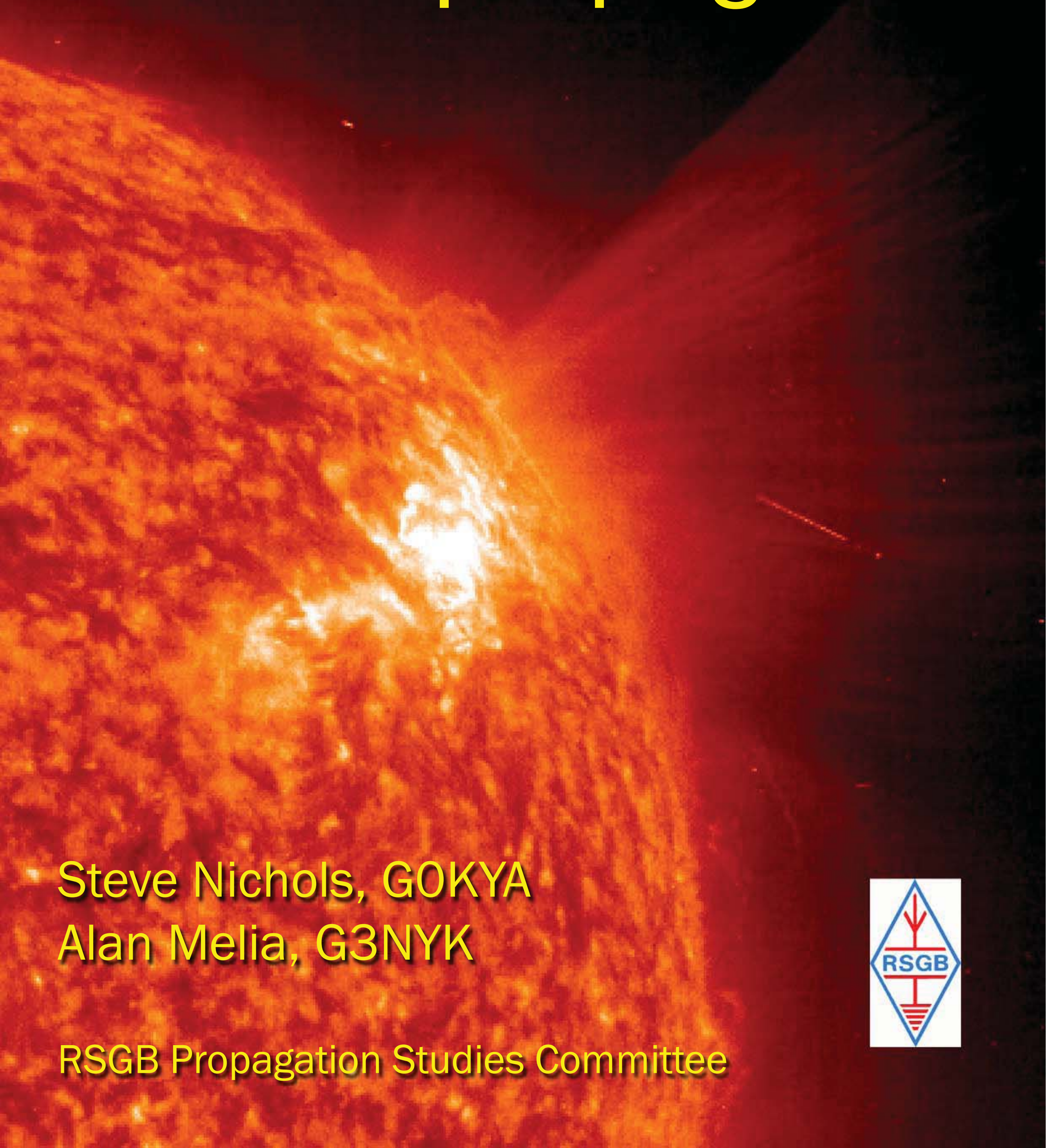
Understanding LF and HF propagation



Steve Nichols, G0KYA
Alan Melia, G3NYK

RSGB Propagation Studies Committee

Understanding LF and HF Propagation

Introduction

In 2008 it was suggested to me that "RadCom", the RSGB's member publication, could run a series of features looking at an "HF band per month". The idea was that I would pick the band each month that offered the best chance of good propagation.

After a bit of head scratching I worked out which band would slot into which month. But I was also determined to make the series much more than that. I wanted to look at the processes behind ionospheric propagation and try to explain some of the terms that are commonly used, such as solar flux index, K index, interplanetary magnetic field (Bz) and many more.

The end result was a series of features that formed a good introduction to the topic. When I finished, my good friend Alan Melia G3NYK, took over and wrote three more features on LF propagation – a topic he is very well placed to explain.

After answering questions at the 2009 and 2010 Newark Hamfests it dawned on me that these features could be bundled together into a single PDF, so giving the reader a good grounding in LF and HF propagation. I hope you agree.

Even though by the time you read this the solar cycle will have advanced somewhat a lot of what is said about each "band per month" still applies.

It starts with the 20m (14MHz) band in October, ends with 10m (28MHz) in June and also includes a look at how to use beacons and WSPR. It finishes with Alan looking at LF (generally considered to be the bands below 300kHz).

Steve Nichols, G0KYA
RSGB Propagation Studies Committee

STEVE NICHOLS
20 HOLLY BLUE ROAD, WYMONDHAM
NORWICH NR18 6XU
RSGB PROPAGATION STUDIES COMMITTEE

E-MAIL STEVE@INFOTECHCOMMS.CO.UK

G0KYA

Understanding propagation

Band of the month October 2008 – 20 metres (14MHz)

GOOD OPPORTUNITIES. Welcome to a new series that takes a look at a different HF band each month. In each column, I'll choose a band that I believe will offer beginners and newly-licensed amateurs good DX openings. I'll tell you a little about HF propagation and what you can expect to work or hear.

At this point in the solar cycle it is going to be tough to get the predictions right. We expect solar cycle 24 to kick off at any time but, at the time of writing, the solar flux was sitting stubbornly in the 65 – 70 zone, with no visible sunspots whatsoever.

My best guesstimate is that the solar flux for October will be in the range 65 – 75, although don't be surprised if sunspots suddenly make an appearance.

At the same time, the sun passed through the equinox on September 22 and is rapidly heading south. This means that the ionosphere in the northern hemisphere is cooling down and becoming denser.

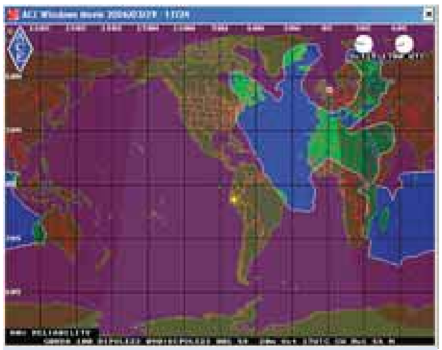
So, although there is less sunlight hitting the regions that make up the ionosphere in the northern hemisphere, the actual F layer ionisation is higher than it was in the summer and D and E layer absorption is now lower than it was. As a result we find that the maximum usable frequency (MUF) during the day is higher than it was in summer.

On the flip side, the sun sets a lot earlier than it did in summer, so we can expect the higher HF bands, 21MHz (15m), 18MHz (17m) and 14MHz (20m), to close earlier than they did, with only 14MHz remaining open until around 2100 – 2200hrs.

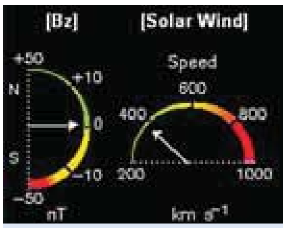
At this point in the solar cycle, the sun is less active, both from a sunspot and a geomagnetic disturbance point of view. That is, solar flares and coronal mass ejections, which both throw out tonnes of charged particles into space at unbelievable speeds, are much less frequent.

Take a look at the real-time solar wind 'speedometer' at www.solarcycle24.com. From that you will see that speeds of around 400 – 1,000km per second are not uncommon. In fact, this solar wind gauge is a useful indicator of HF conditions. If the solar wind speed rises and the gauge marked 'Bz' (the interplanetary magnetic field) swings to the south, this is an indication that the interplanetary magnetic field could couple with the earth's magnetic field and highly-charged particles are going to be channelled towards the earth.

As the particles approach us they are funnelled towards the north and south poles, resulting in visible and radio aurora. The ionosphere's F2 layer could become unstable and may even disappear and there may be massive absorption in the D layer, both of which can shut down the HF bands. The effect of this massive bombardment can be seen on the earth's magnetic field, which 'wobbles' as a result. This can be measured using a device called a magnetometer and the result is seen in the higher A and K indices that you might hear mentioned on the GB2RS news service or in solar reports.



A screen grab from ACE-HF. The blue area shows the parts of the world that you might be able to work on 20m from the UK at 1700UTC with 80% reliability, 100W, dipole-to-dipole, namely north/east USA/Canada, Northern Africa, parts of Europe and a path into the Indian Ocean.



The solar wind indicator at www.solarcycle24.com showing fairly settled conditions. A solar wind speed of about 380km/s and the Bz field neutral. At this point the K index was 1 and falling, the A index was 3 and the solar flux 66.

We can take a closer look at the A and K indices at a later date but, for now, just remember that low A (below 10) and K indices (look for 0 – 1) with the Bz being neutral or pointing 'north' are usually good signs for the HF bands.

So in summary, it is Autumn so HF conditions are better than in Summer, but we still don't have the long winter nights that make 3.5MHz (80m) and 1.8MHz (160m) really come into their own. At the same time we don't have the high solar flux levels that make 21MHz (15m), 24MHz (12m) and 28MHz (10m) really hum.

