Chapter 11

Propagation Topics

William Hepburn's VHF/UHF Tropospheric Ducting Forecast

Created By William R. Hepburn

William Hepburn has kindly allowed us to reproduce the following from his Web Site
http://www.iprimus.ca/~hepburnw/tropo_nwe.html
The Hepburn Tropo Index (HTI)
The HTI is the degree of tropospheric bending forecast to occur over a particular area, which is an indication of the overall strength of Tropospheric DX conditions on a linear scale from 0 to 10."

Negative Tropo Index = Below normal conditions. Bending occurs, but skyward.

Tropo Index of 0 = Normal midday "dead-band" conditions (Standard Atmosphere). Tropo Scatter only.

Tropo Index of 1 = Some downward bending occurs, but usually no discernible tropo.

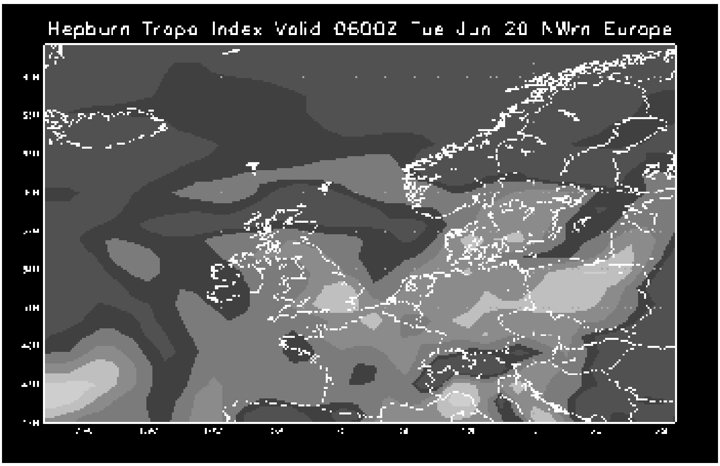
Tropo Index of 1.4 = Seems to be the average threshold of discernible tropo.

Tropo Index of 2 = Weak opening.
Tropo Index of 3 = Fair opening.
Tropo Index of 4 or 5 = Moderate opening.

Tropo Index of 6 or 7 = Strong opening.

Tropo Index of 8 = Very strong opening.

Tropo Index of 9 or 10 = Extremely strong opening.
(Yes, the Tropo Index can indeed exceed 10!...it is not a finite scale).



Background

I first attempted to receive distant TV signals in 1970 as a kid playing around with rabbit ears in my hometown in Southern Ontario. My first DX (tropo) was seen in 1972 when I received Channel 11 Toledo before our local Channel 11 came on the air. I started keeping a log of stations received on July 25, 1976. I had no knowledge of DX modes or that there were others who DX'd. On that 1st morning, I broke the Toledo record by picking up Channel 6 Columbus. Then on my 3rd day of organised DXing, I received Channel 3 Pensacola, FL (to my dad's amazement), destroying the Columbus record. (I wrote to the address given in an news editorial and was pleasantly surprised to find a WEAR-TV QSL Card in the mail the next week!). After picking up Florida from Canada, I wondered just what the limit was (of course, that was E-skip).

I later learned more about DXing from a copy of Communications World" magazine. In that magazine, I learned of the "World-wide TV-FM DX Association" (which I joined in early 1977) and learned about the various modes and what others were picking up. In 1981, I got my first taste of F2 skip with TV audio from the UK & Franc, and probable video from Ireland.

Other modes such as Meteor Scatter and Aurora were stumbled upon as the years passed. Forecasting Tropo. Using my many years of experience as a professional meteorologist with Environment Canada and an avid TV/radio DX enthusiast...I began experimental text DX forecasts for the Toronto-Buffalo area in 1997 (using E-mail). Once the Internet & newsgroups caught on, the forecast coverage eventually grew to cover North America. With continual gains in experience and real-time feedback from DXers, I was able to refine my methods and to gradually improve the quality of the forecasts. Later I developed the Hepburn Tropo Index to attempt to quantify the strength of Tropo Ducting Areas. Over time, the Index has been adjusted and refined and now does a decent job of representing the potential strength of Ducting. Then in May 2000, I prepared my first forecast maps. I automated the forecasts by having a computer program emulate what I had been doing manually to prepare the text forecasts and now have the computer prepare the maps. As a result of this automation, I have been able to expand the forecasts' coverage to encompass much of the world.

The Tropo Index alone is not an indicator of whether or not there will DX. The HTI is only indicative of favourable conditions overhead. In order to receive distant DX, the HTI will need to be relatively high over a large area. The larger the area, the longer the potential DX paths. Ducting paths will be straight-line (or Great Circle) only. Remember also that the longer the path, the more signal attenuation becomes a factor. Therefore for very long paths, a higher Index will be needed than that required for shorter paths. If an area's HTI is above normal, it indicates that conditions are favourable in that area.

The actual combination of weather conditions on surface and aloft will be the final factor in determining whether or not DX will be received in any particular locality. As well, physical barriers such as large hills or mountains may make reception via ducting practically impossible in some directions.

The Tropo Index does not factor in variations in Tropospheric Scatter, only Tropospheric Bending (Enhancement & Ducting). In the absence of any enhancement, and with only ever-present weak Scatter, the Tropo Index will be near 0. Also, don't be too concerned with the exact value of the Tropo

Index at your exact location. The purpose of the Index is to show potential duct paths (it is NOT a reading of the "probability" of ducting). Often, if you are within line-of-sight or within tropo scatter range of a duct located nearby, you may get in on that duct.

Tropospheric DX Modes: "Tropo"
The modes are defined by the mechanics behind them. A tropo DX mode is any condition that scatters, reflects or refracts signals in the Troposphere allowing DX to occur. Refraction occurs when the normal Index of Refraction has been altered. Vertical boundaries between different types of air masses usually cause this, where a temperature inversion (warm air over cooler air) exists. However, the most important influencing factor is water vapour (humidity). Thus, a warm dry air mass on top of a cooler humid air mass produces the best conditions. Dry Mexican air flowing across the Gulf of Mexico or Dry Saharan air flowing across the Mediterranean are two examples of prime tropo-producing conditions.

High pressure subsidence (the sinking and drying out of air), if it occurs over the oceans, can produce reception across several thousands of km! Hawaii to California reception, both on UHF and VHF, is not as uncommon as one might think. On the other hand, high mountains can physically block tropo DX, and deserts are generally too dry for tropo. Thus, tropo is rare in the very mountainous or dry regions of the world.

As far as classifying DX, enhancement and ducting in particular form a grey line. As a rule of thumb, enhancement is DX via inversions below 450 m (1500 ft) above ground...Ducting is DX via inversions above 450 m. (The layer of the troposphere below 450 m is called the "boundary layer" in meteorology).

