been thinking about this for the past 100 or so years, too, so maybe we should give them a listen. Our “democracy of the dead” may have something to teach us newbies.

Humans have spent a lot of time brooding, arguing, experimenting, and theorizing about RF energy in the past 100 years. Remember, that radio is really quite a new thing. When people do this kind of time wasting, many times they come up with mathematical descriptions on paper. These mathematical models usually have to assume a vacuum, antennas above perfect ground, or free space, and perfect conductors, among other assumptions. This is really because things otherwise get real complex and unsolvable real fast, and we want to do *something* with our mathematical models, so we mostly play at the edges, make assumptions that make things work out, and stay where it is safe.

If you are a recurrent reader, you may be thanked, have your head examined, or whatever, but you also very well may recall that in the EFHW article, I showed Maxwell’s equations in the point form. James Clerk Maxwell had a splendid beard, but he also came up with a set of like 18 equations that were later vectorized by Oliver Heaviside, who had no appreciable beard, into four compact vector equations being something like this, viz.

$$\begin{aligned} \text{curl } \mathbf{H} &= \dot{\mathbf{D}} + \boldsymbol{i} \\ \text{curl } \mathbf{E} &= -\dot{\mathbf{B}} \\ \text{div } \mathbf{D} &= \rho \\ \text{div } \mathbf{B} &= 0 \end{aligned}$$

Where:

$$\begin{aligned} \mathbf{D} &= \epsilon \mathbf{E} \\ \mathbf{B} &= \mu \mathbf{H} \\ \boldsymbol{i} &= \sigma \mathbf{E} \end{aligned}$$

I don’t expect you to have any idea what any of this deluxe vector field gobbely-dee-gook means, but it is a mathematical model of electromagnetic energy behavior. This was significant.

Remember that these guys were around before really useful things like cat videos on YouTube and arguing with each other on social media, so a few of them occupied their minds with manipulating math equations. I want you to notice this last blob of whatever, with the ϵ , μ , σ in them. Those ϵ , μ , σ really describe the matter or whatever else that the electromagnetic energy encounters. Let’s focus on that.

Now these nice vector models are somewhat of an oversimplification, in that it takes all of God’s infinite unknown time-space continuum creation, and boils it down into three constants, but even that can sometimes be useful, mostly because we homo-sapien-sapiens are actually not that wise. Remember that a grossly over simplistic model often allows us to do some real

calculations to get our mathematical abstraction feelings around what happens in our real world of taxes, coffee, car insurance, and knee surgeries.

So what happens when trapped electromagnetic energy goes through space and time? Well, these waves can do a few things. They can be:

Absorbed, modified and re-radiated, or dissipated in the material somehow.
Reflected, refracted, twisted, or bent away from the matter or material.
Transmitted through, or penetrate the matter or material, and pass through.

This happens whether the material is solid, liquid, gas, or plasma. Plasma? What's that? It is the fourth state of matter we regularly come into contact with. In fact, plasma is one we actually are all familiar with on HF. The ionosphere, or Heavyside layers, (same guy as above) are a cloud of gaseous ions, which is what is known as a plasma. To much joy of us hamsters, this plasma just so happens to look quite reflective at certain RF frequencies, mostly in the HF range, at certain times of day or night. That is why we hamsters focus on solar indices, sunspots, and solar winds, etc, but I digress.

I also digress, but would like to study the effects of supercritical matter on electromagnetic radiation, but again, I digress. Maybe I will do this in my garage sometime….

OK, ok, ok, but what of vacuum? Well, there is even some effect of RF energy passing though "nothing". Again, Maxwell. And his excellent beard came up with this. And that is where the "speed-o-light" stuff comes in. In fact, I showed this equation, awhile back, so here it is again:

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

Look! There's some of those μ_o, ϵ_o symbols in there, like before. Right this second, there are currently a bunch of people trying to make this mean something, with ideas like the "quantum foam", but, we don't really know quite what a vacuum is right now. It apparently does things to electromagnetic radiation, like perhaps limit it's speed? Yeah, but why? Well, as for me, I got nothing.