Therefore I am going to settle for 14MHz (20m) as my band of choice for October, although much of what follows could equally apply to 18MHz, so don't ignore it.

20m or 14MHz, has become one of the main DX bands during sunspot minimum. It has consistently given good DX openings to all parts of the world and as a contest band often has lots of rare stations that are relatively easy to work.

Around the equinox it really starts to improve. Opening just before sunrise and remaining opening until after sunset, worldwide DX openings are possible and also probable at this time of year.

At the beginning of the month, the amount of solar illumination in the northern and southern hemispheres is still roughly equal, meaning this is a good time for north-south paths, such as UK to South Africa and South America. Easterly paths are common at sunrise and the propagation will shift southwards as the morning wears on. The prime time for contacts into South America is therefore around 0900 – 1000hrs and again in the late afternoon, when it may also open to Africa.

Paths to the eastern states of the USA should open up shortly after noon and remain until sunset. This path will be much better than it was in the summer and signals will be louder. Look out for long path openings to Australia (VK) and New Zealand (ZL) during early to mid morning and again at sunset. These will favour those HF operators with good beams.

The band is likely to close within an hour or two after sunset, although it may last longer if conditions are good.

The highlight of the month if you are chasing DX is the 2008 CQWW SSB Contest, which takes place from 0000UTC on 25 October through to 2359UTC, 26 October. This is a fantastic opportunity to make SSB contacts with stations all around the world and it should be possible to contact more than 100 countries over the weekend if you really put your mind to it.

You can also find out what DXpeditions are operating by subscribing to the reports at www.425dxn.org/ and www.papays.com/opdx.html. Watch out for the Willis Island (VK9DWX) Dxpedition in mid October.

Do let me know what you manage to work on 20m in October.

TECHNICAL FEATURE

STEVE NICHOLS
20 HOLLY BLUE ROAD, WYMONDHAM
NORWICH NR18 6XU
RSGB PROPAGATION STUDIES COMMITTEE

E-MAIL STEVE@INFOTECHCOMMS.CO.UK

GOKYA

Understanding propagation

This month's chosen band is 40m but before we look at what you can work, here's some background on the band.

PROPAGATION THEORY. The solar flux remained stubbornly in the 60s in September and, although we can expect a rapid rise in solar flux and conditions on the upper bands as Cycle 24 progresses, at the moment things are not good. The 1.8, 3.5 and, to a lesser extent, the 7MHz bands are susceptible to D layer absorption and the lower sunspot numbers mean lower absorption, which is good news for 40m or the 7MHz band.

The low A and K indices at this point in the solar cycle usually mean good low band propagation. Against that you do find that DX conditions on 40m are usually better with a higher solar flux – there often isn't enough ionisation to keep DX paths open throughout the night at this time. So 40m is benefiting from low absorption but the low solar flux will probably stop the band from providing fantastic openings throughout the whole night. Nevertheless, you should be able to work many DX stations if you pick the right time.

Just because one day or one hour appears to be rubbish, other times and days could be much better. The secret for DX working is to check the bands every day.

The 40m band should be open to European stations during the day and you may be able to work other UK stations too, if the distance between you is more than 250 - 300 miles. Closer stations might be inaudible on 40m and you would be better off heading towards 80m.

With so little solar activity and therefore ionisation, signals that are sent straight up, which are above what we call the critical frequency (f_0f_2), don't get reflected back to earth, but carry on into outer space. If the critical frequency is lower than 7MHz you will find it difficult to work stations in a radius of up to 150 - 200 miles from you, while still able to work stations further afield due to the lower angle of the radio waves hitting the ionosphere. You can access real-time and historical date for the critical frequency at www.ukssdc.ac.uk/wdcc1/wdc_menu.html, although you do have to register.

PROPAGATION IN PRACTICE. Local daytime contacts are not what 40m is really good for – its DX potential is what attracts people to the band.

It is said that the low bands open up to DX after sunset and before sunrise but that isn't quite true. 40m is a lot higher in frequency than either 80m or 160m and therefore D layer absorption is a lot less. This means that 40m can start to open to DX in the afternoon in late autumn and remain open to DX for a period after the sun has risen. In fact, the first 60 minutes after sunrise in the winter on 40m is not called the 'Golden Hour' for nothing.

Forty metres will start to open up to DX in an easterly direction and to Scandinavia in the late afternoon and will get stronger after sunset. Propagation will swing around as night progresses and Africa should be possible too. Later in the evening, propagation will start to go 'long' as the critical frequency drops and a lot of the European QRM diminishes, leaving more DX signals.


A screengrab from Geoclock showing greyline conditions at sunrise in mid November.

You also have a good shot at the North-East coast of Canada and Newfoundland from around 1700 - 1800hrs and onward until the early hours. This path peaks again at sunrise and onwards until about 0900hrs. Openings to the Caribbean and South America are also possible at around 0300 - 0400hrs and again from around sunrise for a further hour. After sunrise, the QRM from European stations to the east of us is greatly reduced, making it easier for us to work stations to the west.

Also look out for greyline openings. There are, in fact, two types of greyline paths – those where both stations are enjoying a concurrent sunrise or sunset and those where one station is experiencing sunrise while the other has sunset and vice versa. For example, back in 2002, I showed that on a true sunrise/sunrise greyline path between the UK and VP8 (The Falklands) we saw enhancements on 40m of up to 10dB (that's 2-3 S points) around 30 minutes before sunrise.

Sunrise/sunset greyline enhancements on 40m are also possible, such as the path between the UK and the west coast of US/Canada (W6/W7/VE7) at UK sunset and UK to Japan (JA) at sunrise, but at this point in the cycle such openings may be difficult, especially for modestly equipped stations. Although most people think of greyline enhancement as occurring on paths that lie along the terminator this isn't the whole story. You can also get good enhancements on paths that are at right angles to the terminator and into the night zone. These are often mistakenly called 'greyline', and should technically be called sunrise and sunset enhancements.

Look for enhanced signals from the east at or 30-60 minutes before your sunset. You will also see enhanced signals from the west on 40m, perhaps from 0-60 minutes after your sunrise. Propagation prediction programs don't generally predict sunrise/sunset or greyline enhancements, but they can show you sunrise/sunset times and the night/day areas of the world.

While there is no doubt that CW (Morse) will increase your chances of working DX on 40m, do try with SSB. The band can sound like a zoo at times and is narrow, but hang on in there. And if you are a CW fan do take part in the CQWW CW contest on 29/30 November. There will be plenty of rare entities and they often operate on other modes before and after the contest.

Don't forget to let me know what you manage to work on 40m in November.

STEVE NICHOLS
20 HOLLY BLUE ROAD, WYMONDHAM
NORWICH NR18 6XU
RSGB PROPAGATION STUDIES COMMITTEE

E-MAIL STEVE@INFOTECHCOMMS.CO.UK

G0KYA

Understanding propagation

Band of the month, December 2008 - Top band (160m).

THEORY. We are now heading towards the winter solstice (21 December), when the sun reaches the most southerly point of its travel and is overhead at the Tropic of Capricorn. In the Northern Hemisphere we have long nights and short days – on 21 December the sun actually rises at 08:04hrs and sets at 15:54hrs, giving more than 16 hours of darkness.

The ionosphere is now cooler and denser and the actual ion density is higher than it is in summer. At least that's what the classical theory says. More modern research has shown that the chemical/molecular make-up of the upper layers also changes in the winter, making ionisation more likely and recombination slower. So we actually have higher daytime MUFs (Maximum Usable Frequencies) in the winter than we do in summer.

But it is what is happening down in the D region of the ionosphere that is more important for the band I have in mind. The D region is predominantly an absorption band at the lower frequencies such as 1.8MHz – 7MHz. In fact, the absorption goes as the inverse square of the frequency so the lower the frequency the more absorption we get.

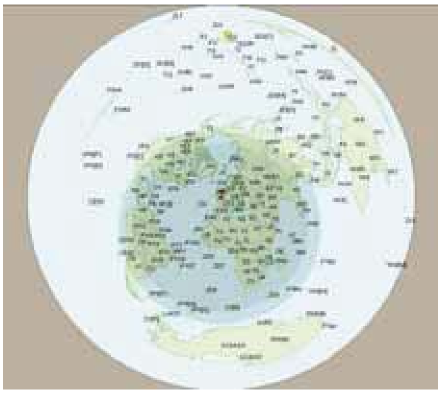
But with such short days and small sun 'grazing angles' the D region is nowhere near as ionised as it is in summer and its absorption effects quickly disappear as sunset approaches, giving great conditions for the lower bands. So, hopefully, you can see why I have chosen Top Band (1.8MHz or 160m) as my band of choice this month.

Many newcomers avoid Top Band as they assume that they need massively long antennas. An end-fed quarter wave is 132ft long on Top Band but in an inverted L configuration it can be fitted in to many smaller gardens.

Verticals are the way to go to get the low angles needed for reliable DXing on 160m, although you may get the odd surprise with horizontal antennas, especially at sunrise and sunset when ionospheric tilting and ducting can occasionally bring DX signals in at higher angles.

IN PRACTICE. So what is propagation like on Top Band in December? The MUF on any path is *always* higher than 1.8MHz, so absorption becomes the main concern.

During the day, expect to be able to make ground wave contacts out to around 50 miles or so. Sky wave signals will be attenuated by the D layer, so don't expect to work DX, especially if you have a less than perfect antenna system. It is possible to work further afield on Top Band during the day as Jeff Briggs, K1ZM/VY2ZM showed in December 2006. He managed to receive signals from the GB3SSS 1.8MHz beacon in Poldhu, Cornwall at his holiday home on Prince Edward Island at 1031, 1615, 1659 and 1745Z – with much of the path in daylight. He put his success down to it being mid-winter at the bottom of the sunspot cycle with solar activity, and therefore D region absorption, at a minimum.