Tropospheric V/UHF DX Modes.. Line-of-Sight (GW)
is normal continuous reception where the receiving and transmitting antennas can see each other, taking into account the 4/3 Earth curvature of radio waves.

Tropospheric Scatter (TrS)
is ever-present under normal conditions. That's the mode that produces the distant fluttery signals that randomly fade in and out. These are your most distant regular stations that barely make it in.

Depending on your location and equipment, tropo scatter can extend to 300..500..or even 700 km. The theoretical maximum limit for most TV/radio DXers is 800 km (500 miles) (Some semi-professional set-ups can extend further). Scatter is caused by small particles/droplets in the air such as haze, dust, volcanic ash, clouds, etc.

Tropospheric Enhancement (TrE), (aka Tropospheric Refraction) is common under normal conditions. On most clear nights, the ground radiates and the air near the ground cools. Eventually an inversion is formed and signals begin to refract off the inversion. Stations that normally fade in and out via tropo scatter come in continuously, with increasing strength. Also, weaker tropo scatter stations that are normally not heard (because their signal strengths never cross the background noise threshold signal level) also begin to appear. When the sun comes up, the ground & air heats up, the inversion breaks down, and the enhancement disappears. The enhancement is subtle on some nights, and very obvious on other nights. Distances are no different than your tropo scatter catches, it's just that the signals are stronger. Tropo enhancement is greatly influenced by terrain, with valley and coastal paths favoured.

("Fog-prone" areas are also "DX-prone" areas!!). From a DXers point of view, multiple directions usually are enhanced at the same time.

Tropospheric Ducting (TrD)
is an abnormal condition. An inversion has formed at a much higher level above the ground...the vast majority of duct-producing inversions lie between 450 and 1500 m (1500 to 5000 ft) with a few between 1500 and 3000 m (5000 to 10,000 ft). These inversions are not formed due to night time radiation/cooling, but rather because of some other weather phenomenon (high pressure subsidence aloft, warm frontal boundary, cold frontal boundary, oceanic or lake inversion, Chinooks, etc.). Because of this, ducting can occur day or night (though it strengthens at night), is not usually influenced by terrain (East of the Rockies), and from a DXers point of view is usually either uni- or bidirectional. In fact, typical ducts are sharply directional. Signals refract off of and also travel along the inversion, thus the analogy of a duct. Distances are theoretically unlimited. One large area can have multiple ducts going on simultaneously, but they are usually parallel paths. It is possible in a very strong high pressure system to have large areas of ducting creating multi-directional openings. These are the rare "blockbuster" openings that make DXers' mouths water.

Additional Characteristics of Ducting. Ducting may or may not occur simultaneously with enhancement (caused by night-time cooling). Often there is both a low-level radiational inversion caused by night-time cooling producing enhancement)...and a mid-level "system-produced" inversion above that (producing ducting). However, just as often there is only the higher duct-producing inversion, especially if the skies are cloudy or if it is windy. So, do not use your regular scatter/enhancement stations as propagation beacons for longer distance DX achieved via ducting! Sometimes ducting can even display a "skip-like" character where distant stations on the same frequency and bearing can be received while closer-by stations are nowhere to be seen.

Ducting is also very height selective, with maximum signal transmissions at and just below the altitude of the inversion. Side lobes (what most ground-based DXers see from ducts) are similarly directional and narrow. Thus, conditions usually vary over short time periods as opposed to enhancement which is more stable. Ducts located behind cold fronts ("post-frontal ducts") are notoriously unstable as paths can even be interrupted by things such as heavy rain showers associated with the cold front itself.

Expect the unexpected from these types of ducts with sudden and rapid changes in signal strengths quite common (some post-frontal ducts last only 15 to 30 minutes). High-pressure and oceanic ducts are a bit more stable and can last for days, but again expect the unexpected as changes can occur quickly. Frequencies affected by ducting are determined by the vertical thickness of an inversion. Individual ducts will have a LUF (Lowest Usable Frequency) associated with them. Thin inversions (i.e.-thin ducts) will only propagate Microwaves. Thicker inversions will propagate UHF signals as well, while the thickest inversions will also propagate VHF signals. Unfortunately there is no reliable method known for forecasting inversion thickness’. See LUF page. Special Cases (Exotic DX Modes)..

Rain Scatter (RS)
is a rare mode that sometimes occurs on the higher UHF-TV channels. A band of very heavy rain (or rain and hail) at a distance can scatter or even reflect signals. The effect is the one used for microwave Weather Radar. Distances

are typically around 160 km, though up to 650 km (400 miles) is theoretically possible. (Note that heavy snow is not an useful reflector).

Ice Pellet Scatter (SS)..(called Sleet Scatter in the US)
is similar to Rain Scatter but is caused by bands of Ice Pellets in the wintertime.

Aircraft Scatter (AS)..(aka Tropospheric Reflection)
is simply reflection off of aircraft, although reflections off of flocks of birds are also possible. A rare form of reflection is "Chaff Scatter". Chaff is strips of metal foil sent out by the military during training exercises. Chaff helps to confuse enemy radar, but also helps to produce DX. Maximum distances for all reflection modes are again up to 800 km (500 miles).

Lightning Scatter (LS)
is a mode that is sometimes discussed, but there is little documentation on it. The theory is that lightning strikes produce ionised trails. Reception is similar to other forms of scatter except that the DX is more burst-like similar to MS. LS is a mode that is very hard to distinguish and rarely reported. Reflections off of hills and mountains, and Knife-Edge Diffraction are not considered true DX modes since they are Omni-present, though they can help to extend DX via the other modes.

So these are the conditions in the troposphere that allow reception of VHF and UHF signals beyond their normal range. Basically, these are DX modes that are affected by the weather.

In the forecasts, the reason that I stick with just Ducting is because it is a large-scale phenomena, can be put down in a forecast in a reasonable amount of time, and produces the best tropo. Enhancement is forecastable, but it is so dependant on regional and local terrain and conditions that it would be a labour-intensive effort (not to mention a very lengthy one) to forecast for all of North America. The process that one would have to use to properly forecast Enhancement for a particular area is the same that a meteorologist would use to forecast overnight low temperatures, chance of fog patches, etc.

There are also conditions in the ionosphere that produce distant reception via a whole different set of modes. Ionospheric "skip" and scatter are not caused by the weather, but instead by the interaction between the Sun and the Earth's outer atmosphere, or by objects such as meteors. For information on these modes, consult the ARRL Handbook.

A ‘New’ Propagation Mode

Some observations by Phil Scorah, GW3PPF

Editor’s comment:
If you will pardon the pun, a lot of water has flowed under the bridge since this article was written and the existence of sea ducts are pretty well established . I thought I’d include it though, as well as Martyn Vincent, G3UKV’s reply. for historical interest.

