Rain, Rain, *Don't* Go Away!

With precipitation on the increase across the Americas, it is time to talk about rain scatter. Although some of the most spectacular thunderheads occur during the months of May through August, much of the gentler and certainly more frequent precipitation covers our continent during the late autumn, winter and spring months.

One of the peculiar properties of microwaves is the ability to make use of scattering from precipitation. Scattering, as the word is applied to other events, in radio means the process that sends RF in directions other than originally sent.

All non-line-of-sight communications use scattering. With VHF and UHF most tropospheric scattering is caused by turbulence that makes small pressure differences in the air. These small and very slightly higher and lower pressure regions have different refractivity that scatters VHF and UHF signals. Although turbulence generated tropo scattering has an effect at 10 GHz, it is not much greater than on 1296 MHz. There is some contribution to microwave tropospheric propagation by airborne dust and insects as is evidenced by clear air turbulence radars.

Scattering by Particles

When an RF field encounters a region of particles, some of the energy excites those particles and they re-radiate the energy. The amount of energy that is scattered increases with the density of particles. It also increases by the fourth power of the frequency. Recall that increasing frequency is the same as decreasing wavelength. Once the wavelength is as small as 10 times diameter of the particle, this fourth power factor begins to reduce. When the wavelength is the size of the particle and smaller, the scattering efficiency remains constant (does not increase with frequency), but the pattern of scattered energy changes. One common misconception is that scattering is the same as reflection. Actually, the scattering objects re-radiate the energy that enters them. This helps explain why there is forward scattering, and why polarization is maintained in most scattering situations.

Why is the Sky Blue?

Even the oxygen and nitrogen molecules that constitute air are particles that scatter electromagnetic radiation. These molecules are very small compared to the wavelength of light. Because blue is a higher frequency than red or yellow, more blue light is scattered by the air than other colors, and because it is scattered in all directions, no matter where we look the sky is blue. The gas molecules are too small to be useful scatterers at any but visible and shorter wavelengths (representing frequencies of 500,000 GHz and above).

What about Water Particles?

It appears that atmospheric water takes on a few ranges of particle sizes (rather than a continuum). Water vapor consists of individual molecules that have properties similar to other atmospheric gasses. Although the dew point is a precise indicator of the amount of water vapor in the air, we often use percentage of humidity to describe it. Humidity of 100% represents the maximum amount of water vapor that the air can hold at a given temperature without condensing into particles larger than single molecules.

Water particles that range from under 0.001 µm (a thousandth of a micro-meter) to 0.01 mm are called haze. Cloud particles range from 0.001 mm to 0.1 mm. At 10 and even 24 GHz, it is not practical to get useful scattering from clouds and haze—the return power levels are far too low for communications. (Scientific cloud radars that can accurately measure particles of these sizes operate at frequencies between 30 and 100 GHz.) When atmospheric water particles are in a size range from about 0.5 mm to 3 mm (drizzle to tropical downpour) we call it rain. These particles are too heavy to be kept aloft by random air motion, and fall to the ground. One could not choose a better frequency than 10 GHz for rain scattering. Drops are $^1/_{10}$ to $^1/_{60}$ of a wavelength—and so the heavier rainstorms give the best scattering returns and communications paths.

The author and others have used rain scatter for communications on 5 GHz, and have observed scattering on 3 GHz and 2 GHz, but with very low signal levels. Recall the fourth power law—at 5 GHz (about half the frequency) we would expect to receive $^1/_{16}$ the signal (½ to the fourth power)—representing 12 dB less received signal level than what we would receive at 10 GHz with the same antenna gain and power. At 3 GHz ($^1/_3$ of the frequency) we would expect to receive $^1/_{81}$ of the signal, or about 19 dB less signal than at 10 GHz. Rarely are rain scatter signals at 10 GHz 20 dB or more over the noise, and so it is only the strongest storms and the use of higher power that provide a useful communications path at 2 and 3 GHz.

How does Scattering Direct and Polarize Signals?