But for true DXing on Top Band, you need a dark (night-time) path between you and the other station. To make this easier to visualise you can use a computer program, such as Sunclock, or perhaps one of the propagation programs like W6ELProp, ACE-HF or VOAProp. There are various internet sites that will also show you the same information – just search Google for 'sunclock'.

Most propagation programs don't cover 160m, but as a very rough guide see what they predict for 80m.

Top Band is also famous for the greyline propagation into the dark (night) zone that can occur at your sunrise and sunset. While greyline is technically the propagation of signals along the terminator between day and night, the term is often used to describe any sunrise or sunset enhancements, regardless of the direction of the signals.

The furthest you can work under true greyline conditions is halfway around the world when you and the other station are *both* experiencing a concurrent sunrise and sunset. For example, the UK at sunrise to Auckland or Tokyo on December 21. These openings might only be possible for a few minutes, if they occur at all, making them very hard paths indeed. PA3CQR's 'Grayline' program, which is a free download from the internet, can help to predict these.

In fact, Top Band is probably the most difficult band to do propagation predictions for. Yes, a dark path is needed, but beyond that, many attempts at trying to correlate the solar flux and/or A/K indices with good conditions have failed miserably.

Paths that go through the auroral ovals (100km above the Arctic and Antarctic circles) can be very difficult on Top Band, especially when the A and K indices are high – showing that charged particles are pouring into the polar regions and likely to trigger aurora - Polar Cap Absorption (PCA) events.

My analysis of 160m contacts between the 3Y0X DXpedition to Peter the First Island and the UK showed that the few contacts that were made were fairly random and impossible to predict.

Top Band is also close to the 'gyro-frequency' of the electrons that surround the earth's magnetic field lines, which, put simply, means that the electrons may absorb a lot of your radiated energy – a bit like driving your car through thick mud!

Logic would suggest that a low solar flux/low or no sunspots and a settled ionosphere with low A and K indices would be best, but beyond that it is pretty much suck it and see.

If you are truly interested in finding out more about Top Band and how to work it, I can thoroughly recommend ON4UN's book *Low Band DXing* and also Jeff Briggs' *DXing on the Edge – the Thrill of 160m*.

You should be warned that Morse or CW is the preferred mode on Top Band and DXing is not going to be as easy as 20m. But, if you can put up a decent vertical antenna and like late nights, it can be both a compelling and frustrating band in equal measures.

Understanding Propagation

Try out 80m during January and see what you can work.

THE THEORY. Last month we looked at Top Band (160m or 1.8MHz). As it is still mid winter, a lot of what I said then can be applied equally to this month's band 80m (3.5MHz), although we should be careful not to suggest that propagation on both bands is identical.

Eighty metres (3.5MHz) is almost twice the frequency of Top Band, so it is well away from the electron gyro frequency (as talked about last month) that can cause absorption on 1.8MHz.

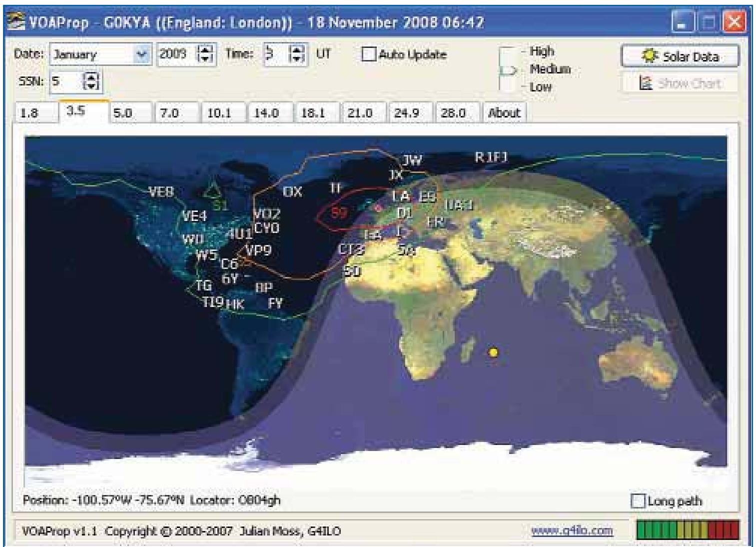
During the daylight hours, the sun's UV and soft X-ray radiation ionises the lowest D region of our ionosphere, but as absorption is related to the inverse square of the frequency, it is only roughly a quarter as bad on 80m as it is on Top Band. This solar radiation also illuminates the E and F layers too and, during the early morning and late afternoon in winter, the low sun grazing angles means that 80m may support DX even in daylight. Putting these two factors together means that you stand more chance of working DX on 80m than Top Band.

IN PRACTICE. Staying with the daylight theme, you will find 80m an excellent band for inter-G contacts. Expect to be able to make ground wave contacts out to around 50 miles or so and sky-wave contacts too, as long as the critical frequency stays high enough. The critical frequency is that which will just return signals back to earth if they are directed straight up. Many contacts around the UK are the result of NVIS or near vertical incidence sky-wave signals.

If there is sufficient ionisation, the critical frequency will stay above 3.8MHz and the signals will return. If there isn't, the signals will continue to go on into outer space. You can check the real-time critical frequency at www.ukssdc.ac.uk/ionosondes/view_latest.html, but you have to register first. These graphs show you the F_0F_2 (F2 layer) and F_0E (E layer) frequencies as measured by an Ionosonde at Chilton. The "F_0" denotes a signal going up vertically.

If the critical frequency falls below 3.8MHz in early morning and late afternoon you may find that it is hard to work close-in UK stations, but signals from Europe are still loud. This is due to the lower skip angles that the signals are taking to reach the UK from Europe. For the same reason you may find that you can work stations in Scotland or Cornwall from the Midlands, but nothing closer.

If the F_0F_2 (critical frequency) is higher than 3.8MHz you will no doubt get good 80m coverage around the UK at all distances. As I am writing this, the latest ionogram at Chilton is showing $F0F_2$ as 5.054MHz and UK signals on 80m are romping in at 59+. In all cases you may find that signals are weaker around local noon when D layer absorption is at its highest.



The illustration shows VOAProp predicting 80m propagation to the USA at sunrise in January.

Start to look for DX on 80m to the east during the late afternoon and to the west up to and past sunrise. The best place to look for SSB DX on 80m is in the top 5 – 10kHz of the band where there are often nets in progress. Many amateurs have worked their first US and Canadian stations on the band in this way.

80m really starts to shine as a DX band after sunset. At this point D layer absorption is declining rapidly, while the F layer(s) will still support long-distance DX.

We have a double whammy at the moment as not only is it winter, with long hours of darkness, but it is also sunspot minimum with few solar disturbances. The lack of solar flares and coronal mass ejections means that fewer charges particles get funnelled towards to the earth's magnetic poles, resulting in increased absorption and fluttery signals that have to cross the polar regions.

MORE THEORY. While we are on the subject, people often get confused between the A and K indices. In fact, they are pretty much a measure of the same thing – both measure the impact of fast-moving charged particles from the sun on the earth's magnetic field. The difference is that the K index is logarithmic. It is a whole number in the range 0 – 9 and measures the disturbance over the last three hours. The A index is linear and is an average of the disturbance over the last 24 hours.

The logarithmic nature of the K index can be deceiving as a jump from a K index of 1 to 5 is roughly equivalent to a jump in the A index from about 3 to 48. So if you are looking for a near real-time measure of the disturbance, the K index is more accurate. The A index tells you how conditions have been over the past day.

As long as the K and A indices remain low, night-time DX conditions on 80m can be good, so keep an eye on these figures, either via www.solarcycle24.com or one of the other propagation sites such as http://dx.qsl.net/propagation/.

For the best DX on 80m, you need a dark (night-time) path between you and the other station. To make this easier to visualise you can use a computer program, such as Sunclock, or perhaps one of the propagation programs like W6ELProp, ACE-HF or VOAProp. There are various internet sites that will also show you the same information – just search Google for 'sunclock'.

Look out for sunrise enhancements too – start to look around 60 minutes before the sun shows its face and keep going until around 60 minutes after sunrise.

In general, the best conditions will occur in the early hours of the morning with DX being workable as far afield as the mid-western USA, the Middle East and Asia, depending upon the quality of your antenna. On the whole paths to the southern hemisphere will be very difficult as it is mid summer down there and absorption will prevent good openings. As always, a good propagation program will show this.

Understanding Propagation

In February, try using the 30m band as it can be a great band for DXing.

30M: BAND OF THE MONTH – FEBRUARY 2009. So far in this series we have looked at 160m, 80m, 40m and 20m. The keenest of you will have realised that we have missed a band. But I aim to put that right this month by focusing on 30m (10MHz).

Thirty metres was given to radio amateurs in 1979 as part of the WARC (World Administrative Radio Conference). It is often forgotten about, but is actually a great band for DXing, as long as you like digital modes and CW (there is no SSB segment on the band plans).

THEORY. I have often read that 10MHz shares the characteristics of both 40m and 20m, but at first sight this sounds ridiculous. Twenty metres (14MHz) is predominantly a daylight band, closing after dark in the winter as the MUF (Maximum Useable Frequency) drops. Forty metres (7MHz) on the other hand is not much of a DX band during the day, but comes alive after dark. The purists will realise that this isn't strictly true as 40m can be open 24 hours a day in mid winter and 20m can be open late into the evening in the summer, but bear with me.