With great reluctance, I have to concede the existence of a propagation mode that lies somewhere between Super Refraction (SR) and Tropo Ducting (TD).

For a few years now, Simon, G3LQR, has been reporting what he calls "Water Ducts" (WD), across the North Sea to Holland, that last all day and night. Penetration inland is limited but is significantly further than SR appears to go. Martyn, G3UKV has noticed that, during the Telford Microwave Expeditions, when good propagation occurs over the sea, it lasts all day. I have tried to explain it all away as TD with the occasional bit of SR but justification has become increasingly difficult with time!

Super Refraction has been hard to study since the move to narrowband operation on most of the microwave bands. All the suitably sited beacons are still on wideband! The arrival of Eric's' (F1GHB) beacons in Brittany has afforded a fresh opportunity to take SR measurements. Although the beacons are well inland, I suspect that they are RF line of sight to the sea beyond the North Coast of Brittany.

On the 12th July 1999, Roy, G3FYX, and I went to Seaton, Cornwall, IO70TI, (not the one in Devon). Whilst I spent all day measuring the F1XA0 and F1XAP beacons, Roy listened for F1XAQ mostly but failed to hear it. The graphs of our results (figs.1 and 2) show the standard SR shape, with the classic early evening peak.

On the morning of the 4th of September 1999, I was expecting Tropo Ducting and drove to my new site of Cefn y-Galchen IO81LSl9 (Mynydd Maen is no longer available to me). Finding no TD, I made a spur of the moment decision to return to Seaton and hope for a better SR situation than I found on 12.7.99, It was obvious from "switch on" that this was a much superior duct and I was hoping that the early evening peak would approach the Perfect Duct value. In the event, there was no evening peak and the awful truth slowly dawned on me ... that I had found one of Simons' infamous water ducts! Running in parallel with the SR and WD observations of XAO and XAP, I was monitoring the Guernsey 70cm Repeater GB3GU (vertical polarisation). It was not heard at all during the SR session but was heard, albeit weakly, during the evening only of the WD session. SR is renowned for only occasionally propagating 70cm but it usually propagates 23cm signals. It looks as though Water Ducts will be similar. More observations are needed, especially from those involving accurate measurements. I have some unpublished SR data from around 25 years ago and I am currently dredging through it trying to identify and WDs. Although Simon, G3LQR, is somewhat reticent on the subject of Water Ducts, the credit for their discovery is undoubtedly his, and quite rightly so!

Congratulations Simon!

Commentary on GW3PPF's article

Martyn Vincent, G3UKV

For as long as I've been active on 10GHz, 20 years plus, super-diffraction (or refraction, however you wish to name it) across the sea has been a recognised mode of propagation. The gurus of propagation led me to believe that stations at each end of a link had to be **in** the duct, i.e. on the beach or low cliff at each end, to use this mode. However, every time we've been portable at a sea location, we've found enhanced signals at 10GHz, notably from G3FNQ's personal beacon on 10368.2 MHz. Typically, signals start building up in the late afternoon around 1700 hrs, and peak soon after dark - typically 2200 in the summer. They then remain so until we go to bed! In the morning, they usually have returned to normal. Some days, no enhancement takes place, but on other days it remains all day. Generally settled weather gives rise to best SD propagation, as you would expect. Whilst portable on the cliffs in Guernsey in 1994, I was urged to go down from the cliffs (about 200ft high) to take advantage of SD, so we took all the gear apart and moved base about 1/4 mile to be on the beach: result ? Identical signal strengths from the GB3SCX beacon which showed the typical diurnal changes of SD on Guernsey.

So, for my money, there is only one mode involved giving enhancement on sea paths. It relies on stable temperature differences between the sea and the air above it. My results rely on evidence accrued in summer weather conditions, and may not apply at cooler times of the year. So long as there is a visual path to the sea, the duct can be used from any altitude. The name we give this propagation is irrelevant - but as super diffraction came first as far as I am aware, I'd settle for that as a label. Its enhancement properties are far more frequent and reliable than overland non line-of-sight paths. Personally, I'd settle for a QTH on the summit of a 1000 metre ASL hill by the sea, anytime !!

47GHz Propagation Observations

John Hazell, G8ACE

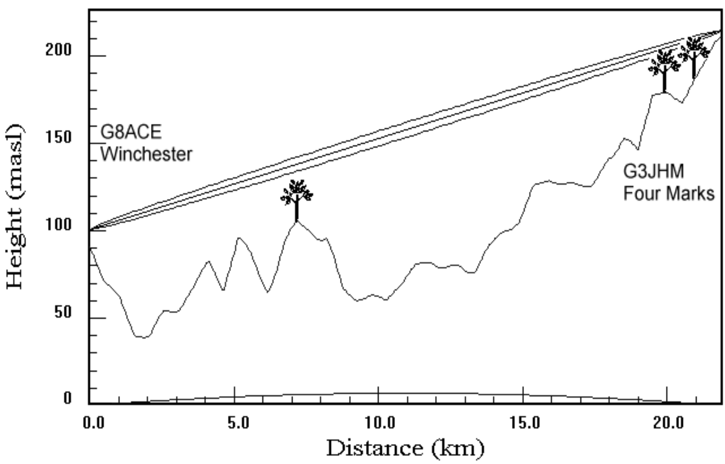
Propagation at 47GHZ is interesting to the writer insofar that, even after doing all the path profile work, signal exchanges can be equally poor or remarkable! Monitoring signal levels between particular locations is often only for a few hours, then not again for perhaps some months or longer. A beacon could be a solution to studying propagation variations, if one existed that could be heard at the home QTH of a 47GHz equipped microwave station. Looking at the profiles from local beacon sites to equipped local stations quickly revealed this as much of a non-starter.

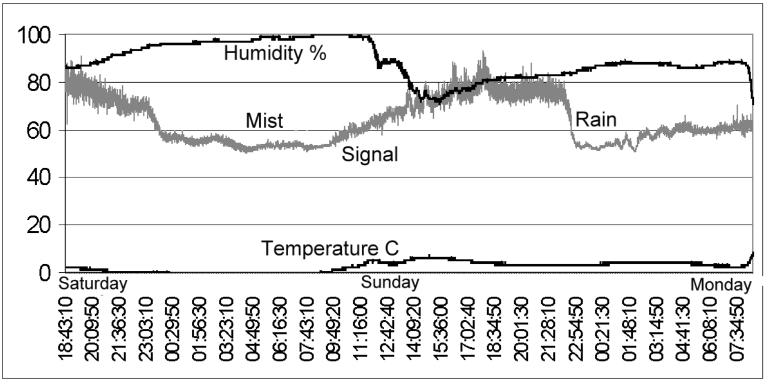
G3JHM at Four Marks is 22km distant from G8ACE in Winchester. Most of the path from G8ACE is good, as it sets off over the Itchen Valley, the Four Marks area being visible on most days. A QSO on 24GHz has already been conducted from dishes on tripods, garden to garden, so it looked optimistic for tests. G3JHM, having interests in propagation, was also keen to see if a 47GHz link could be established successfully.

