Microwave Propagation

If you think that the microwave bands are only good for line-of-sight communications, well, you haven't been reading this magazine very closely...

"In regard to the limited range of propagation of these microwaves, the last word has not yet been said. It has already been shown that they can travel round a portion of the earth's curvature, to distances greater than had been expected."—Guglielmo Marconi, 1932

In 1932, during this same speech inaugurating the Dover-to-Calais ITT microwave link, Marconi reminded the audience that, at the time of his 1901 Transoceanic tests, mathematicians had calculated the maximum range of electric waves to be 165 miles.

Ask just about any of your friends on 75 meters or one of the repeaters, and they'll tell you that microwaves are line of sight. "If you can't see them, you can't work them," they'll tell you with complete confidence. Yet you keep hearing me talk about 100-mile contacts any time of the day or night, and even occasional 1,000-mile QSOs, on microwaves. What gives?

Inside Microwave Propagation

There is a variety of factors that allow microwaves to travel beyond the horizon. The first factor is the density profile of the atmosphere itself. The air is denser near the ground and gets thinner as we go higher. In my simplified drawing in Figure 1, you can see that the air itself is like a prism, continuously bending radio waves back towards the Earth. And a prism bends or refracts smaller waves more than longer waves. So the atmosphere naturally bends microwaves better than UHF, and UHF bends better than VHF, etc.

From a band opening point of view, this means 10 GHz opens first, then the opening works its way *down* to UHF, and finally to VHF. So when you hear that nice tropo opening on 2 meters, the microwave bands have already been open for some time. This top-down opening has been confirmed by many propagation studies and by radar operators.

Density Altitude

If you've ever worked with the equations predicting repeater or television coverage, you've used the "$^4/_3$ Earth's curvature" formula. This formula says that if true line of sight is 15 miles, then use $^4/_3$ x 15 miles, or 20 miles, as your normal range. This $^4/_3$ formula allows for the natural bending of the radio waves in the atmosphere (see Figure 2).

So is coverage better than $^4/_3$ ever possible? Certainly! The density of the prism is changing all the time. The denser the prism, the better the atmosphere bends radio waves, and the father your signals go. For those of you who are pilots, this is called your *density altitude*. So, those cool, damp mornings with a high barometric pressure, when you can take off with four passengers, luggage, and a full load of fuel, are also the mornings when the microwave bands are open.

So what are we looking for? Key factors are barometric pressure much higher than normal and a high humidity. The air's density increases when it is carrying a lot of water, and the signals travel as far as the high pressure area extends. With slow-moving high-pressure areas, microwave openings of thousands of miles (especially over water) are relatively common.

Atmospheric Scatter

Scatter propagation takes advantage of turbulence in our atmosphere. Take a look

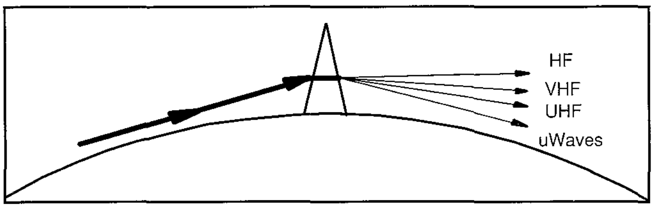

Figure 1. Density Profile of the Atmosphere. The air is denser near the ground and gets thinner as you go up. The air itself is like a prism, continuously bending radio waves back towards the Earth. Since a prism bends smaller waves more than longer waves, it is most efficient at microwave frequencies.

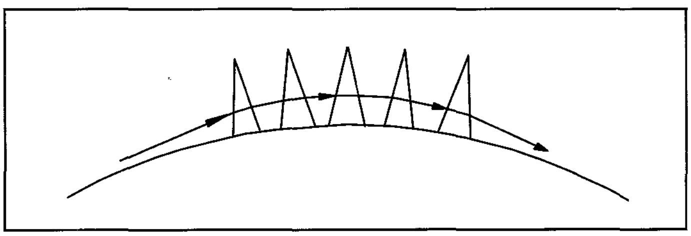

Figure 2. Refraction Effects of the Atmosphere. Without any atmospheric enhancements, the radio horizon is normally considered to be $^4/_3$ of the visual horizon, so a 15-mile visual "line-of-sight" path provides a 20-mile radio path.