So how can 30m have the characteristics of both bands? To answer that question we need to go back to first principles.

Propagation on any DX path is fundamentally subject to two factors – the Maximum Useable Frequency (MUF) and the Lowest Useable Frequency (LUF). The MUF is determined by the sunspot number, the time of year and the time of day, and generally is higher during periods of heightened solar activity. The MUF is the highest frequency that the F layer(s) can refract over a given path, if working DX. Go higher than this and your signals escape into space.

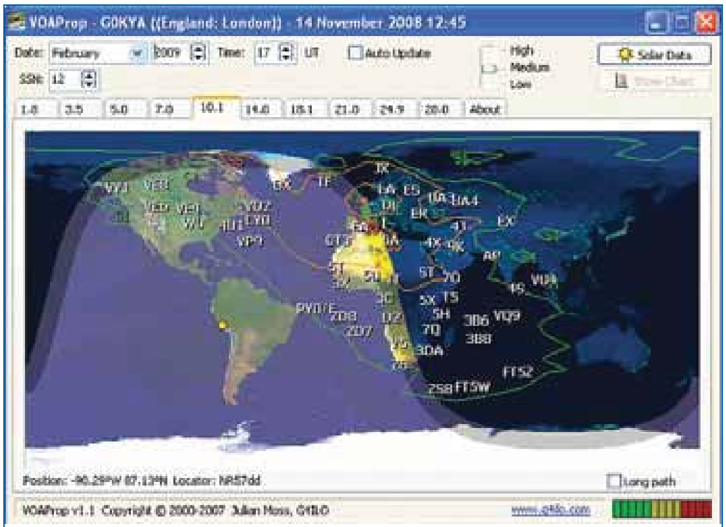
At the same time we have the lowest useable frequency, which is the lowest that can be propagated along the same path without being totally attenuated by the D layer. Go lower than the LUF and your signals are absorbed before they get to their destination.

So put the two together and we are left with a small range of frequencies, a channel if you like, that we need to work in to make our contact.

Now we begin to see how 10MHz fits in with the adjoining bands. At times 20m and 30m will both be open to the same parts of the world. At others, the MUF will have dropped so that 20m is closed and 30m and 40m able to propagate signals.

Conversely, there will be times when 20m is closed, but the MUF is high enough for both 40m and 30m to be open at once. But during daylight hours the LUF might be higher than 40m, so closing the band to DX, but leaving it open on 30m.

We must think of the band in terms of the current lowest and maximum useable frequencies in order to make any sense of it. This is where a propagation prediction program like the paid-for Ace-HF, or W6ELProp and VOAProp (both free) come into their own.



Propagation on 30m at 1700hrs in February according to VOAProp. The band is open to a large part of the World.

IN PRACTICE. So what can you expect to hear on 30m? Well at midnight in February we find that 30m is likely to open to the south, taking in Northern, Central and Southern Africa. As the night moves on the propagation will shift to the south-west, heading towards the Falklands and South America by about 0000-0400hrs. Propagation then shifts towards the east as the MUF on that path rises as the sun comes up over Africa and Russia.

By 10am, D layer absorption in the southern hemisphere (where it is summer) is so high that the path is closed. But now we have propagation to North America and the northern climes of Asia.

This continues through the morning and early afternoon, and by 4pm the band is now open to Western Australia, Asia and north-west Canada. As the afternoon progress to evening we can now work the whole of Africa again.

This is what makes 30m such a fascinating band – it is open to somewhere virtually 24 hours a day, whereas 20m is often closed during the night and 40m won't get far during the day thanks to D layer absorption.

The other good news is that, on the whole, you won't be fighting stations with massive Yagis and a half-wave dipole is actually quite short, at only 15m in length.

I have worked many DX stations on 30m, often with very few pileups. In fact, it is my first band of choice whenever a new DXpedition starts up. I have managed to snag Mauritania (5T5DC), Syria (YK9G), San Marino (T77C), Libya (5A7A), St Branson (3B7C) and Oman (A45XR) on 30m, all on CW and often with about 25W.

This may seem like small fry to many DXers, but they were all caught using either an inverted V half wave dipole on a fishing pole, an MFJ 1786 magnetic loop in the attic or an 85ft end-fed wire (W3EDP), which was catapulted over the roof of the house and is almost invisible.

No wonder 30m is such a well-kept secret! If you are not a fan of dits and dahs, turn to 10.140MHz and join in the fun with PSK31. There is lots of activity.

In fact, you can try working some 30m DX yourself in February, thanks to the Desecheo Island DXpedition running from 12 to 26 February.

Desecheo is a small, mountainous island in the Mona Channel, approximately 14 miles west of Punta Higüero, Puerto Rico.

From the UK, the 30m band should open to KP5 from around 0930 – 1230hrs, and then again from 1730-2200hrs, with another opening in the early hours of the morning.

Understanding Propagation

Although just seven discrete frequencies, the 5MHz band (60m) has been allocated as a trial to experiment with propagation.

SUNSPOTS. So far in this series, we have looked at all the HF bands between 160m and 17m. I have deliberately left the 21, 24 and 28MHz bands until a) we have more sunspots or b) we have Sporadic-E conditions (mid May onwards).

The astute among you will have realised that I have, so far, missed out 5MHz (60m), so let's put that right.

The 60m 'band' isn't a band as such, but seven discrete USB frequencies – 5258.5, 5278.5, 5288.5, 5366.5, 5371.5, 5398.5 and 5403.5MHz. These have been allocated to UK radio amateurs as a trial and to enable us to experiment with propagation on a band that sits mid way between 3.5MHz (80m) and 7MHz (40m). As such, it occupies a unique part of the RF spectrum that is very suitable for high-angle or NVIS (Near Vertical Incidence Skywave) communications.

Before I go any further, to operate on 5MHz you must be a holder of a full amateur radio licence and also obtain a NoV (Notice of Variation). Ofcom has agreed with the MOD to permit experimental operation until 30 June 2010 and you can find out more at www.rsgb.org/spectrumforum/hf/5mhz.php.

THE THEORY. Now, let's take a look at propagation on 60m. You may recall from our discussion on 80m in January that contacts around the UK rely on high-angle signals being transmitted towards the ionosphere. This needs the critical frequency to be higher than the frequency we are using – the critical frequency being that where a wave sent vertically from our station is just reflected back to earth.

We denote the critical frequency of the F2 layer as being f_oF2, where f_o denotes a signal sent up with zero degree deviation from the vertical.

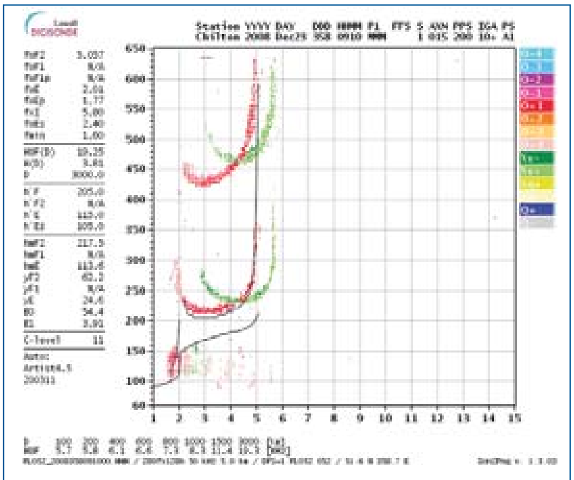
If f_oF2 is higher than 3.5 – 3.8MHz we can generally use 80m for inter-UK contacts. At times of high solar flux, we often find that f_oF2 is higher than 7MHz and 40m can be used for inter-G contacts too. But then the increased solar activity can cause greater D layer absorption so 80m contacts around the UK become more difficult.

There can come a point where the critical frequency is not quite 7MHz, but absorption is too high on 80m for reliable contacts. So what do you do?

This is where 5MHz comes into play. In theory, it can offer reliable inter-G contacts at times when both 80m and 40m are unsuitable, which is why the 5MHz experiment was set up.

So how can we predict propagation on 60m? As always, our good friend the Chilton Digisonde has the answer – see www.ukssdc.ac.uk/ionosondes/view_latest.html.

You have to register to download the data, but it is very easy. The Digisonde data are updated on a regular basis and, in theory, all you have to do is look for the f_oF2 figure. If this is above about 5.4MHz then you should be able to use the band for close-in inter-G contacts. If it is just below 5MHz you may find that you can talk to stations at the other end of the country, but not closer as the angle of incidence is more shallow the further we wish to communicate.



This Chilton Digisonde image clearly shows the critical frequency of the extraordinary wave (green) is higher than the ordinary wave (red) by about 0.7MHz. 5MHz was probably open to stations around the UK at this time.

Unfortunately life isn't quite that simple, as fellow RSGB's Propagation Studies Committee member Marcus Walden, G0IJZ showed in his article in the March 2008 issue of *RadCom*.

The charged particles in the ionosphere lead to refraction or bending back to Earth of the radio waves. Additionally, the Earth's magnetic field leads them to have a second refractive characteristic. This means the ionosphere has two different refractive indices – we say that it is birefringent (double refracting). Some crystals are optically birefringent giving a double image when objects are viewed through them.

The result is that a passing radio wave is split into two components; the ordinary and extraordinary waves. Research has shown that the critical frequency of both these waves is slightly different and we need to look at both f_oF2 (ordinary) and f_xF2 (extraordinary) – the critical frequency of the ordinary and extraordinary waves – if we are to actually predict whether we can use 5MHz for NVIS communications. Generally, the ionosonde parameter f_xI can be used as a measure of f_xF2.