A personal beacon was constructed and installed on the chimney at G8ACE in Winchester. At Medstead, (home of GB2RS in the south) just to the north of Four Marks, an excellent signal was receivable on the transverter, without any aerial, the unit being hand held. This was a true LOS path from Winchester, G8ACE's nearby landmark/ microwave reflector (HM Prison !) being clearly visible.

Moving south to G3JHM, the results were quite disappointing. The signal could just be found using a 45cm dish. The signal was spread over an angle of around 10 degrees with multiple peaks dependant on the elevation used. This is due to the large amount of vegetation clutter from trees and bushes in the last kilometre of the

The path profile showing the signal obstruction caused by vegetation clutter at G3JHM:





Signal level variation over a 36 hour period

path. The small horn initially used in the transmitter was replaced with a 30cm dish and the receiver for reception at G3JHM was constructed using a 60cm dish. This improved the signal so that good quieting can now be obtained using FM in "normal weather" conditions.

The RF Equipment:

The modules necessary for the transmitter and receiver were either specially built or already in the "cum-handy" box. The transmitter uses a G8ACE MKII ovened oscillator so that the frequency can be easily dc controlled with a multi turn pot. The FSK ident signal is added to this control voltage. My thanks go to Chris, G8BKE, for the building and programming the PIC ident generator. This drives a modified G4DDK multiplier to provide in excess of 20mw at 2.4GHz. With the enhanced 2.4GHz drive the multiplier to 11.7GHz uses just two GaAsFETs. The G3WDG009 is modified by removing the input mmic and replacing with a 3db pad. The multiplier GaAsFET is used as in the original design and the first amplifier is used alone to provide 10mW output at 11.7GHz. This simplified 2 GaAsFET version requires 7mW of 2.4GHz drive for full 10mW output using a 5v rail and recovered "Blue Cap" GaAsFETs. 10mW is more than adequate at this frequency for driving further multipliers. The 47GHz signal is achieved from three NE325 GaAsFETs. A doubler to 23.5GHz, then an amplifier is followed by further doubler. Between 5 and 10mW output can be achieved from this module for 2-3mW drive at 11.7GHz. Since the drive requirement is modest, the module is mounted behind the dish to minimise 47GHz losses and fed via 2m of 0.141 rigid coax at 11.7GHz from the original beacon unit now in the loft.

The receiver uses the same module arrangement as the transmitter to reach 11.7GHz. The 47GHz receive mixer is the original transverter built for the band by G8ACE and is similar to the DB6NT design.

Now a spare, it is utilised to save construction time. All the modules are mounted in a weatherproof box behind the receive dish with the signal leaving at 145MHz, the first IF frequency.

The IF uses a simple FM strip containing a 10.7Mhz crystal filter. The 2nd local oscillator is fixed tuned with a crystal. Tuning of the 47GHz signal is achieved by DC control to the outdoor unit (97MHz) 1st ovened oscillator. The RSSI output from the FM demodulator is used to drive the data logging equipment.

Dishes (see photos on the next page)
Weather proof dish feeds needed to be created for this project and the arrangement is the result of some experimentation. It was found that 40mm Marley plastic waste pipe, slid over a splash plate feed, had negligible effect on the gain of the dish. The feed is constructed using 6mm o.d. copper tubing with a bore size similar to the usual 4mm circular waveguide used on 47GHz. This is fitted through a boss in the centre of the dish. The reflector is mounted at the far end of the plastic tube and the tube adjusted back and forth on the centre boss for focus. The tube is sealed with silicone sealant at either end. The wave guide then passes directly into the equipment box on the back of the dish.

Data logging:
A trawl of the Internet did not reveal any suitable software for signal logging purposes. Also the ability of G8ACE at writing PC software is non-existent. Equally, an A-D chip was not to be found in the cum-handy box. The BBC micro, long forgotten by most of us now, is easy to program and contains a four channel A-D. I should mention at this point a diversion into using the games port on a PC resulted only in wasted time as a practical test revealed each channel resolves only 16 levels … fine for a joystick but no use here. The BBC was duly programmed to draw a graph of received signal strength and record the levels to file. By chance, a screen dump program was found, thus allowing the graph to be printed. The dot matrix printer used, however lacked the quality we have become accustomed to and the problem of how to extract the data from the BBC still existed. A further Web trawl only produced complex answers to this problem; maybe I use the wrong search criteria?

Transferring serial data to the PC is easy, I finally discovered. Windows Hyper Terminal will log incoming Com Port data to a log file. Thus few lines of programme to the BBC and the data was leaving the BBC RS423 port to be easily transferred into Excel for a higher quality graphical display, analysis and print. A humidity detector and thermometer have been added to the data logging and three channels of data are now presented to the PC for saving to hard disk. A DOS terminal program was discovered so that data logging currently consists of the BBC for acquisition, sample interval selection and graphical display of signal in real time and an old 286PC for storing the files. G3JHM has undertaken to analyse the data and will produce the long term conclusions about propagation on the path. Already it is possible to readily see the effects of rain and mist. Some deep fades being noted. The project has entailed about 4-5 months of precious construction time but is enabling some propagation monitoring, perhaps not done before on this amateur band.

60cm Rx dish used at G3JHM

The 30cm Tx dish

A Digital Weak Signal Mode for Microwaves?

Chris Bartram, GW4DGU

Returning to an active interest in microwaves over the last year or so, I've been struck by the way in which there has been a drift of formerly active microwave people to VLF. While I appreciate the challenges of longwave, and could even share the enthusiasm of a friend, professionally involved in RF power amplifier design, who points out that he can legally and easily build 10+kW power amplifiers for 136kHz(!), I feel that the bands above 1GHz still offer some serious challenges. This doesn't necessarily mean translating existing (dated!) technologies to higher and higher frequencies, interesting as this can be.

An area where the VLFers have made progress has been in the application of very narrow band modulation schemes, allowing them to combat the inherent high antenna noise temperatures and small antenna efficiencies at those frequencies. It's easy to do this at VLF where the transmission path has relative phase and amplitude stability.

