Rain scatter - European style

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Rain scatter is now the most popular 10GHz mode of communication in Europe, especially during late spring and through the summer. It is not at all difficult to see why this has happened. Rain scatter provides even modest 10GHz stations with the ability to work other 10GHz operators over distances of hundreds of miles from home station sites that are less than ideally placed for 'normal' VHF, UHF and microwave terrestrial operation. This paper reviews current rain scatter techniques, equipment and results. But first, a look at the mechanism of rain scatter.

Scatter

All that scatters isn't rain! The scattering mechanism can take place from a variety of rain-related objects that include rain, hail, melting ice and snow, collectively called hydrometeors. For simplicity, I'll call it rain scatter except where necessary to explain some particular effect.

It is not unusual for rain to fall more or less uniformly along the whole of a 100 to 200km path. But, it is my experience that this particular condition, whilst still useful for rain scatter communications, often does not produce the best results for reasons I shall examine later in this paper. The best results are usually achieved when an intense thunderstorm, of the type often found in summer over continental areas, produces torrential rain somewhere along the radio path of interest. These areas of intense rain associated with thunderstorms are called cells.

Scatter takes place as a result of the transmitted radio signal encountering rain drops of a size some significant proportion of the signal wavelength. The signal is scattered (re-radiated) by the rain drops. And, because the mechanism is scatter rather than reflection the signal is re-radiated from the rain drops equally in all directions, causing not only forward scatter, but also for side and back scatter as shown in figure 1.

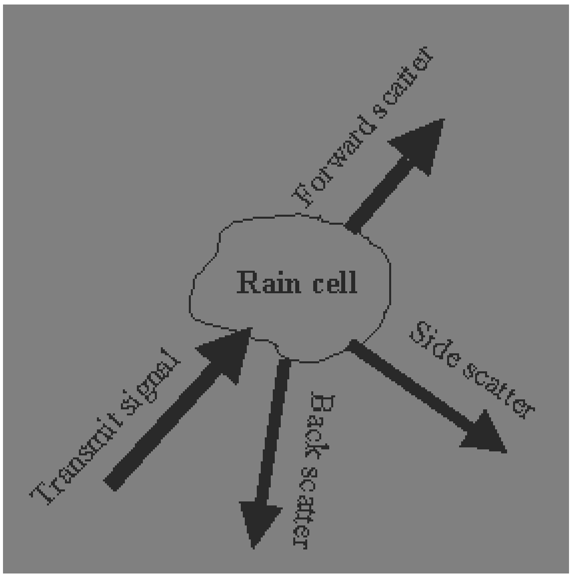

Fig 1. Plan view of forward, side and back scatter from a rain cell.

Provided a suitable receive antenna is pointed towards the area where the scattering is taking place, a signal will be received. The common region of scatter seen by both the transmit and receive antenna is known as the common volume. The strength of the received signal depends on both distance from and the 'reflectivity' of the rain cell. As we have seen, the mechanism is scatter, but weather forecasters refer to the radar returns from rain as 'reflections'. The strength of the reflection depends on the intensity of the falling rain and is referred to in millimetres of rain per hour or mm/hr. A very heavy rain storm can produce a rainfall of 25 to as much as 50mm/hr in Europe. It should be noted that the higher amounts are very rare in the UK but much more common over continental Europe.

The signal received from scattering by rain in the cells consists of many separate signals each scattered from many rain drops leading to a complex wave front at the receive antenna. When the signal scatters forward through the cell it has the least complex structure. Side and back scatter leads to a very complex wave front often with bad distortion of the signal. CW signals can be satisfactorily demodulated from side and back scattered signals, whilst SSB is often perfectly satisfactory in forward scatter. Frequency modulation (FM) can also be used but does tend to use up a lot of spectrum! Side and back scatter signals at 10GHz sound very much like auroral signals on 2m.

In addition to the distortion caused by the large number of separate scattered signals, a thundery rain cell can be moving quite fast. In Europe a speed of 50km/hr is quite common. Not only is the rain cell moving laterally, but the rain within the cell may be both falling at the base of the clouds and also being driven vertically upwards within the cloud at a very high speed due to the very turbulent up-draughts associated with thunderstorms. This leads to Doppler shift on the received signal. The Doppler shift can be both negative and positive leading to smearing of the signal over several kHz at 10GHz. I have observed spreads of up to 5kHz on our local 10GHz beacon signal.

I mentioned in the introduction that scatter can take place from all sorts of hydrometeors, not just rain drops. This is significant for two reasons. Firstly, rain can only exist up to a certain height before it freezes and turns to ice and this implies a certain maximum scatter range. Secondly, strong scatter has been observed during snow storms and hail storms.

As you move up through the atmosphere the temperature falls. At 0^{o} C water freezes. The freezing height is very variable but a good average annual height is given by the formula:

h_{freeze} = 5800 - 72.6Ø metres [1]

Where Ø = latitude in degrees

The error in this formula is normally within a hundred metres between latitude 35^0 and 70^o It must be emphasised, this is a mean height and is subject to large variation during the course of a year.