Over the UK, the extraordinary wave critical frequency f_xF2 is higher than that of the ordinary wave by about 0.7MHz.There have been many occasions when f_oF2 has been lower than 5MHz, but the band has still been open.

EXPERIMENTAL WORK. To help you get a better feeling for the band there are three beacons, GB3RAL, GB3WES and GB3ORK, operating on 5MHz that will give you a real-time indication of conditions. More information on these beacons is available at http://www.rsgb-spectrumforum.org.uk/5mhz%20beacons.htm.

But what about propagation from further afield? There are many countries where the 5MHz is in use, including Canada, USA, St Lucia, Greenland, Finland, Denmark, Eire and Iceland.

A good propagation program like VOAProp will be able to predict openings to these countries, although as a rule, the frequency is so low that you really require a dark (night) path between you and the other station. This means that DXing on 5MHz is really a night-time pursuit, although mid-winter (especially at sunspot minimum) can throw up some real surprises.

At the moment, the band is an oddment in the HF spectrum. We only have a few spot frequencies, you need a notice of variation to your licence to use it and it should really only be used for experimental purposes. Working DX on the band goes against the original idea of allocating it to UK amateurs, although many people do.

Working overseas stations on 60m is certainly harder than, say, 20m, but there is definitely a club-like feel to the band. And, if you do experiment on 5MHz, you could be paving the way for the UK to have a wider allocation in the future.

Understanding Propagation

On our monthly journey through the HF bands we now only have three left – 15 metres (21MHz), 12m (24MHz) and 10m (28MHz).

A LOT TO OFFER. This month we are going to look at 15 metres, leaving the other two for when Sporadic-E conditions bring the bands alive over the next couple of months.

Fifteen metres is a band that can offer a lot – antennas are smaller than those used on 20m and you have a full 450kHz to play with. D layer absorption, which you may recall is related to the inverse square of the frequency, is also less than the lower bands. Noise levels tend to be lower too, which means you can work stations even if they are only S1 or S2 – try doing that on 80m! I can recall working stations solidly on the higher bands when the signals didn't even move the meter.

So far, so good – so what's the catch? The problem with 15m metres at the moment is that it really needs a fairly high solar flux to come alive and, at the time of writing, we are still waiting for solar Cycle 24 to really get into its stride. That isn't to say that there aren't good openings on 15m with low solar flux levels, but they may often be fleeting, weak, short or non-existent.

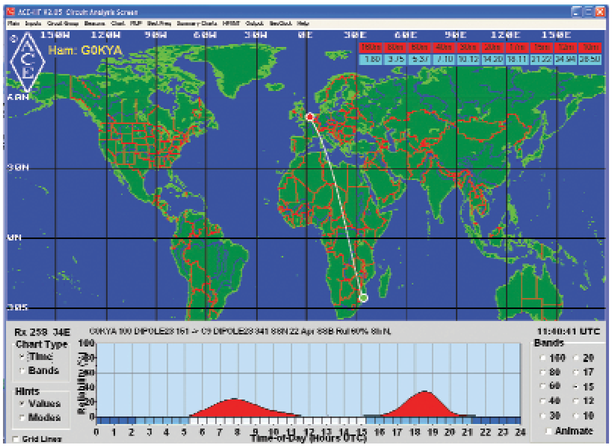
So what can we expect on 15m in April? If you don't have a propagation prediction program use the HF charts in *RadCom*, prepared by Gwyn, G4FKH.

Using a VOACAP-based propagation prediction program like VOAProp or Ace-HF and a sunspot number of 22, we see that there is virtually zero probability of 15m being open at night from the UK. Once the sun has set, the level of ionisation in the F1/F2 layers drops quite quickly and cannot support propagation on the higher bands.

There are always exceptions to the rule, especially if there are solar disturbances. If the A and K indices go up dramatically and the Bz goes south (see www.solarcycle24.com), showing that the interplanetary magnetic field is coupling with the earth's magnetic field, you can get Auroral E enhancements at night that can give relatively short distance contacts into Europe, but these are relatively rare. At this point in the solar cycle, geomagnetic disturbances due to solar flares or coronal mass ejections, which both pump out massive clouds of hot, ionised gases, are not so prevalent as they will be near the solar maximum.

Once the cycle really gets under way in a couple of years time, we can expect more disturbances, which is generally not good news for HF propagation overall.

WHAT WILL YOU HEAR? With a guesstimated sunspot number of 22 for April, we find that 15m is slow to open in the morning, with weak propagation first appearing to North Africa and Central Europe around 8am. By noon, although still quite weak, much of Central and West Africa is now possible.



ACE-HF shows that the path to April's C91FC DXpedition to Mozambique is predicted to be quite weak on 15m with a maximum probability of about 35% (100W SSB dipole to dipole). For CW it is about 75 – 80%.

Propagation builds during the day towards Southern Africa too, swinging towards South America before sunset. Again, at sunset expect 15m to begin to close quite rapidly.

Because of the low levels of ionisation, you may also find another apparent anomaly. The F layer(s) may not be able to return relatively high angle signals on 15m. This means that you may be able to hear DX signals (which typically arrive at your antenna at angles less than 10 degrees), but can't hear mainland Europe, such as Germany or Italy.

As Solar Cycle 24 progresses and the sunspot number/solar flux increases, we can expect to see 15m become far more reliable. Predictions using a sunspot number of 50 show reliable propagation to most of Africa in April – even Antarctica is possible in late afternoon.

With a high solar flux and a decent antenna, such as a Yagi at 30 – 40ft or more, long-path openings to the Pacific may be possible after sunrise and again in the late afternoon.

You will definitely find that a good antenna will help – long wires, G5RVs and 80m Windoms (OCF dipoles) are not at their best on 15m and will likely be beaten by even a half-wave dipole at 25 – 35ft.

You may wonder why I haven't mentioned propagation on 15m to the USA. This is because the equinox months (late March/early April and late September/early October) tend to favour north/south paths, where ionisation north and south of the equator tends to be similar. If you want to work 'across the pond' in April, 20m (14MHz) is a much better bet. Working the USA on 15m is more reliable in late October/November or December/January when the sun is in the southern hemisphere. Again, a good propagation program will help illustrate this.

Now that you begin to understand propagation on the band, it starts to make sense. The MUF (maximum usable frequency) on a given path from the UK may hover around the 21MHz mark. For much of the time you may hear nothing, but then signals may pop out of the noise, only to disappear again a few minutes later.

A cursory glance at the band might lead you to believe that it was totally dead, but you might be wrong. A tip is to check propagation on 17m (18MHz too). A DX opening there might suggest that one is on its way on 15m too. Also check the International Beacon Project chain on 21.150MHz.

These are the only beacons operating on 15m, which is a shame really. If your CW is rusty or non-existent, both VOAProp and ACE-HF can be configured to show you which beacon is currently transmitting, just make sure that your computer clock is accurate to the nearest second. For more details of the IBP project http://www.ncdxf.org/beacons.html.

Understanding Propagation

With only two bands left, this month we look at 12m (24MHz).

Richard, G3RWL worked 351 stations on 12m in a single session while on Mayotte.

WARC. The 12m band was given to radio amateurs in 1979 at the World Administrative Radio Conference. Covering 24.890–24.990MHz, it offers some great qualities.

First, it is quite high in frequency so noise is not as big a problem as the lower bands. In fact, at my quite noisy suburban QTH, the average noise level on 12m is about S2, compared with about S9 on 80m and S8 on 40m. This makes it much easier to hear weak signals. At the same time, the band is low enough to benefit from F2 layer openings with relatively low levels of solar flux, often at times when 10m (28MHz) is closed.

Indeed, as I write this, I have just worked FH/G3SWH in Mayotte on 12m CW using just 20W to a loft-mounted antenna – and that wasn't even resonant on 12m. For those of you who don't know where Mayotte is (I certainly didn't), it is a small island off Madagascar. Richard, G3RWL and Phil, G3SWH worked nearly 500 stations on 12m during their time on Mayotte.

OPENINGS. At the time I made the contact, the solar flux was only 69 so DX openings are quite possible on 12m, even at sunspot minimum. Having said that, these are likely to be sparse, fleeting and unreliable at the moment, at least until Solar Cycle 24 gets going properly.

A good starting point to check for openings is the NCDXF beacon chain on 24.930MHz. In three minutes you can soon find out if there is any propagation to many parts of the world.

Looking at propagation in May, the band is likely to be closed at night, other than ground wave propagation to local hams out to around 15 – 20 miles. After sunrise, the band will be slow to open as F layer ionisation builds up. By about 9 – 10am, you might see one-hop signals starting to appear from North Africa and by early afternoon these may by joined by two and three-hop signals from the southern part of Africa, such as 9Q (Congo) or 5H (Tanzania).

If the band opens at all it will be optimum by about 6pm UTC with potential coverage to much of Africa and the mid Atlantic. But, by dusk, the band will shut down again for the night.

SPORADIC-E. Twelve metres really is a band that will benefit from higher sunspot numbers, but in the meantime it has another trick up its sleeve this month – Sporadic-E, which will begin to show itself later in May and continue throughout the summer.

While the factors behind Sporadic-E are not well understood, we do know what it is and what its effects are on radio signals.

In summer (in the UK), clouds of ionisation can form in the lower E region of the ionosphere (90 – 100km). These are difficult to predict and are fast moving, often measured at up to 160km/h or more. They are, however, very intense and capable of reflecting/refracting radio waves of frequencies of up to 144MHz. Records even show that at times this has reached 250MHz.

I have certainly heard the effects, when a Spanish FM station completely overpowered Radio 2 as I drove through Lincolnshire in May last year. This only lasted a few minutes but was quite startling.

Sporadic-E can occur at any time, day or night, although there can be peaks of activity in the morning and often at 2000 – 2200hrs UTC.