It's still possible to do similar things at VHF: Joe Taylor, W1JT, has demonstrated that his JT44 multi-tone FSK modulation (anyone remember Piccolo?) scheme based on the work of Bob Larkin W7PUA, operating in 5.8Hz demodulation bandwidths, has been effective for 50 and 144MHz and, to a lesser extent, 432MHz and 1296MHz EME using relatively small antennas. Bandwidth reduction also has applications on the microwave bands but there's a snag: microwave transmission paths, particularly beyond line-of sight, tend to be anything other than phase and amplitude stable! Poor phase and amplitude stability results in the spectrum of the signal spreading: quantifying this isn't a precise art, but tropo scatter at 1.3GHz results in a received bandwidth of perhaps 30Hz, whilst 24GHz EME has been reported to show spreads of maybe 250Hz. Conventionally this limits the minimum usable bandwidth to those figures: reducing the bandwidth further will decrease the signal to-noise ratio, or conversely, increase the receiver threshold! Human ear/brain processing can sometimes recover data from decorrelated signals but even that has limits. If a way can be found of reducing the decorrelation, the benefits could be very significant. 13dB system gain could potentially be obtained by reducing the decorrelation bandwidth of a 10GHz EME signal from, say, 100Hz to 5Hz. Potentially, this could allow contacts between stations using good quality tropo systems (5 - 10W and 100K receivers with cheap(ish!) 1.5m offset dishes using off-the-shelf satellite TV positioners, making 10GHz EME a very attractive proposition to a large number of operators.

So how can we do that? The key seems to be the use of a modulation format which includes a reference vector. A reference vector is simply a component of the modulating signal of which the receiving system has a priori knowledge. It could be as simple as a constant carrier. If the received reference vector can be reconstructed, then as we are considering a narrowband signal, the complex function required to reconstruct the reference can be applied to the whole signal spectrum, and data can then be recovered in narrow bandwidths. There's nothing really new in this. A similar technique has been very successfully used in the Linear Modulation (LM) systems developed for ssb speech and data transmission in mobile radio environments. Incidentally, the use of a reference vector isn't the same as the use of a reference frequency in the JT44 modulation format. That provides a non-continuous frequency reference: I'm suggesting that the reference vector is transmitted continuously to provide a coherent reference.

Although some elegant solutions, such as various forms of PSK, and even QAM, exist, multi-level FSK combined with a reference vector could provide a simple solution. This wouldn't give a constant amplitude signal - which may or may not be desirable - but it would work with standard ssb transmitters, albeit probably generating some transmit intermodulation. It presents a similar challenge in terms of transmitter linearity to PSK31. Whether this is significant (most of the time!) on the microwave bands is a moot point! There are a number transmitter linearisation techniques, particularly Cartesian feedback loop topologies, available if it's necessary to clean-up the intermods. These ideas need testing by proper modelling (Matlab, anyone?) and maybe then by building a test system based around PC sound cards. I can't see myself having the time to do this in the next few months as I'm involved in a protracted house-move and I'm also pretty busy in my work. I'd also be on a steep learning curve in certain areas. I'd be very happy to co-operate with anyone with the necessary skills. I believe algorithms exist to allow reconstruction of the reference vector and the other signal processing tasks are if not trivial, not the DSP equivalent of rocket science.

As the VLFers and K1JT/W7PUA have demonstrated, the use of PC based techniques to increase the capability of existing VLF to VHF systems is entirely practicable. Currently available software is of limited use in the microwave bands, and a properly thought-through system taking into account the properties of the microwave transmission medium is needed.

Rain scatter – Where, When, How?

Uffe Lindhardt, PA5DD

This paper formed the basis of a talk on rain scatter given at the Adastral Park Microwave Roundtable on 14 November 1999. It deals with the practical aspects of using rain clouds as a mean of reflection on frequencies around 10 GHz. It also includes a look back on the rain scatter season 1999 as seen from the Netherlands.

Frequencies

For radio amateurs the main frequency band of interest for rain scatter contacts is 10 GHz. Rain clouds offer very good reflectivity at this frequency, and atmospheric losses are low. At the same time the availability of high performance components and circuits for this band has increased the last few years.

On lower bands the reflectivity decreases drastically due to the size of raindrops compared to the wavelength. According to WA1MBA (see Internet resources below) this amounts to –12dB at 5.7 GHz and –19dB at 3.4 GHz in relation to 10GHz. These figures seem to match the practical experience of many amateurs. DX-contacts (over 400 km) are quite difficult on 5.7 GHz. Also the number of stations QRV on this band is much smaller.

Rain scatter on higher bands than 10 GHz is an area where very little experience has been gathered. Due to the still very merger activity and the small output powers on 24 GHz, very few contacts has been made. Certainly atmospheric losses start to play a role on this band. It seems though, that shorter contacts of up to 200 km can be made when strong forward scatter is present on 10 GHz. For these contacts elevation is essential.

Equipment

Any equipment used to make tropospheric contacts will do, but to make full advantage of this propagation mode a narrowband mast mounted home station is essential. The weather patterns that rain scatter are linked to, do not invite for hill top portable operation. It is also very difficult to predict when good rain scatter openings will occur, and it is therefore essential, to monitor the conditions over longer periods.

QTH

It is not essential to have a high-elevated QTH for working rain scatter, as it is often the case with tropospheric contacts. High altitude will give only little enhancement in the achievable ODXs. What is important is a clear horizon because even a few degrees of horizon elevation are going to block for DX contacts. The rain clouds reside only up to a maximum height of 10 – 12 km, and it is essential to have a clear view of the reflection areas on the horizon if you want to achieve contacts of 600 – 800 km.

TX

A reasonable ERP output power is important. Output powers of up to 1W are available at low cost (e.g. QUALCOMM surplus modules), and with that power and a parabolic dish of 50cm, you have a good rain scatter station. In fact most of the QSOs reported at the end of this paper were worked with 1W and a 45cm dish, including several QSOs of 600 – 700 km.

Since the station should preferably be mast mounted - because of the high feed losses at 10 GHz - solid-state amplifiers are easier to install.

On the other hand the cost of solid-state at a power outputs above 1W are still very expensive.

Installing a TWT amplifier in your mast can be quite cumbersome. Nevertheless many stations using 10W or more are QRV via rain scatter, so be prepared for some frustration if you go on the air with 200mW !

RX

Since low cost HEMTs like the NE325 are now available, the receiver should have a noise figure of 1 – 2dB. On the other hand since many high power stations are QRV any receiver will do.

Antenna

For maximum size/gain performance a parabolic dish of at least 40cm should be used. Using a relative small dish gives some advantages in finding the optimum reflection point and also removes the need to elevate the antenna at medium distance contacts.

A larger antenna gives the advantage of a larger ERP output power, which can prove essential for DX contacts. Exact pointing gets difficult from a dish size of 70cms onwards using the normal commercially available azimuth rotators. My advice is to use a 40 - 50cm dish if you are looking for many QSOs (like in a contest), and a larger (70 – 90cm) if you are a DXer.