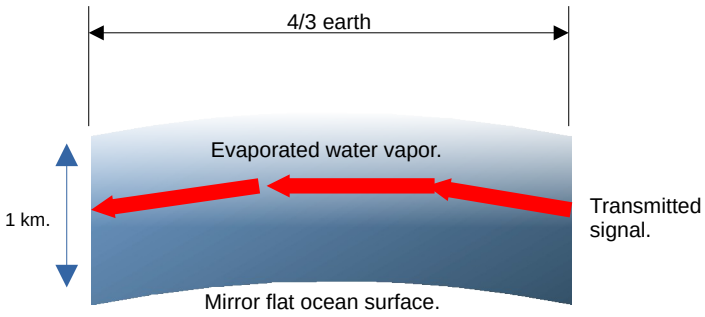
A hundred or so years ago, our esteemed elders theorized that a vacuum may contain "ether", or such, but this "ether" is not detectable, you know, kinda like "dark matter" and "dark energy". I suppose it really is a placeholder to keep our reason patterns intact until we sapiens-sapiens find something else more satisfying to our curiosities. So I can't really give you a better explanation of this. But just remember, these ϵ , μ , σ of whatever do stuff to our VHF and UHF radio waves, ultimately limiting it's speed to less than the speed of light. So that is the fastest we can theoretically move energy and information around.

But enough of this. Let's take a real example.

Let's say we take a trip out on our sailboat, in the Chesapeake. Given a radio equipped boat,

with an antenna high up on a sailboat mast, out over the ocean, I pull up the boat's VHF FM marine radio microphone, set the dial to channel 16, 156.8 MHz, and key down the 25 watt transmitter. Since it is a calm clear spring day, and my boat is out over the calm sea waves, I can talk and hear out to about 4/3 beyond the earth's horizon. My signal goes further than what I can see. Why is that?

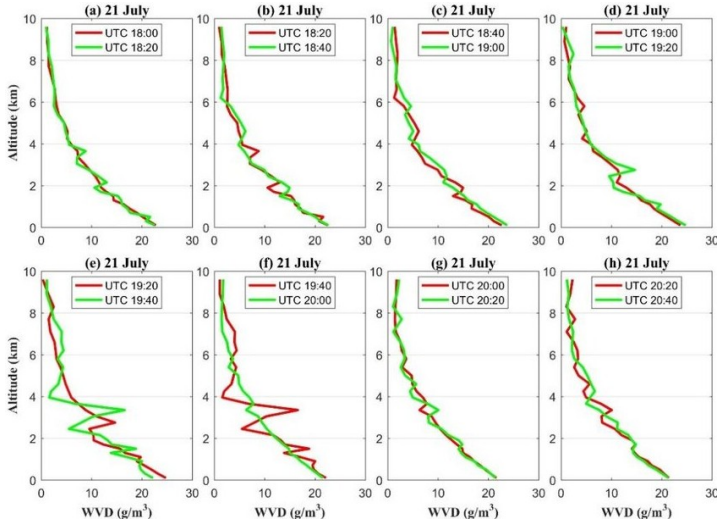
The RF will go a bit further than the "line of sight" otherwise expected. That signal should not be heard over the horizon, but it is. I have performed this experiment many times. Why does the signal do this? Maybe this is happening:



So, somehow, at the VHF channel 16 frequency, the radio energy is being bent a bit back towards the earth. It perhaps because of the atmosphere above the water. Like other electromagnetic waves, the energy is refracted. Let's look at this closer.

Consider what happens to water. As the sun comes up, it heats the water, and water evaporates. Depending on a bunch of things like temperature, pressures, water composition, water surface roughness, etc, the water evaporates and makes it's way up towards the sky. More dense stuff will not go as high, colder things will go lower, hotter lighter things will go higher, and such.

Supposedly, we figured out a painstaking way to measure this water vapor density, and we then plotted water vapor densities for various days and times of day. We would get density profiles over the water like these shown:



...where WVD is water vapor density. They differ from day to day, but generally, the lower the altitude above the water, the denser the water vapor. A more dense atmosphere tends to “slow” down the radio energy propagation more than the higher elevations. With a gradient of more to less dense, the end result is that the RF gets “curved” towards the denser atmosphere, that is, in our example, back toward the ocean surface. It “hugs” the ocean surface for awhile. It bends the RF by enough to make it go a little beyond the horizon.