There are many theories as to what causes Sporadic- E, including charged 'sprites' leaping up from the tops of thunderstorms. But equally, there are many instances of Sporadic-E where there is no lightning activity. It is also linked with meteor showers, solar and geomagnetic activity. Local TV weatherman and radio amateur Jim Bacon, G3YLA and I had a long chat at a local Norfolk Amateur Radio Club event last year. Jim favours the wind shear theory.

Try to imagine waves propagating through the atmosphere, caused by fast-moving winds being diverted as they cross mountain tops. This shearing effect of the wind can cause ionisation and Jim says there is strong correlation at times with winds moving high above the mountain ranges of Europe and Scandinavia and incidences of Sporadic-E.

The ionisation is thought to occur with metallic ions, such as iron and magnesium, with many people suggesting that these come from meteor material. There are several meteor storms in June/July/August that correspond with the Sporadic-E 'season' in the Northern hemisphere, but often the season starts before the showers arrive, so as a finite theory it falls down. How ions become concentrated into thin layers at mid latitudes is also still under debate. I think the truth is that Sporadic-E can be multi-factorial.

WORKING WITH SPORADIC-E. But what can you work with Sporadic-E on 12m? Much of what I have said here will apply equally to 10m, which I am covering next month.

In general, under Sporadic-E conditions, you should be able to work stations at a distance of around 1200 – 1400 miles. The signal strengths will be high, with S9+ signals commonplace. There will be rapid QSB (fading) though and you may be able to see the effects of the fast moving Es clouds as signals from one area are replaced by those from another in just a few minutes.

If you are very lucky, and especially if you have a beam, you could benefit from multi-hop Sporadic-E, whereby your signals are reflected off one cloud, bounce of the ground and then reflect back off a further cloud to their ultimate destination. This can result in trans-Atlantic contacts, especially on 12m, 10m and 6m.

Next month, we will look at F2 layer propagation and what we can hope for on 10m and 12m when the sun finally wakes up.

Understanding Propagation

This month we look at 10m – or 28MHz – and I have saved the best for the last.

Aurora is just one of the mechanisms that can enhance 10m propagation. Photo: Joshua Strang, USAF.

JUST YOU WAIT! Ten metres may not seem like much of dynamo at the moment, but just wait until sunspot cycle 24 really gets going in a year or so. The band is wide and has plenty of room for CW, data, beacons, SSB, satellite and even FM and repeater operation.

Many books will also tell you that 10m is subject to tropospheric enhancements. But, if you are expecting the kind of long-range openings you get on 2m, I think you may be disappointed. I have never heard a really long-range tropo opening on 10m and, while I wouldn't say they don't exist, they are not the best mode for good 10m propagation.

In May to July, you will hear the odd fleeting opening from one end of the country to the other, but this is usually short-skip caused by Sporadic-E, which I covered last month. You can sometimes get other E layer enhancements caused by high energy particles impacting the ionosphere after a coronal mass ejection (CME) or solar flare. If you hear European stations on 10m and it is not the Sporadic-E season, then a high A or K index is a good indication that this is what is happening. These type of events are often followed by more characteristic Auroral openings with their characteristic 'whispery' sounding voices.

Another check for this is to see if the interplanetary magnetic field (Bz) is pointing south and the solar wind speed has increased – see the gauge at www.solarcycle24.com. A south pointing Bz shows that the IMF is coupling with the earth's magnetic field and the hot ions are flowing towards Earth and being funnelled towards the poles.

F LAYER PROPAGATION. But while E layer propagation is better than no propagation at all, it is still relatively short distance (unless you get multi-hops). For truly long-distance propagation we need the higher F layer to provide us with the longer skip distances.

But for F layer propagation on 10m we need high levels of ionisation. This is caused by the ultra-violet and soft X-ray output from the sun and linked (not surprisingly) with the number of sunspots on its surface. To recap, there is strong correlation between the amount of noise received from the sun at 2800MHz and the amount of ionising radiation. We call this 2800MHz measurement the 'solar flux index' (SFI), although let me reiterate, radiation at 2800MHz does not cause the ionisation – it is just a convenient way of measuring the solar output.

For 10m to open up to DX reliably we need an SFI higher than we have had at solar minimum. That isn't to say that there are not 10m openings at solar minimum, but they tend to be fleeting, hard to predict and generally in a single direction.

But fast forward to the day when the SFI is 200+and 10m will open reliably to all parts of the world. And you don't even need a flux that high to see results. My own experience shows that a flux of 100 or more will bring reliable 10m F layer openings to the USA, typically starting in late September and October. Ten metres is also unique as an HF band as it has lots of beacons. They are a great indicator of conditions with many running less than 10W. But that is still enough for propagation over long distances. For a full list of beacons see www.keele.ac.uk/depts/por/28.htm.

Then we have the FM repeaters in the range 29.610 – 29.700MHz. These are situated all over the world, but the European ones such as HB9HD on 29.660MHz come alive during the Sporadic-E season and others in the USA are a good indicator of F layer propagation. Throughout the last solar cycle, I could virtually guarantee hearing W1OJ in Boston on 29.620MHz, booming in at S9 plus every day from about noon. For a full list of 28MHz FM repeaters see www.thiecom.de/10mlist.htm.

GOOD PROPAGATION. So why is propagation on 10m so good? Much of what I said about 12m last month applies to 28MHz too. Noise levels are very low on 10m and antennas tend to be very short – a dipole is only 5m/17ft long. D layer absorption is also very low too. As it is related to the inverse square of the frequency, absorption is four times less than it is on 14MHz and 16 times less than 7MHz.

When the band really starts hopping at the peak of the next cycle, you also see other effects too. At high SFI levels you often get ionospheric backscatter too. This is when signals from the UK are not only reflected back towards their ultimate destination, such as the USA, but a small proportion of the signal is also reflected back. Backscatter has a very characteristic hollow sound to it.

I have also noted a lot of evidence for skip focusing on signals from the East. This occurs as the sun sets between you and the DX station and signals from many different take-off angles are brought together to provide one stronger signal. I have noticed this effect on signals from India and Pakistan, but be warned – skip focusing enhancements are usually a sign that the path is about the close, so work them quickly.

This month you are likely to see relatively short-skip openings via Sporadic-E to Europe with better-equipped stations seeing a few multi-hop openings, perhaps to the USA. But, hopefully, as the cycle progresses 10m will become your favourite band with easy DX using only a few watts and a simple antenna.

STEVE NICHOLS, G0KYA ♦ E-MAIL: STEVE@INFOTECHCOMMS.CO.UK

Understanding Propagation

Using beacons to monitor HF propagation

THE BEACON NETWORK. We have now finished looking at what powers ionospheric propagation on all of the HF bands. But if no one is calling CQ, how do you know if a band is open?

The answer to that question lies with HF beacons – small, usually low-powered and unmanned transmitters that announce their presence on the bands 24 hours a day using Morse code. And if that last phrase frightens you, don't worry – the Morse is usually quite slow and you can also use a look-up table or beacon list to find out which one is transmitting.

I'll start by looking at the most famous beacon chain – the NCDXF/IARU International Beacon Project (IBP). This is a worldwide group that operates on 14.100, 18.110, 21.150, 24.930 and 28.200MHz.

The beacons are in USA (New York, California and Hawaii), Canada, New Zealand, Australia, Japan, Russia, Hong Kong, Sri Lanka, South Africa, Kenya, Israel, Finland, Madeira, Argentina, Peru and Venezuela, although the Sri Lankan and Venezuelan beacons are off the air at the time of writing. Each beacon transmits in turn – a 10-second sequence every three minutes. Once they have sent their sequence on, say, 14MHz, the beacon moves up to 18MHz and repeats it and another beacon takes up their slot.

As well as the beacon's callsign, it transmits a constant tone that begins at 100W before stepping down to 10W, 1W and finally 0.1W in one-second steps. And if you don't think you can hear a 0.1W CW transmission from around the globe take a listen – you'll be amazed. You can usually hear the OH2B beacon in Finland down to 0.1W on 14MHz quite easily. The beacons mean that you can get a good idea of propagation conditions from around the globe in just three minutes per band.

You can either listen for the beacons with an accurate clock (I have a cheap radio-controlled one) or use a piece of PC software, such as BeaconClock, which can be downloaded from http://huntting.com/beaconclock/index.html, or VOAProp at www.g4ilo.com/voaprop.html. These will tell you which beacon is transmitting and when.

You can find out more about the beacons, including how to conduct unattended propagation research using a program called Faros, at www.ncdxf.org/beacons.html.

Once you step away from the NCDXF beacon chain, coverage can be a little more patchy. Take a look at G3USF's Worldwide List of HF Beacons at www.keele.ac.uk/depts/por/28.htm and you'll see what I mean.

IARU Region 1 discourages beacon operation on 1.8 – 10MHz, but even so there are quite a few on these bands that are active. These can be quite interesting to track down as their power output ranges from 0.1 – 100W. For example, I have regularly heard SK6RUD on 10.133MHz in Oxaback, southern Sweden, even though it only runs 0.5W to a quarter wave vertical antenna. The beacon sends the message "VVV QRPP BEACON DE SK6RUD, QTH JO67KI, PSE RPRT TO WWW.RADIORUD.SE" and five or six people a day visit the beacon owner's website to log a reception report. SK6RUD also has 500kHz and 3.5424MHz beacons, but it is the 30m one that you most likely to hear during the day from the UK. It sometimes has its 24.912MHz beacon running too.