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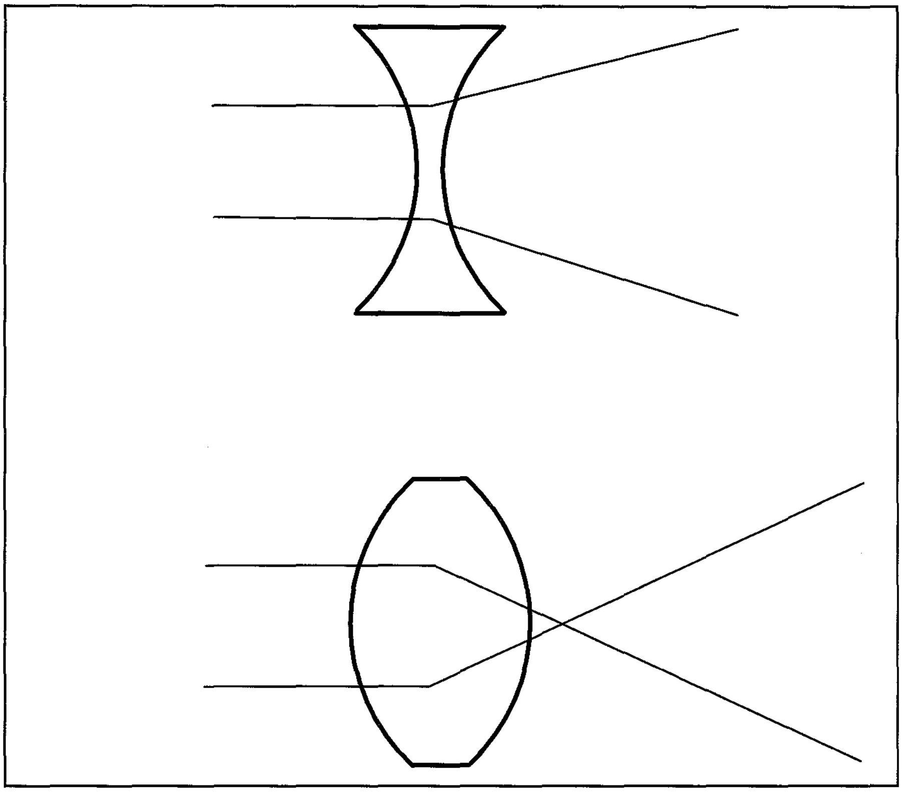

Figure 3. Convex and Concave Optical Lenses. If you shine a light up onto either a convex or concave optical lens that's horizontal above you, some of the light will be scattered up and some will be scattered down...and it doesn't really matter which shape the lens is.

> ***"With slow-moving high-pressure areas, microwave openings of thousands of miles (especially over water) are relatively common."***

at Figure 3, which shows you what happens to light when it passes through convex and concave optical lenses. Note how each different type of lens bends the light waves differently, but, in each case, some goes up and some goes down.

Now let's put these same types of lenses in the atmosphere (see Figure 4), where they will be like a bubble of air that is either more or less dense than the surrounding atmosphere. It doesn't matter if that bubble's density is greater or less than what surrounds it, as long as it's different. In either case, a portion of the energy is deflected back toward the ground. Clouds themselves do not reflect radio waves, but clouds are common where there are density changes in the atmosphere. Again, it doesn't make much difference whether this bubble of air is warmer than the surrounding air, or cooler, or wetter, or drier. As long as it causes a density change in the atmosphere, a portion of the radio waves hitting this pocket will be directed back to the ground.

Rain Scatter

Another atmospheric phenomenon that reflects microwave signals is water, or, more specifically, raindrops. These little dielectric blobs are just about the same size as half-wave dipoles on our 5.7-GHz and 10-GHz amateur bands. Shooting a beam of microwaves into a rainstorm is much like shining a spotlight into a snowstorm. The signal reflects everywhere! (see Figure 5). I remember W5UGO de-scribing a 5.7-GHz QSO with K5PJR on an Oklahoma summer day with his three-foot dish pointed straight up into a thunderstorm.