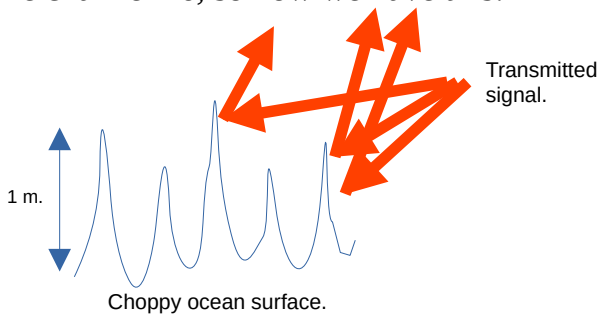
Think about it, like when you drive on an icy road. Suppose one wheel is on the icy side of the road, while the other is getting traction on the less icy side. The car starts to veer because one wheel is getting better traction than the other. The car starts to turn, even though you are not changing the steering. Something like this happens to the radio energy as it goes through a graded atmosphere. The signal that is in the denser atmosphere gets slowed down more than the one that isn’t. So the signal turns towards the denser atmosphere.

The RF is passing through the air, laden with water vapor of varying densities, and getting bent by the non-uniform vapor, modifying the ϵ , μ , σ of our wave energy, based on elevation above the ocean. The wave front that is higher up “goes faster” than the waves closer to the ocean. So, we get roughly 4/3 earth horizon propagation. The waves are “reflected”, or more aptly, bent, not so much that the waves come back at us, but enough to curve them a bit, so that they go beyond the line-of-sight horizon.

This actually occurs anywhere on the earth’s surface, not just over water. The atmosphere itself is more dense towards the surface, and less dense as you go up in altitude, so it probably also happens on planets with atmospheres, like Mars, Venus, Saturn, etc. There probably is a planet somewhere that has an atmosphere and frequency combination where the energy will just hover above the surface for the entire planet diameter, although I know not where.

This is a nice example. But we need a relatively calm surface, and a decreasing water vapor density profile, with a relatively uniform heating coefficient to get the maximum effect. So, yes, many things have to come together for this to happen. But let me throw a few wrenches into this nice example.

Suppose it is a choppy day, with a storm approaching, and wave height is now around 3 feet, instead of the mirror surface before. So what do you think will happen? Salt water is a pretty good conductor around marine channel 16, so now we have this:



These ocean surface waves look like nice half wave resonators. Our RF marine VHF

wavelength radio waves will see these ocean waves, and reflect off them, or be absorbed by them. As the waves roll and change, the reflected signals will go haywire, and scatter all over the place, canceling in some places and adding in others, all while moving as the waves move.

If you are listening on the other end, this kind of effect will usually sound like low frequency amplitude and phase “rumble” modulation, as the waves roll and scatter the RF energy. The signal also weakens and broadens, due to the phase changes. Any modulation imposed upon the signal will also be distorted.

No more 4/3 earth enhancement stuff now. Instead, we have a bumpy, modulated, weak signal at the receiving end, that drops off completely, where just yesterday, it was full scale, constant, steady, and full quieting.

Long ago, when this first happened to me, I immediately suspected that my station was broken somehow. It was just working yesterday. What happened to it? Did the antenna fall over? No. Is the receiver still working? Yep. Did the other station’s transmitter quit? Nope. So eventually, using my deductive wisdom, I figured that it must be some sort of strange propagation stuff happening here. So I started to investigate this whole business.

Now, as I toss another wrench into this example, the water vapor can be too dense, and bend the signal right back into the ocean surface, where it either reflects up and is scattered, or is absorbed by the ocean surface. Or the signal can do the opposite. That is, the RF energy will not curve enough, and gradually graze up and away from the surface of the earth, never to return. This whole business is frequency and modulation dependent, that is, the FM marine channel 16, 156.8 MHz may bend nicely, where 446.0 UHF ham simplex will do no such thing, or vice-versa.