Elevation can be very useful in rain scatter openings. For medium distances (300-500 km) it can mean a difference of 10 – 20 dB in signals. It is however my experience, that you will work these stations also without elevation but probably AFTER that the stations with elevation are done rag chewing. For 24GHz, elevation is essential for rain scatter.

Modes

All though rain scatter is possible using broadband equipment real DX requires the better system performance of narrowband modes like CW, SSB & narrowband FM. CW (telegraphy) is by far the most efficient mode. Due to the fast random orientation wind speeds in rain clouds, reflected signals are subject to Doppler distortion, which makes the signal sound like white noise. The size of the Doppler effect is on 10 GHz very similar to the one known from 144 MHz Aurora reflection. This distortion makes it difficult to understand SSB signals, especially when using side scatter (i.e. the reflection point being offset from the direct line between the two stations). On the other hand SSB is normally quite useful for making DX QSOs, which are always forward scatter.

For local or medium distance contacts - where signals can be very strong – narrowband FM is also an option. In FM the Doppler distortion disappears all together, due to the low deviation of the Doppler effect as compared with the modulation. For making fast comfortable QSOs or for rag chewing FM is the perfect mode, it is however recommended to QSY from the narrowband part of the band to prevent disturbance to other stations.

Finding rain scatter

Finding rain scatter openings are quite a challenge because of the sparse distribution of stations and beacons, and because of the narrow beam angles associated with 10GHz antennas. The rain scatter season – at our latitudes - extends from approximately begin of May to the end of September, with a peak in the month of June. Certainly rain scatter contacts can be made outside this season, but they rarely produce any DX contacts.

At present most of the rain scatter QSOs made are made along the 50º latitude. From my experience rain scatter is less frequent at higher latitudes like 55º. It is however difficult to separate the effect of the generally low 10 GHz activity level there and possibilities for rain scatter. There seems however to exist a belt of high thunder activity going from the Biscay bay and North- East towards central Europe. In any case there will certainly be some variation in rain scatter activity from region to region.

At present the main warning channel for rain scatter openings is the Packet Cluster network. *(or nowadays the ON4KST Chat site. Ed.)* This network links most of Europe together for fast real-time spotting of rain scatter observation. The ideal rain scatter spot contains information of the QTH of the two stations, and the azimuth angle QTF of the reporting station. Unfortunately only the newer DX cluster software has a good support for reporting 10 GHz contacts, and this software is not yet installed throughout Europe (e.g. not in the UK). For example CLX provides excellent features like dedicated 10 GHz spotting and reflection point calculation. WW-converse is also available via the Packet network. It is a "chat mode", and allows real-time communications between rain scatter stations on channel 10368.

Unfortunately WW-converse is also not available everywhere, and normally less than 10 stations van be found here during openings.

The Packet cluster & WW-converse can also be reached via various "back doors" on the Internet. So can some of the professional weather radar's. These radars typically work at around 9 GHz, and they can therefore provide very useful information on current rain scatter conditions. The main problems in using these sources are the cost of real-time information, which is sold at commercial terms. The information that is publicly available is normally some hours old, and does for example not include elevation scans, which are essential for the evaluation of DX possibilities. A few exemptions are mentioned under the Internet resources below. Beacons are another essential tool in finding good rain scatter reflection points. It is however essential with high power beacons (1W or more), since the beacons are required to have an Omni-directional antenna pattern, and hence have relative low ERP. It is also important that beacons are placed between places, where actual activity can be expected. A good example of such a beacon is DB0JK in JO30LX, which serves the three main areas of activity at present, namely the Randstad NL (JO22), Ruhr D (JO31) & Rhein/Main D (JN49). Unfortunately the lesser-activated areas (like the UK at present) suffer from the mutual concentration of activity between these centres. One answer to solve this problem is the deployment of beacons to attract attention.

A final means of locating rain scatter reflection points is the use of another local station as "sounder". In my experience the backscatter signal of a station close to you gives the best indication of the beam angle towards the DX stations. Beacons which are often received via side scatter will give a beam angle slightly offset to the forward scatter beam angle. A very good teamwork can evolve between two close-by stations alternately giving CQ, while the other station are optimising his beam angle.

Combined with some kind of backbone communication, this can be a powerful tool to find the reflection in directions, where no beacons are present. It can however be difficult to determine the distance to the scatter point using this technique. Maybe in the future amateurs will be able to do their own "sounding", using fast RX/TX switching and precise time mapping of the return signal.

Finally it cannot be stressed enough, that activity brings on more activity in quite a surprising way. It is my estimate that at present, there are close to a doubling of rain scatter activity every year on the continent, at least if measured by the number of contacts made. For an indication of the present activity, you can check the list of stations compiled by DG1VL and referenced below under Internet resources. This list is only the top of the iceberg!

Operating

The rain scatter activity is concentrated around 10368.100 MHz. During openings the activity can extend well beyond the band 10368.080 – 10368.150 MHz. It is apparent,that more spectrum will be needed if activity continue to increase at the present level.

It is not unheard of to hear 10 stations giving CQ at the same time in this band segment during an opening. Most contacts are made randomly following a CQ without any prior arrangement. This makes rain scatter contacts an extra treat, since most other contacts on 10 GHz are made after contacts made on lower bands. The normal operation style is to have an automatic keyer make a CQ in the direction, where the rain scatter reflection point is assumed to be. These CQ calls can be quite long but ,in order to find the rain scatter, it is important that the on-air time is kept high. Unfortunately this leads some operators to call CQ for more than 10 min, without checking for stations coming back to their call. If this happen to be the rare DX station you are looking for, be sure to have some tranquillisers at hand! Calls in SSB are also made, but usually even stations that cannot read CW uses an automatic keyer to make the CQ.

A main activity during a rain scatter opening is to keep track of the reflection area. The reflection point is often moving (though not fast), and DX stations will have slight variations in the optimal azimuth angle, depending on the angle they have towards the reflection area. In some big openings there are 2 or 3 different reflection areas, which can be challenging to the operator. A good working Packet cluster can help to focus on the best direction.

At the IARU conference in Lillehammer 1999 it was decided to replace the last character of the RST report with an S (e.g. 59S) in rain scatter contacts. This reporting is used on CW as well as phone. Log analysis 1999 To round off this paper I have made some simple analysis on the rain scatter contacts that I have made during 1999. All of the contacts were made from my home QTH that is situated at –2m ASL, but with 360º of free horizon take-off. Most of the contacts were made with 1W output and a 45cm parabolic dish (actually a lampshade). Towards the end of the period I have upgraded to 10W output and a 70cm dish. These improvements were made as an effect of the good results made with the original set-up.

The first figure in appendix 1 shows the distribution of contacts and distances over the season. Of course the number of contacts are highly dependent on when I was actually QRV, but still the figure are rather interesting. It should be noted that many stations have been worked more than once. For a detailed analysis I refer to the complete log in appendix 2.