The directivity pattern from a typical rain scattering volume can be thought of just as if an antenna were placed at the center of the volume When the drops are on the order of $^1/_{10}$ wavelength and smaller (like rain at 10 GHz), the scattering plot is as shown in Figure 1. View these plots just like an antenna plot as seen from above. The incoming signal (the "illumination") arrives from the bottom of the figure, and the rainstorm is at the center. First, let's look at vertical polarization. Figure 1A shows that the scattering is almost completely isotropic—the same in all directions. In other words, imagine that we are looking down on a vertical antenna. The energy arrives from the bottom of the figure, and radiates from the scattering volume just the same as a vertical dipole antenna would radiate the energy if it were located at the center of the scattering volume.

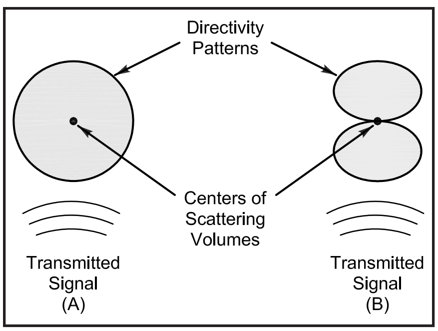

Figure 1—The directivity patterns for a signal emerging from a scattering volume as viewed from above. A—vertical polarization; B—horizontal polarization.

Resources

To listen to some rain scatter, set your browser to **www.wa1mba.org/scatter.wav**.

A recent article in *DUBUS* magazine describes some technical details of rain scatter: G. Vollhardt, DL3NQ, "Rain Scatter on 10 GHz," *DUBUS*, 2/2002 Vol 31, pp 7-28.

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Getting around Obstacles

We use horizontal polarization on narrow-band 10 GHz. Scattering for this condition follows the pattern shown in Figure 1B. This is the same pattern that a horizontal dipole would have if centered at the scattering volume, resulting in dramatic consequences for those trying rain scatter. Signals become very weak when the rain is at a point that causes the two stations to aim at 90° relative to one another. At shallower and greater angles, the signals increase, very much like they do for a horizontally polarized antenna. To maximize the likelihood rain scattering, rain cells that do not cause this 90° relation should be sought—see Figure 2.

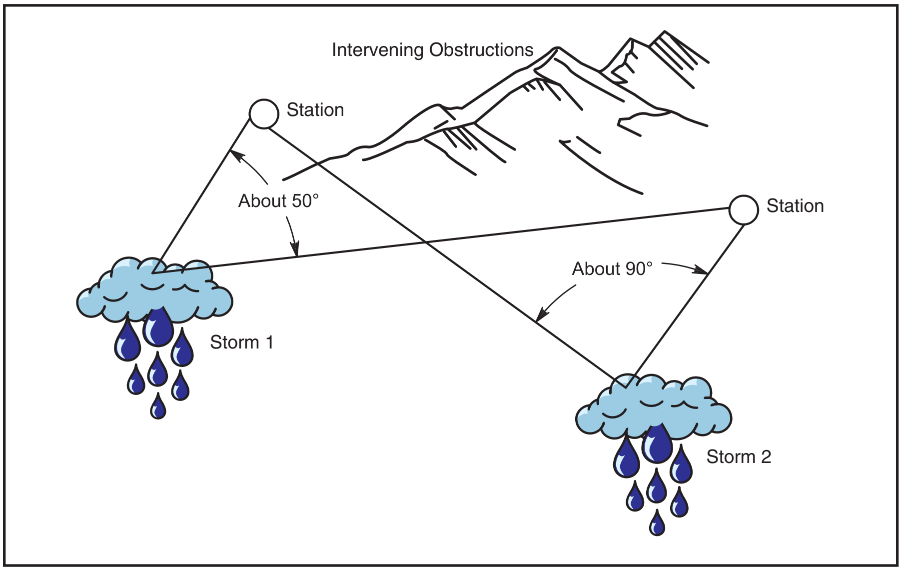

Figure 2—In this example, the two stations will have better signals using storm 1 because storm 2 creates a 90° angle.