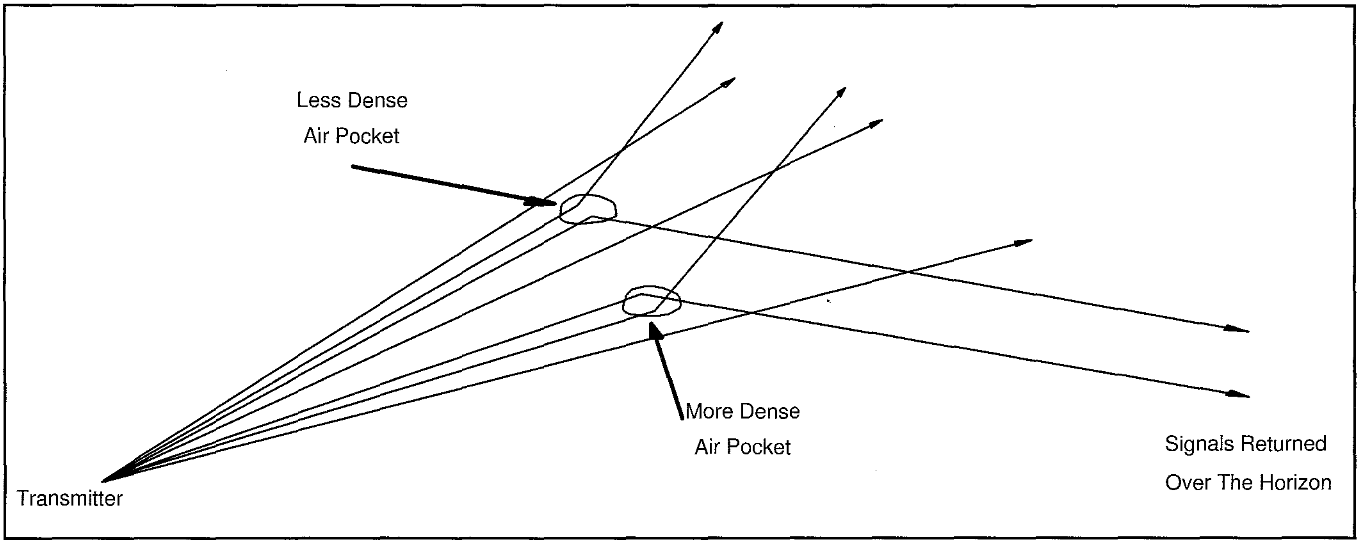

Figure 4. Atmospheric Scattering. Think of a concave or convex lens at radio frequencies. Any change in the density of the atmosphere—it doesn't matter if it's higher or lower—will result in scattering of signals at microwave frequencies.

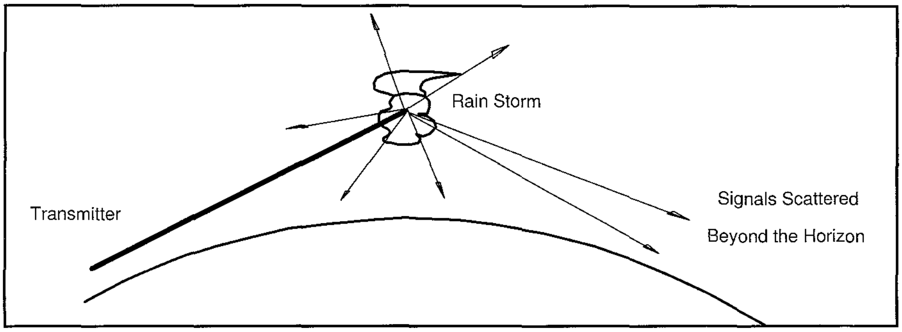

Figure 5. Rain Scatter of Microwave Signals. Raindrops look like half-wave dipoles to a signal at 5.7 or 10 GHz. Transmitting into a rainstorm will result in significant scattering—and much farther than "line-of-sight" distances—at microwave frequencies.

His signal went up several thousand feet, scattered off the raindrops, and went all over Oklahoma.