The first figure shows 5 – 6 real DX openings concentrated in the period May, June and July. The DX openings are characterised in that contacts over 450 km are possible. These contacts are much rarer than contacts of 200 – 400 km.

This is shown more clearly in the second figure, where the same contacts has been sorted after distance. DX contacts are more difficult to achieve due to the fact that openings are shorter, and DX openings can rarely be detected using beacons. The signal strengths of DX stations can be quite impressive though.

Conclusion

It is my hope that this paper shows that rain scatter reflection on 10 GHz is a mode that everybody can enjoy, and that we can continue the rising trend of rain scatter activity in Europe in the coming years. Today the achievable DX results on 10 GHz far succeed those of the lower microwave bands like 2.3 GHz. This is a surprising development, from which we have only seen the beginning yet.

Internet resources WA1MBA, on the basics of rain scatter:
http://www.wa1mba.org/10grain.htm

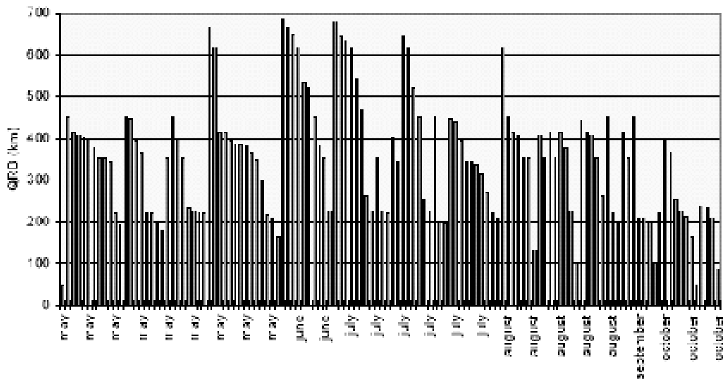
DG1VLs list of rain scatter stations:
http://www.qsl.net/dg1vl/RS_05_02_99.txt

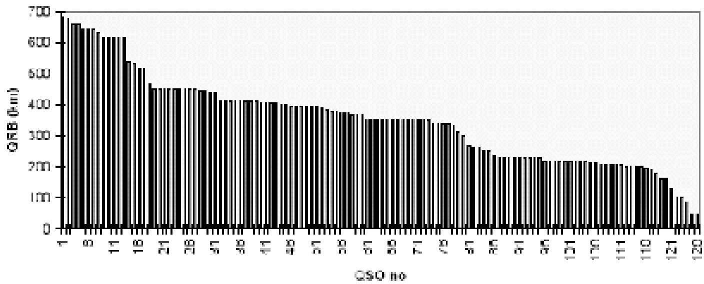
Weather radar for the Netherlands:
http://weerkamer.nl/radar/

Weather radar for Bonn, Germany with elevation scans:
http://www.meteo.uni-bonn.de/Deutsch/Forschung/Gruppen/radar/radar_en.html

PA5DD, Authors homepage:
http://home.worldonline.nl/~nouchavw/

Appendix 1





5760 MHz Rain Scatter Detector

Rudi Wakolbinger OE5VRL

I have been making QSOs for many years using Rain Scatter (RS) on the microwave bands. Through tests with DL6NCI, DD7MH, HG1YA and many others, I have confirmed that 3cm is not the only band suitable for RS. It is also possible on 6cm (very good), 13cm (just about), and 24GHz (very rarely). 9cm is not available in Austria so my experience of that band is minimal.

To make RS contacts, you must first find a suitable cloud that can act as a scatter point. The finding of these clouds has until now been mainly through listening for beacons. With this method it is only possible to find the direction of the scatter point but not its distance, so it is not possible to determine the actual location of the scatter point. That brings me to my idea, to receive my own reflected signals and to measure the elapsed time. I have had this idea for years … it was recently re-activated through an article by LX1DU in DUBUS.

I must acknowledge my radio friends for solutions to several technical problems. Above all is my friend Erwin (OE5UXL) and I must not forget Michael (DB6NT) with his excellent modules and amplifiers. I had many QSOs with Ulrich (DG2MF) in which we discussed fundamentals. Ludwig (DC8NV) provided the most significant part, a circulator. Dieter (DL3NQ) gave me many important tips. Ferdi (DC8EC), Erhard (DC4RH), and many other helped with their specialised knowledge to help me realize this project. Based on my experience of RS and the availability of cheap components I decided to operate my Rain Scatter Detector (RSD) on 6cm, 5.7GHz.

I needed a number of units for the system. A pulse generator to produce the transmitted pulse and receiver phase, a transmitter oscillator (120MHz), a 48x multiplier to produce 5760MHz at 100mw, an 5W amplifier, a converter 5760MHz to 144MHz, a 144MHz receiver with a S-meter output and, finally, a circulator. An oscilloscope is used to display the results. The pulse generator produces a 30µs pulse with a frequency of 375Hz. This controls the transmitter that produces a 30µs carrier, 375 times a second. There is a single buffer amplifier after the oscillator and three multiplier stages in the transmitter driver. The transmitted signal is amplified by a two-stage amplifier up to the 5W level and through a circulator to the antenna (3m dish).

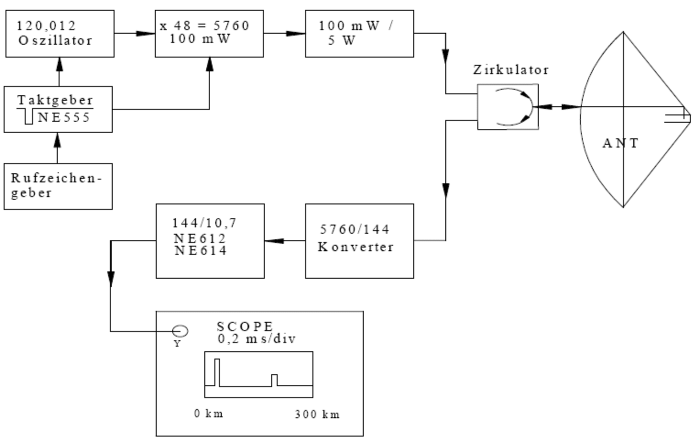
A very good match at the antenna is a basic requirement, otherwise too much reflected power may flow over the circulator to the receiver and result in the destruction of the input transistor. The isolation between the transmitter and receiver ports is 33dB. Approximately 3mW from my transmitter appears at the receiver input. During tests I determined that the input transistor (NE325) could survive this power level.

The antenna radiates the transmitted pulse and when no reflector is available, it disappears. A small amount of the transmitted signal is received via the circulator and this causes the oscilloscope to display a large Y deflection for the duration of the transmitted pulse. The transmission of the pulse triggers the start for the X time base. Suppose that within 300kms of my antenna is a good reflector, a proportion of the transmitted pulse is reflected and if strong enough, it will appear on the oscilloscope as a deflection on the Y axis at a point in time on the X axis.