At my QTH latitude of 52^o N the formula gives a value of about 2km.

Rain radar has shown that reflectivity below the freezing level is nearly constant with height. However, melting ice particles cause the reflection to increase strongly just above the freezing level. Enhancements of 5 to 10dB are often seen giving rise to the term 'bright-band' enhancement. Above the bright band the reflection normally falls gradually with increasing height. However, the presence of large hailstones just below the towering cloud peak of some storms can also produce strong scatter signals. It should be noted, the effect of the bright-band falls with increasing frequency. At 24GHz its effect may be negligible, whilst at 10GHz it is quite noticeable.

If we take a height of 2km as producing the scatter signals then the maximum scatter range for this mode would be for forward scatter when the transmit and receive antennas are both seeing a common volume at 2km altitude on the horizon. The distance to the radio horizon over smooth earth to sea level from a height of 2km is given to good approximation by:

D (km) = 3.57 * (Kh1-h3) $^{1/2}$ [2]

= 184km

Where K = 1.33 (effective earth curvature), h1 height above sea level = 2km, h3 = sea level (0)

This distance must be doubled since both receiver and transmitter can see the same

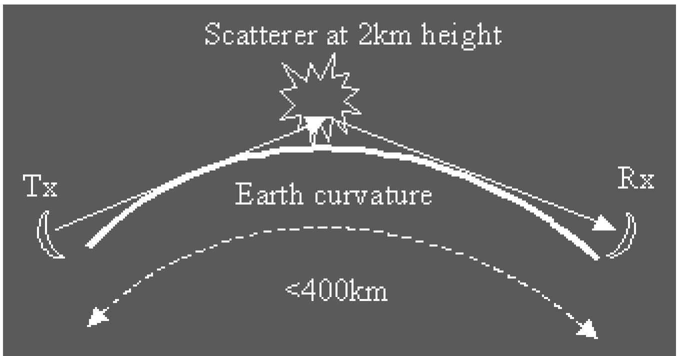

Fig 2 Earth curvature and maximum range

common volume on the horizon, therefore the maximum range approaches 400km.

When scatter takes place from ice and hailstones above the rain freezing height scatter distance can be increased considerably. Hydrometeor scatter has been observed at ranges approaching 800km and since hailstones can reach heights of 12km to 15km in some of the more intense continental thunderstorms, over 1000km may be possible.

Ice crystals tend to be small and therefore do not provide very effective scatter at low frequencies. At 24GHz it may be possible to scatter from ice clouds at altitudes of up to about 15km, especially if there are no rain-producing clouds at lower altitudes to provide water vapour absorption. It is interesting to speculate that 24GHz may provide better scatter range than 10GHz!

Atmospheric gases such as water vapour and oxygen rapidly attenuate the higher frequencies (shorter wavelengths) whilst the longer wavelength signals are less effectively scattered due to the limited size of the hydrometeors. For these reasons the

Fig 3. Approximate 400km and 800km range map for rain scatter communications from grid JO02 in the UK.

5.7, 10 and 24GHz bands are most often used for rain scatter communications. In practice, the lower power and less sensitive equipment currently available on 24GHz, together with significant water vapour absorption tends to make this a more difficult band to use with this mode. By far the most popular band for rain scatter operation is 10GHz although in Europe 5.7GHz is fast catching up due to the increasing availability of relatively high power surplus ex-commercial amplifiers. Fifty and 100W solid state (GaAs FET) TWT-replacement amplifiers have occasionally appeared on the UK market.

Hydrometeors vary in size leading to scatter over a wide range of frequencies which for amateur radio purposes means from as low as 1296MHz up to at least 24GHz. I know of no recorded evidence of amateur reception of rain scatter signals at 47GHz and above.

Finding the rain

This is where rain scatter communication gets very interesting. It should be obvious from the previous section that there are two sorts of rain that can be used for rain scatter communication. Normal stratified rain due to approaching fronts allows scatter up to around 400km at a latitude of 52^0 whilst convective rain (from thunderstorms) allows communication up to around 800km (and maybe more). Finding the rain is the most difficult part of the whole exercise.

Most thunderstorms last, on average, no more than one hour, but normal convective conditions can give rise to a whole series of storm cells, overlapping each other in time to give the impression of one continuous storm. In Europe these storms cells often appear first over France or Spain, and then slowly drift north east across western Europe over a period of many hours or days. Other storms appear over Germany and likewise drift north east. It is these storms that give the best conditions from the UK into central Europe.

Studying weather maps as provided by BBC TV, ZDF in Germany and other broadcasters in Europe is one way of discovering where the rain storms are, especially since (at least with the BBC) rain radar plots are often shown overlaying maps of the UK. The UK maps provide some indication of rain patterns into the nearer parts of mainland Europe, but are usually of most use in determining whether rain scatter is possible within the UK. The rain plots are artificially coloured so that it is possible to gain some idea of the intensity of the rain and hence the possibility of successful scatter communications. The problem with these rain radar plots are that they are only broadcast with main news bulletins which means at mid day, around 6pm local and then again around 9pm local. Often the plots will be several hours old and therefore of limited use

The next best method of finding the rain is to study the Cluster reports. Operators throughout Europe regularly report rain scatter contacts, but unfortunately, less so by other UK operators. For this reason this method is of greatest use in working into mainland Europe. When a station locates rain he or she will report it on the Cluster. This report is usually (if it is to be of any real use) accompanied by a bearing to the rain scatter. E.g.