My introduction to 10-GHz "rain scatter" was from G3WDG/W5. Charlie had set up a small station 40 miles away, and we had been playing with signals for a day or so. When a Texas rainstorm hit (I always loved his quote, "It doesn't rain like this in England!"), he called me up and we went to 10 GHz. Normally, the beamwidth of my 18-inch dish is only 5 or 6 degrees. If I turn the dish any more than that, the signal goes away. But with all the rain scattering the signal, his direct signal was 2 S-units weaker. Only now I could rotate the dish *30 degrees* in either direction and still hear his CW!

Doppler Shift

There is another effect to sending CW signals through a rainstorm. When 10-GHz signals bounce off of moving objects, the signal now has a Doppler shift (an apparent shift in frequency based on your frequency, the speed of the moving object, and whether it's moving toward you or away from you). So what's the Doppler shift of billions of swirling raindrops? Yeah, billions of different frequencies. The net result of this is a CW signal about 5 kHz wide that sounds a lot like keying a compressed air hose. SSB signals get spread out and you can barely hear your own call come back, much less understand a conversation. So rain scatter is mainly a CW mode.

Rain scatter has become a big sport in Europe. After a rain front moves across England, and is over the North Sea and the English Channel, British microwave stations point their antennas southeast. Word gets out to the European stations on the continent and hundreds of German microwave stations point back to the Northwest. Result: 200-to-400-mile rain scatter QSOs are quite common between England and Germany while it's raining over Holland and Belgium.

Aircraft Scatter

I did a paper on aircraft scatter for the 1992 Central States VHF Society *Proceedings*. Bouncing signals off of aircraft is a far more complex subject than you might first think, but, in general, you need big antennas and lots of power.

As an example, for a 200-mile QSO on 10 GHz with a 747 halfway in between, you would need 10-watt stations, 18-inch dishes, and GaAsFET front ends. In the practical ham world, it's just another of the dozens of objects out there reflecting a small part of your signal. Work 'em first, figure it out later!

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New North American Records on 120 and 144 GHz

From out west, we have news that KF6KVG and WØEOM have been working with their millimeter gear again (these amateur bands have a wavelength of 2 millimeters). They both use Hughes harmonic mixers and 9-inch dishes. WØEOM uses two antennas and two mixers, with one optimized for transmit and the other optimized for receive. KF6KVG uses one dish and mixer, but changes the diode bias between transmit and receive. On October 2, 1998, they had a one-way QSO of 4.9 kilometers (just under 3 miles) on 144 GHz, beyond the current U.S. record, but were unable to complete a two-way QSO due to KF6KVG's lower power.

They modified their equipment for 120 GHz, and on November 16, Will and Bob completed a 5.3-kilometer (3.18-mile) QSO for a new U.S. record. Look for them to be revisiting 144 GHz soon.

"Shooting a beam of microwaves into a rainstorm is much like shining a spotlight into a snowstorm. The signal reflects everywhere!"

For those of you who may scoff at a 5.3-km record, I just challenge you to see how far you can get with a few microwatts of RF. Also, the atmosphere itself absorbs the signals on these bands. So QSOs are like trying to communicate with searchlights in the fog. But as technology marches along, the potential for our millimeter wavelength bands is tremendous. The bandwidth to run hundreds of TV channels, hundreds of thousands of repeater channels, thousands of T-1 data lines, or most anything else we may want, is a *big* resource. We should encourage and support those hams who are experimenting there or, better yet, join in the activity.

Microwave Update 1999

The North Texas Microwave Society will be hosting this year's Microwave Update Conference. Al Ward, W5LUA, and I will be the hosts. This annual conference on amateur microwave operation, construction, and techniques will be held October 22 and 23 at the Harvey House hotel and conference facilities in Plano, Texas. I will be organizing one of our world-famous electronics surplus tours on October 21st. I hope many of you will be able to attend and I'll be passing along more details as we get closer. ■

Resources

For additional information on 10-GHz propagation in particular, see "10 GHz—A Good Band for a Rainy Day," by Tom Williams, WA1MBA, in the February, 1997, *CQ VHF*. Back issues are $4 each to U.S. addresses, postage included. Contact *CQ VHF* magazine, 25 Newbridge Rd., Hicksville, NY 11801; Phone: (516) 681-2922; Fax: (516) 681-2926; E-mail: <backissues@cq-vhf.com>; Internet: <http://www.cq-vhf.com>.