The size of the Y deflection is proportional to the strength of the reflected signal and the distance to the reflector is calculated by measuring the time difference between the pulse being transmitted and the reflection being received. An elapsed time of 1ms = 300kms which is produced by 150km there + 150km return, indicating 150km to the scatter point. I have the X axis time base set to 0.2 ms/div so 300km are easily seen.

To date (beginning March), there have been no thunderstorms and that's why I still do not have much experience of the range of my RSD.

The RSD first went into service in mid February and I easily received a reflection from a hill in the Swabian Mountains on an azimuth of 271 degrees and at a distance of approximately 370ks . In the north direction I can see a number of hills at around 200km distant. My RSD not only detects rain scatter, but also Over Rich Distance Detector ORDD. Over the summer months I hope to show how close to theory will be the results in practice. This system functions only when using a reasonably large antenna (3m dish). If I had only a 1m dish, then I would need a power of 500W to get the same strength from the reflections. With a 70cm dish I would need 1kW.



A Proposal for a Passive Rainscatter Monitoring System

Lehane Kellett, G8KMH

Introduction

The UK Microwave Group was recently discussing potential projects and the perennial discussion of beacons came up. In the UK, at least, it has become difficult to find acceptable sites or groups willing to take on the establishment of 10GHz beacons or for that matter beacons on other bands. There are already a number of beacons but these may not be in the best position to allow the determination of rain cells and hence a significant lost opportunity for 10GHz contacts.

Looking in reverse however, if there can't be enough beacons in the right locations then it might be possible to put receivers in sufficient locations to either receive a beacon or transmissions from stations probing to find scatter (or even tropo ducts).

Putting a receiver in place is one thing but there has to be some feedback path to the user(s). In an ideal world a nice high speed connection to the Internet would be available with FFT displays at the user end. In the real world the best we could achieve at present is an audio quality line from a GSM cellphone.

This paper discusses the approach for a simple beacon monitor and discusses what might be possible in the future. In essence the concept is to produce a self contained box which requires only power (240V AC or 12V DC) and siting on a mast or other convenient location.

Rain scatter monitoring

There is little point in covering what rain scatter is in this paper. There are plenty of references to it elsewhere. For the purposes of the monitoring system there are two key points

- The rain cells move fairly rapidly and therefore a path between two sites is only transient.

A system must therefore have a reasonably large beamwidth to cater for many path permutations.

- The signal suffers from dispersion due to the random Doppler from the raindrops.

Ideally a system would cover a wide bandwidth with digital signal processing of the signals.

Whilst we can provide for a reasonable beamwidth using a horn antenna (at 10GHz) – in fact their small size is a positive bonus!

However, it is not easy to provide a large bandwidth, say 25KHz, and send processed data down a 3KHz audio or 9600bps digital link. So, for the first phase the receiver will be no more than a standard SSB receiver with 2.4KHz bandwidth.

It may be possible to use a wider bandwidth and use some audio frequency folding - 4KHz becomes 0Hz, 6KHz translates to 2KHz, etc. This would best be done using DSP.

Phase 1 Remote receivers

Our first system is likely to use readily available components – a 15dB horn, LNA, 10GHz down converter and then a commercial (trans)receiver. It would be advantageous to create a modified receiver board (Plessey, Howes, etc) in place of the commercial unit, if only to reduce power requirements. The GSM phone is key to the operation of the system. It is not known if a similar system has been used commercially – probably given some of the roadside boxes with 900MHz antennas - but it is understood that the approach has been used in clandestine operations. It is not legally possible to take a cellphone, open it up, and attach wires to the keypad, reset lines, etc., although this would be easiest. Another approach has to be taken and some means of controlling the phone is required, as well as access to the normal hands-free / car-kit microphone and earphone connections.

Initially the search was for phones with a logic level ring indicator and answer system but this didn't prove fruitful. Next those with data connections were looked into and there are two main candidates – most Nokia and some Ericssons. The latter have an easy to use Hayes command set but crucially lack the ability to turn the phone on if it has been powered off (which may happen during a prolonged power outage). So a Nokia it is – probably a 6100 series. Unfortunately the protocol for the data connection is not published by Nokia (except under NDA) but has been reverse engineered by the Linux community and the details put on the Internet. The cellphone (or at least the SIM) will be one of the popular pre-pay systems with vouchers that are valid for a long period without the need to top up the phone. Some allow incoming calls for 6 months after the expiry of the voucher. A controller board will interface between the receiver and the GSM phone. It will provide for all the call control – answer, hang up after preset time, power on, etc. It will also have DTMF decoder for future options.

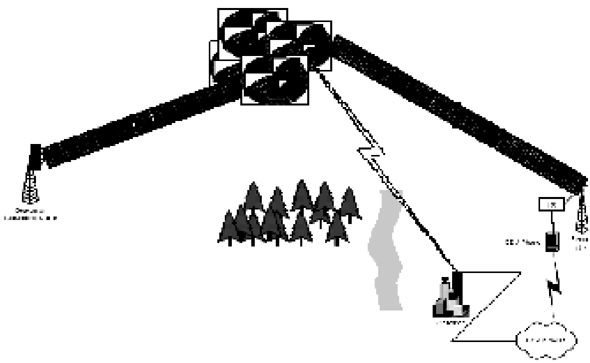
Phase 1 operation

In Phase 1 only the most basic operation is possible. Here the operator makes a call to the unit and then listens – either for other operators/ beacons or transmits his/herself. By using different beam headings it would be possible to 'probe' for areas of scatter. Of course, with sufficient units a local system may just be used to check you are still transmitting – very useful when there seems to be no-one else on the band!

Phase 1a,1b,2 – futures

Looking to the near future it should be easily possible to replace the commercial transceiver with a simple SSB receiver. It would then be possible to add some additional facilities, namely:

- Switchable LO crystals or PLL LO operation



- Switchable filters
- RSSI/AGC A to D conversion
- Audio fold back (mixer and filter)

The PLL control of the LO would be very simple to add as most of the work has been done by Andy, G4JNT. All these functions would be controlled by means of DTMF commands. In the future it would be nice to add DSP capabilities and make the results available on the Internet via a push server. This may be possible if an academic establishment makes a site and bandwidth available.

With some care it should be possible to use a solar cell to provide the power, with the logic board monitoring the voltage levels and turning off the receiver if necessary.

Conclusion

A rain scattering system looks feasible and should be reproducible at low installed and running cost. How many could be established in the UK would depend on funding but certainly as many units as there are beacons should be a target. The use of a cell-phone makes the unit almost completely self contained.