There are a small handful of other non-NCDXF beacons listed on 14MHz, 18MHz, 21MHz and 24MHz as well, but when I listened none were audible. This was probably due to the K Index being four at the time of writing and the Interplanetary Magnetic Field (IMF) Bz pointing south, showing that the IMF and the earth's magnetic fields had coupled with lots of charged solar particles streaming into the ionosphere, wrecking HF propagation. You can monitor this at www.solarcycle24.com.

Step up to 28MHz though and the world is your oyster. There are literally hundreds of 10m beacons in existence between 28.110 – 28.322MHz and tracking them all can become a full-time hobby. Again, many of them are very low powered, typically between 5 and 10W. When the solar flux heads up towards the 200 mark it is relatively easy to hear some of the US beacons. For example, I have a QSL card from NS9RC in Winnetka, Illinois, which I received after e-mailing the North Shore Radio Club a reception report at the height of the last cycle. Their beacon on 28.297MHz consists of a Kenwood TS-140S connected to a homebrew controller, MFJ-971 antenna tuner and running 8W to a Solarcon A-99 vertical antenna at 70 feet.

But you don't have to wait for the next solar cycle to kick off to hear some 10m beacons. Sporadic-E is bringing in lots of them from all over Europe. Just the other day I logged IW3FZQ/B on 28.226MHz and IZ3LCJ on 28.207MHz in Italy. These were quickly followed by DK0TEN on 28.258MHz and DL0IGI on 28.205MHz in Germany and OE3XAC on 28.188MHz in Austria. You can track the Sporadic-E clouds as they move and some beacons vanish to be replaced by others.

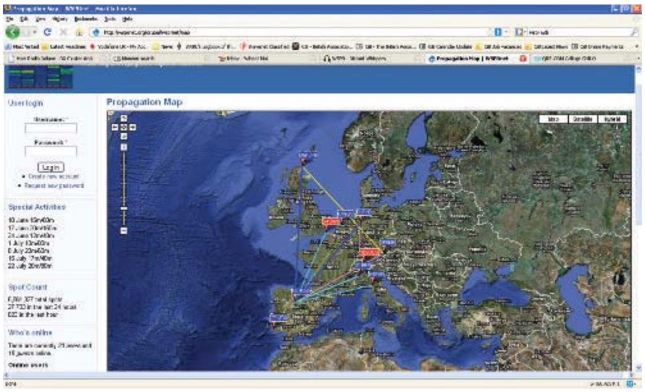
Much of what I have said applies equally to 50MHz (six metres), where there are beacons all around the world. See www.keele.ac.uk/depts/por/50.htm for details.

If you do get really interested in 28MHz and 50MHz and beacon reception you can even contribute your findings to the Six and Ten Reporting Club – see http://g7kse.co.uk/6and10/.

Beacon hunting can become addictive, but don't forget to call CQ as well. The beacons tell you that there is propagation to a particular part of the world, but it is up to you to make the band active.

Understanding Propagation

Using WSPR to gauge propagation



Picture of WSPRnet.org screen grab showing 10m activity in mid June.

GAUGING PROPAGATION. So far we have looked at HF propagation theory and the use of computerised HF prediction programs like ACE-HF, VOAProp and W6ELProp. Last month we also looked at beacons. But there is another method of gauging propagation conditions using WSPR (Weak Signal Propagation Reporter) and it is gaining in popularity.

WSPR uses software designed by Joe Taylor, K1JT, a Nobel Prize-winning Princeton physicist and originator of the WSJT weak signal software. First released in April 2008, WSPR uses a transmission mode called MEPT-JT - the MEPT standing for Manned Experimental Propagation Transmitter.

WARBLING TONES. The principle is quite simple, although the technology behind it certainly isn't. Stations running WSPR automatically send out a beacon signal on a given frequency. Each transmission lasts for just under two minutes and to make sure this all works you must ensure that your computer clock is set correctly or you will clash. The digital signal sounds like a single tone with a barely discernable warble to it and carries your callsign, your locator and your power output. It actually uses Frequency Shift Keying with a very small shift, occupying a bandwidth of about 6Hz. This means that many stations can be fitted into the 200Hz WSPR window.

When your system is not transmitting it is actually listening for these WSPR beacon signals. If it hears one, it logs it and sends the details via the internet to http://wsprnet.org/. WSPRnet then logs your information and even displays it on a map, with a line showing the paths between the transmitting and receiving stations. If you visit wsprnet.org you can select which band you want to monitor and also what part of the world. Or you can look at the raw received data.

WSPR stations use low power transmissions – typically just a few watts. If you do use the WSPR software you will need to key in your Maidenhead locator square and also your power output in dBm. Both of these have obviously confused some people as you often see stations purporting to be in the middle of the South Pacific or Italy when they should be in the USA – or running power levels that are obviously wrong.

Running WSPR is rather like using datamode software for RTTY or PSK31. To receive WSPR you need to connect your radio's audio output to the Mic or Line In socket. If you want to transmit as well you will need to connect the speaker output to the radio and also arrange for it to be keyed. If you have an interface for data modes you are almost there.

The end result is quite fascinating as it gives you an at-a-glance view of real-time propagation.

ENDLESS POSSIBILITIES. The possibilities for research using WSPR are endless. You can actually test your own antennas using WSPR. Put up a beacon signal and then see how far you can get. WSPRnet will not only tell you who heard you (and usually within a minute or two), but also the received signal to noise ratio, the distance and bearing between your two stations. Let the system go through a couple of cycles and then switch antennas and you should be able to see if your signal is stronger or weaker.

PROPAGATION RESEARCH. You can also conduct other propagation research. I have corresponded with Patrick, F6IRF (http://f6irf.blogspot.com/) over his use of WSPR for greyline studies. Using two different antennas, Patrick managed to receive Joe Taylor, K1JT's own 80m WSPR signal from across the Atlantic and showed clearly that there was a high-angle component to it just after sunrise.

This corresponds with my own work on greyline propagation, which is backed up by work with VOACAP that shows that the numbers of possible paths (or modes) for radio waves to take can change quite rapidly around sunrise, leading to stronger signals on relatively low 80m dipole antennas. As these favour high angle signals you can work some interesting DX around sunrise that conventional propagation models would suggest is impossible.

So what else can you do with WSPR? It is also good for detecting Sporadic-E openings on 10m, showing you not only who is being received, but importantly, who is active but NOT being received. You don't HAVE to transmit either. SWL reports of signals heard are equally important.

So is WSPR the answer to your real-time propagation dreams? Well, not quite. The problem really is that there are not enough users on all the bands. The majority of operators are on 30m (10MHz), which is no doubt linked to the work 30m enthusiasts are doing with low power MEPT. On a typical day you might find two or three people using WSPR on 80m and perhaps one or two on 15m. This isn't really enough to do much serious research. Nevertheless, interest in WSPR is growing. There are typically around 150 WSPR users logging information to WSPRnet.org each day. A year ago there were fewer than 50.

Also, if you are going to use WSPR for research, you need to arrange with the participants that a) they will be on and b) that they won't change their power outputs or antenna arrangements. If they do, your data will be useless.

If you are interested in finding out more about WSPR I suggest you read the excellent article by Julian, G4ILO at www.g4ilo.com/wspr.html. This gives you a good run through what WSPR is about and how to set it up. While you are there, download Julian's VOAProp propagation prediction software too.

You can download the WSPR software and quick start guide at www.physics.princeton.edu/pulsar/K1JT/.

WSPR FREQUENCIES

Band	Dial freq (USB MHz)
160m	1.8366MHz
80m	3.5926MHz
60m	5.2872MHz
40m	7.0386MHz
30m	10.1387MHz
20m	14.0956MHz
17m	18.1046MHz
15m	21.0946MHz
12m	24.9246MHz
10m	28.1246MHz
6m	50.293MHz
2m	144.4885MHz

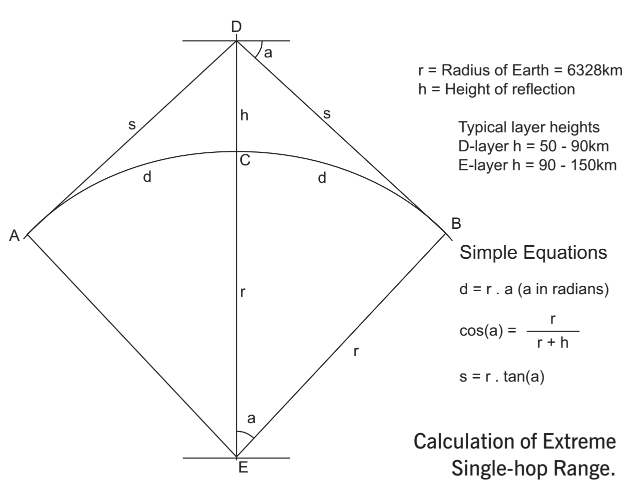
Understanding LF Propagation

Having dealt with the HF side we move lower in frequency to look at propagation there.

LONG DISTANCE AT LF. Most LF (below 300kHz) propagation information is aimed at commercial users. In contrast to commercial radio users, the radio amateur, often working at the threshold of possibility, is willing to wait for – and use – whatever short-term effects are available to achieve his ambition of long distance communication. This means that the priorities of the radio amateur are very different to those of commercial operator.

The signal from a transmitter may reach a receiving site in two ways. First by way of waves that follow the curvature of the Earth to some extent, known as ground waves; secondly by the return of skyward travelling waves by the ionosphere, referred to colloquially as sky waves or, more correctly, ionospheric waves.

GROUND WAVES. The so-called ground waves follow the curvature of the Earth because the speed of the wave is slowed slightly by the dielectric constant of the ground. This has the effect of tilting the wavefront downwards and allows the signals to be detected far beyond the normal visible horizon. Unlike higher frequencies the strength of the ground wave signal is not reduced significantly by absorption. As a result there is no 'dead zone' on low frequencies (LF), except for very low power transmissions and ground wave signals can be detected at over 2000km from the transmitter.