I have some nifty QSL cards showing long haul DX on 1296 MHz, while at the same time, the 432 MHz and below bands were absolutely stone quiet. This is one of the reasons why you may see a VHF/UHF rover with an array of different ham bands installed, like KE4WMF/R’s mobile rig:

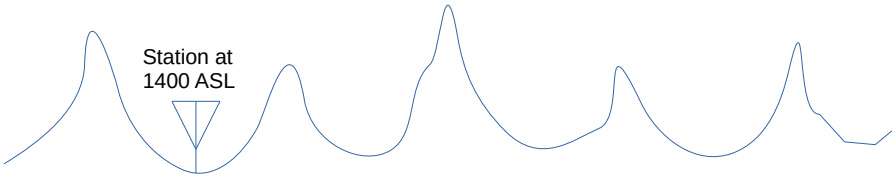
What's the point of this, other than it looks way-way-cool? He wants to try a multiplicity of bands to see if any are open to tropospheric effects. Sometimes, the best way to know if there is any of this type of propagation is to just try it out and see what happens.

We also may do many bands at the home station, building gear with as many of the VHF and UHF bands as possible, up into the microwave region. Here's K5QE's 222, 432, 902, 1296, 2304, 3456 MHz array for hunting the elusive tropospheric ducting signals:

Back on Ohio, when I was WB8ZDF, I also sported a tower up at 1400 ASL with 50, 144, 432, 1296 MHz, and 10 GHz for awhile. It is a lot of fun finding these lower atmospheric band openings!

Anyway, this whole general business of the effects of the atmosphere on radio propagation is talked about in books and papers as "Tropospheric Propagation". So if you want to learn more, go google that and see what comes back.

But this is only one example. There are other things that can happen to radio signal energy at VHF and UHF. Like what is this "ASL" mentioned above? Isn't it true that "higher is better?" Well, ASL is "Above Sea Level". It is what your GPS readout is shown in. This tells you how high you are with respect to the lowest place we humans consider, that is, at zero ASL, or the beach. But this really means little. You can have a really high ASL, and still not do well on VHF and UHF. Why? Simple. Look at this diagram:



This station is well above sea level, but the surrounding terrain is much higher. So we have a measurement of that, too, called height above average terrain, or HAAT. Granted, there is an infinite number of ways to measure the "average" terrain, and how far out to average the surrounding area, etc, but it will help you get a better handle on how "high" your station really is.

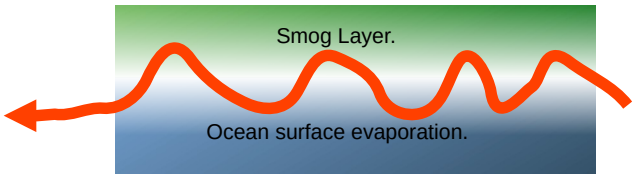
And “highest is best” is only a hamster thing. Broadcasters, cell towers, air navigation, public service, etc. often want to purposely *limit* their signals to prescribed areas on purpose. They don’t want to DX out as far as possible, and have “band openings”, but would like their RF to stay in a limited, well-behaved, predictable area, and be strong, focused, and consistent in this limited area. So often an antenna in a hole is sometimes just what a city police radio needs. Some higher gain commercial vertical antennas even have a “down tilt” element near the base, where the RF is purposefully focused down below the horizon, to get into all the local nooks and crannies.

In some instances, while you gab away, modern cell phones now use electronically steered arrays of antennas focused on a cell phone user in real time. This way, the radio energy is focused only to where it is needed. The highest signal to noise rations and thus information bandwidth can then be realized, providing incredibly rapid cat video downloads.

Also hooking a computer to an electronically steered antenna array means that it can hold several RF beams on multiple users simultaneously within a single cell, while sometimes also occupying several frequencies, all within a single cell. So the engineers who design these systems definitely DO NOT want ducting or tropospheric effects messing all this up.

So back to our general discussion. What are some other things that happen to the RF energy we transmit?

The last example is really a form of reflection called refraction. Others include multi-path and edge diffraction. These we discussed in the previous fox hunt article, but ducting is another type of VHF and UHF distance enhancer I haven’t mentioned before. Suppose instead of one, we had two surfaces that somehow manage to curve our RF energy back to back, like this:



Tropospheric Ducting - Waveguide

In this case, the RF energy gets “trapped” between two gradients. The energy gets bent one way, then the other, and bounces back and forth. The special conditions for a “duct” or waveguide for the RF energy to travel into are quite rare in nature, but we build things to utilize this type of electromagnetic propagation all the time. For instance, the internet is mostly all laser fiber optic now, and uses this waveguide propagation principle in all the connecting fibers. Designed right, these optical fibers can carry light energy for hundreds of miles, sometimes, before needing any amplification. Almost all the light electromagnetic energy stays contained inside the fiber and only comes out at the end. The same kind of thing can happen with the atmosphere and VHF/UHF signals, where they go for thousands of miles.