How do Signals Sound?

One thing you will notice when using rain scatter is *Doppler shift*. This is the phenomenon whereby the frequency shifts if the path between the transmitter and receiver is shortening or lengthening. The rain in a storm is carried by winds, and so the scatterer is moving, causing the path length to change, and so the frequency shifts. In some violent storms the wind is strong enough to move a 10 GHz signal out of the pass-band! In most cases, CW notes become quite fuzzy sounding because the raindrops are moving at slightly different speeds and directions. Microwavers refer to the "Aurora" quality of rain scatter, similar in sound to aurora propagation on 2 meters—at times it can sound like strong noise. Hams exchange "59A" or "59S" RSTs, often to report this type of sound. The A stands for aurora and the S for scattering. When coordinating a rain scatter contact it is advisable to have the transmitting station send CW dashes, so that the receiving operator can distinguish the noisy signal from the background noise.

Can Snow Scatter?

Snow scattering is very much like rain scatter, and at 10 GHz has about the same scattering for the same equivalent rainfall rate. Most snowfall occurs at a slower equivalent rainfall rate than heavy rain, so only the heavier snowstorms are likely to have significant snow scattering. Nonetheless, the author and others have used snow scattering. At times is can be very effective at extending communications even though it is unlikely that hilltop expeditions would take advantage of this mode—it's cold enough at some of these heights even in the summer!

The majority of rain originates as snow because the cloud particles are super-cooled and the air temperature where the precipitation takes place is below freezing. This snow, in most rainstorms will pass through warmer air. As the snow falls through warmer air, the flakes become sticky and clump together to make very large and wet flakes. These become very strong scatterers, much stronger than the separate flakes above and stronger than the rain into which they melt below. Unfortunately, for communications, these layers are not very high in the storms, often only 500 to 1500 meters above the surface. So, although they are strong scatterers they do not support really long haul DX that the upper regions of thunderheads provide as the updrafts in them push their precipitants up to and beyond 8000 meters above ground.

How do I Operate Rain Scatter?

Rain may be a nuisance to operating, but it can be a welcome signal enhancer that lets you work around mountains and more than a hundred miles beyond normal range. So, what should hams do who want to try rain scatter? Of course, having two home stations make this kind of experimentation easy. If one or both stations are portable and you suspect that there are nearby weather events, give it a try. Most contacts in the upper bands are coordinated on the lower bands, typically on 144 MHz SSB. Although home operators may have access to on-line weather radar maps, some of the new third generation cell phones can also deliver this web data to portable operators as well. If storms are found, try to find directions that do not result in the dreaded 90° angle, and then have the strongest transmitter send CW dashes. If you want to operate voice, realize that SSB may be distorted beyond recognition, but narrow-band FM will work well if there is enough signal level. Long-haul rain scatter contacts are usually CW.

STRAYS

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QST congratulates...

◊ George Dowell KØFF, the only ham from the Ø call sign district to earn a 5-Band DXCC with 160, 17, 12 and 6-meter endorsements. He is also the recipient of the SETI League's Extra Terrestrial Century Club 25 award for verified contacts or reception of 25 natural or man-made radio signals from beyond the Earth's atmosphere, including satellites, lunar seismic transmissions, spacecraft and natural phenomena. Nice work, George!

I would like to get in touch with . . .

◊ anyone who monitored communications with Apollo space flights during the 1960s and '70s. *—Jim Oberg, Rte 2 Box 350, Dickinson, TX 77539; voice/fax 281-337-2838*

◊ anyone with information on John Westcott, who lived in Springfield, Ohio, and in New York City, and was licensed in 1921 as W8AGA. He also held K8DKG as well as a 2-land call that we don't have. He became a silent key in the 1980s. If you have any QSL cards from John Westcott or any information on him, please contact us at **w8aga@westcotthouse. org**.*—Matt Cline, KB8WFH, c/o Westcott House Foundation, PO Box 334, Springfield, OH 45502*