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DX de DL2xx: 10368865 DB0JK/B >55RS>JO31TO QTF 225 1507Z
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By studying a number of such reports it should be possible to determine the position of the rain by triangulation. Several areas of rain at one time may make this method somewhat unreliable. However, it is used extensively in Europe to find suitable rain cells and also as a means of finding out whom is currently active. Converse mode is also used by a growing number of operators but hasn't yet reached sufficient popularity to be of great use in finding the rain!

The third method is to use the Internet to find rain. There are no free Internet weather rain plots for the UK, but a service that is up to one hour old is available free from the Netherlands and this just covers the east coast of the UK, so again this is of most use when trying to work into mainland Europe. Rainer, DF6NA, [3] has reported subscribing to a German service that provides regular rain plots together with height information.

Another technique used very successfully by Simon, G3LQR and others is to 'look' for lightning discharges (crashes) on the 70cm band. The directive capability of a moderate to large 70cm station is sufficient to hear lightning crashes several hundred km away. My own modest 70cm station with a single 17 element yagi has, however, proven entirely inadequate for this purpose and storms more than 50 to 100km away are rarely heard. This probably says more about the sensitivity of my station than about the technique. For the record the rig is an FT847 with no mast head pre-amplifier. My previous rig was a Kenwood TR851 and that was equally insensitive to lightning discharges. I have recently started to use this technique on 2m, but the poor directive characteristics of my 10-element beam only gives approximate beam headings. I still have to 'probe' with the 3cm dish to find other active stations or beacons.

It should be possible to use an LF loop or frame antenna connected to a general coverage receiver (or transceiver) tuning 100 to 200kHz to detect lightning crashes. By using the null on the loop it should be sharp enough to determine the direction of a series of discharges to within a few degrees. With a partner the storm could then be triangulated quite accurately over quite a long distance.

Of course these last few techniques are only suited to finding rain associated with thunderstorms.

Rain scatter equipment

You might consider that a suitable rain coat is the most essential equipment when using this mode. However, the best rain is that which is some distance from you!

The rain scatter mode is ideally suited to home station operation. The 10GHz dish does not need to be mounted all that high above ground to use this mode, although the greatest distances will almost certainly be covered by a tower mounted system.

Radio equipment for rain scatter consists of nothing more than a regular 10GHz transverter and amplifier with an output of at least 1Watt. Successful rain scatter is possible at lower power levels but experience has shown that success is much greater at the higher power levels. Unless extreme range is required (when is it not?) a system noise figure of around 2 to 3dB is usually adequate since this is not a particularly weak signal mode. What distinguishes it as a DX mode is the experience needed to find and use the rain and then understand distorted single sideband or read auroral sounding CW.

Because the effectiveness of the mode depends on both the transmit and receive stations illuminating a common volume of space, big dishes with narrow bandwidths are not desirable due to the difficulty of illuminating sufficient scatter common volume. The trade-off here is that small dishes give lower ERP for a given transmit power. A 60cm (24inch) dish is close to optimum for this mode. If the dish can be elevated, even if only by 10 degrees or thereabouts, it can also increase the chances of success.

One station, local to me, uses a 20dB gain horn stuck out of an upstairs bedroom window due to local difficulties mounting an outside antenna. He has considerable success working DX on rain scatter.

Elevation is not essential but if you can't arrange it, it is not too important. There is a strong argument for having a 5 to 10 degree fixed elevation on the dish if you mainly operate using this mode.

Rain scatter on 5.7GHz usually requires much greater power because of the much poorer scattering efficiency of the rain drops in this frequency range. Similarly, 24GHz also requires much greater power than most microwave radio enthusiasts currently have available. The high water vapour absorption in the region of 24GHz leads to greater signal attenuation than at 10GHz, although the rain drop size required for efficient scatter is much less than at 10GHz.

Conclusions

- **Rain scatter is justifiably popular in Europe because it allows increased use of the higher bands when there is little other DX potential available.**

- **It doesn't require high power or a large antenna (at 10GHz).**
- **It is ideally suited to use where there are restrictions on outside masts or towers or where there is little room left for more antennas on an existing mast or tower.**
- **It makes a virtue of some types of bad weather!**
- **It is a DX mode.**

References

[1] Commission of the European Communities. COST 210 'Influence of the atmosphere on interference between radio communications systems above 1GHz'. EUR 13407 EN

[2] RSGB 'Microwave Handbook' Volume 1. Chapter 2, System analysis and propagation. Barry Chambers, G8AGN.

[3] Advance information. Rain scatter paper by DF6NA to be submitted to the 1999 Weinheim VHF conference proceedings.

[4] 'Concepts in Climatology', P.R.Crowe. ISBN 0 582 30013 4 An excellent UK degree study book for geographies.