I just realized I gobbled up another 8 pages with this stuff, and I still have a whole bunch of

things to talk about. Well, next time, I guess. Let me drop anchor here for now. I have so much more to tell you, if you are interested, but I need to stop here, and give y'all a break.

-...-

SPARC Market Place

by

Matt, N3NTJ

Do you know that you can sell things directly to the club members? Sure, but it has to be ham radio related. For instance, the new Marketplace page I created on the SPARC website already has some items. It's for members who have stuff for sale or are looking for items. We already have three items listed. There's a tab at the top of k3ir.org for members to easily find the page.

The club currently has these items for sale to help pay for the solar system, and ultimately reduce our power bill. So you can buy something, and feel good about contributing to the club's well-being, too. Check the website, for more recent items listed/sold.

1. **Tokyo HC-2000 HF Antenna Tuner.** With the price of eggs nowadays, the eggs are not included. Sorry. Tuner only. $400. For sale by SPARC. Contact Harry at **hbauderrm@gmail.com**

2. **Icom AH-4 Remote Tuner.** HF+6m. New – still in box. $425. For sale by SPARC. Contact Harry at: **hbauder@gmail.com**

If you're a member of SPARC and have an item for sale or an item that you are looking for, contact us to place your ad here.

Meeting Night

Like most clubs, there sets in a sort of monthly pattern of meetings, etc. Like, for SPARC, the usual average monthly general membership meeting is held the fourth Tuesday of the month, at 7:00 PM, at the club site. Sometimes these things change. Why are you looking at this inaccurate newsletter for such information? Go to K3IR.org and check the calendar tab.

License Test Sessions

Want to upgrade your license? How about get a license? You will need one to be a ham operator. There IS a test. You are required to know something. It's not just a $$$ thing. Demonstrating that you indeed know something is another matter altogether. So you will need to study some materials. There is plenty of on-line information to help you get your license. Ask us. We are here to serve. Go to k3ir.org and ask for help.

Usually, testing is conducted at the SPARC site on the first Tuesday of every month. The fee to take the exam is usually $14.00 payable on the K3IR website or in person, cash or check only. Go to K3IR.org and check the calendar tab to make sure.

If you do not already have one, go to fcc.gov and register for a FRN (Federal Registration Number). You will need this to interact with the FCC.

You can also pre-register to take the technician test, or upgrade, at Hamstudy.org. There is also a link on the K3IR web site to follow. Check the k3ir.org website for the latest in fashionable ham test news.

Upcoming Hamfests

by

K3KMT, et. al.

As usual, did you know that Ralph keeps a list on his worldwide corporate website of local hamfests? He has a more complete, updated list than anyone else I know of, on this website:

https://www.qsradio.com/index.html

This is great, because I don't have to do this anymore! Go here to this web site and have a look.

Volunteer – The club needs you.

SPARC currently has 131 "active" members on the roster. We have a lot to offer to our members. At this time we have a dedicated group of hardworking volunteers who keep the site running. Some say this is typical with most organizations. I don't think SPARC should be "typical" We need more real active members. Jobs range from the highly technical to the mundane but ALL are important. Please look at the list below and see if there is a place for you.

IT Team

Tower climbers and ground help

Operating building maintenance and cleaning

Operating building equipment maintenance and improvement

Porta Potty cleaning (not Pumping!)

Adopt a Highway crew

Elmers and Elm'ettes

Hamfest help, planning, etc.

Meeting programs and talks

Antennas! ...always more, bigger, higher.

Someone to take the trash home and pitch it when it's full.

Someone else to either eat or toss the old stuff in the fridge.

Someone to put the 6 meter beam up on a rotor.

Solar power wizard experts.

Fiscally rigorous scrupulous bean counters.