Calculation of Extreme Single-hop Range.

SKY WAVES. Because most amateur sized aerials are small compared to the wavelength, considerable amounts of the radiated power are launched at higher angles and rapidly leave any influence of the ground. These waves travel upwards until they reach the ionosphere at around 50 to 100km altitude. Vertical incidence signals will penetrate deeply into the ionised regions but will suffer a great deal of attenuation, but at lower angles the waves will be gently 'bent' (refracted is the correct technical term) back towards the ground. Sky wave returns have been detected at as little as 300km from the transmitting station and result is a slow shallow fading in the strength of the signal.

The change in strength of the signal is due to the change in the distance that the sky-wave travels as the altitude of the 'bending' region alters. The sky-wave arrives at the receiver with a different phase to that of the ground wave, and the two waves may either add, to reinforce the signal, or cancel to reduce it. Complete cancellation only occurs if the ground and sky-wave are the same strength as well as 180° out of phase. Most of the published data suggests that the sky-waves become approximately equal in strength to the ground-waves at around 700km from the transmitter. Beyond this distance the sky wave is stronger. A case of 'dead zone' can appear when of very low power signals are transmitted. In this situation the ground wave, is weaked by the nature of its outwards spread, to levels below the detection level of the receiver, before the angle of the sky-wave becomes low enough to cause them to return, This is often experienced by US FCC Part 15 stations, who are limited to 1 watt input power and a maximum 50 foot long antenna.

A simple geometric construction shown in **Figure 1** allows us to calculate the maximum distance covered by a single ionospheric 'bounce' provided we know the height at which the signal is bent back towards Earth. For simplicity we can consider a mirror like reflection from an altitude we will call the 'apparent reflection height', and we will assume that the signal leaves the transmitting site tangentially to the ground. Experience suggests that the daytime 'reflection level' is around the lower levels of the D-layer at about 50km altitude whilst at night the reflection level is in the upper D-layer near the bottom of the E-layer at around 100km altitude.

Our calculations then show that in daytime a single hop will be of around 1000km, whilst at nighttime a single hop will be around 2000km. It is important to realise that the returning sky wave at extreme range approaches the ground at grazing incidence or tangentially, it does not bounce at high angles like a tennis ball as shown on many sketches. Thus the wave does not need to be 'reflected' from the ground to go upwards for a second hop, it merely slides past, barely touching the ground.

Low frequency radio paths can comprise several such 'hops'. The regular signal heard from VO1NA during 2003 and 2004 at 3600km was probably a two-hop path, whilst the record QSO between Quartz Hill in New Zealand and Vladivostok in Asiatic Russia at over 10,000km was probably around 5 hops. One-way signals from Quartz Hill were detected and identified in western Russia at 16,000km. These exceptional distances were achieved at night with the path in full darkness. The daytime path lengths are usually restricted to around 2000km, due mainly to the higher signal absorption (attenuation) levels in daytime and the loss at each 'hop'. Nevertheless, under exceptional circumstances VO1NA has been copied in the UK at 1200Z, but this is a rare event. Even the powerful (20kW ERP) Naval station, callsign CFH, at Halifax, Nova Scotia, is not often heard in daytime. Fading still occurs on these path although the ground wave signal is now below audibility. In this case the fading is due to interaction between signals from the 1-hop and 2-hop paths.

In practice, the situation is a little more complicated. The 'reflection' of the waves is not without loss. At lower altitudes the daytime ionisation of the D-layer produces a belt of ionisation below the 'reflection height' that absorbs power from the radio waves. At the lower HF frequencies (160, 80 and 40m) this shows as a severe restriction in day-time range, because the sky waves are completely absorbed by the D-layer. After sunset this ionisation in the D-layer quickly decays and the lower HF waves can pass through to be reflected from the F layer and so called 'skip' signals appear. In the LF frequency range the daytime absorption is not so complete and it is possible to receive daytime sky-wave signals at distances of about 2000km, which probably requires two hops. For a given path these signals are never as strong as those received after dark.

In the next part we will consider the effects of solar activity on LF propagation.

ALAN MELIA, G3NYK ♦ E-MAIL: ALAN.MELIA@BTINTERNET.COM

Understanding LF Propagation (Part 2)

Looking at the effect of the Sun on LF propagation

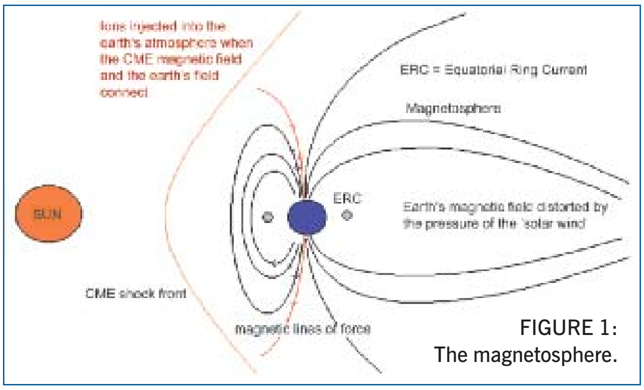


FIGURE 1: The magnetosphere.

DISTURBANCES. Propagation conditions are further affected by solar disturbances. At the height of the sun spot cycle, the sun emits bursts of intense X-rays and ultra-violet light called solar flares. Because the output of a solar flare is an electromagnetic emission (like a radio wave) its effect is almost instantaneous and will only affect the side of the Earth that is currently illuminated. Intense flares cause radio blackouts at HF, because they produce extra ionisation in the D-layer that strongly absorbs most HF radio frequencies. Surprisingly, at LF, the effect is usually the exact opposite. The intense radiation converts most of the normally absorbing level ionisation to a state where it easily 'reflects' LF waves. The result is that LF signals show a strong peak in strength that is a similar shape in time to that of the X-ray flux (as can be seen on the NOAA website). Then as the flare decays, the absorption returns.

This flare enhancement can cause an increase of up to 10dB in the strength of a signal being received in daytime. This can be useful, but the enhancement is much less than is normally achieved on night-time paths and it difficult to catch so is not much used for communication.

The solar magnetic disturbances that produce flares also throw off huge clouds of ionised gas or plasma known as a Coronal Mass Ejection (CME). The plasma travels much more slowly and takes between 36 and 56 hours to reach the vicinity of Earth – a journey of 96 million miles. When these clouds reach the earth they buffet the atmosphere. Because these clouds are composed of fast moving charged particles, the cloud carries with it a magnetic field, and this interacts with the Earth's magnetic field.

The magnetosphere is a distorted doughnut shaped 'cage' formed by the lines of magnetic force generated in the Earth's core (**Figure 1**). The magnetosphere protects us from most of what the Sun can throw at us. Without it, the majority of life on Earth could not exist.

If the magnetic field of the plasma is in one direction, the cloud bounces off fairly harmlessly, like similar poles of small bar magnets. In the opposite field direction the field lines of the plasma are said to 'connect' with the geomagnetic field, like the bar magnet opposite poles. This situation opens up 'cracks' in the Earths 'defences' and charged particles flood into the atmosphere. The most notable visible effects of this phenomenon are the aurora seen mainly in high latitudes after a magnetic storm.

The event also causes the Earth's field to vary wildly for a short period, an event that can be observed on magnetometers and hence the term 'Geomagnetic Storm'. This was thought to be the main source of injected particles but, since then, the use of satellites and the discovery of the Van Allen radiation belts has refined ideas of the process. It has been realised recently that the majority of the particles are swept past Earth and are sucked into the long tail of the magnetosphere on the side of Earth opposite to the Sun. The Geomagnetic field then draws them back into the Van Allen belts, forming a series of circulating rings. Electrons travel one way and ions, because of their opposite charge, the other. More than this, the electrons being much lighter follow paths that spiral round the Earths magnetic lines of force from one hemisphere to the other. They are 'turned round' by the 'cramping' of the lines of force near the poles. Together these rings of circulating charges, which are known as the Equatorial Ring Current, generate a magnetic field of their own, which can be detected and measured by magnetometers at the Equator. The Rings exchange charged particles, mainly electrons, with the ionosphere

It had been noted by many researchers prior to the advent of satellite measurement, that the injection of electrons (called electron precipitation) into the ionosphere, after a geomagnetic storm, lead to severe reductions in distant MF and LF radio signal strengths. The effect did not build up until a day or so after the storm and could often persist for up to 28 days. It is not physically possible for electrons, even very energetic ones, to exist in the relatively high atmospheric pressure at the D layer for very long. So the signal attenuation should decay with the passing of the storm. It has recently become clear that the Ring Current acts as a reservoir of electrons that are bled into the ionosphere at the daylight edge, where the magnetosphere is distorted by the pressure of the Solar wind. Thus the after-effects of a Geomagnetic storm on LF radio transmissions will be felt until the Ring Current is depleted of its trapped electrons.

Fortunately, the charged particle population of the Ring Current can be measured by the field it generates. It is not an easy task because the field due to the Ring Current is about one thousandth of the Earth's field (50 to 400nT against 50,000nT for the static geomagnetic field at the Earth's surface).

Daily estimates of an index, which effectively measures the Ring Current, are published by several institutes. The most useful for LF radio propagation prediction are the (hourly) real-time estimates from Colorado University and Kyoto University, which are both available on the Internet. The Index is referred to as 'Disturbance Storm Time' and carries the mnemonic Dst.

Plasma clouds (referred to on Solar website as Coronal Mass Ejections or CMEs) are also produced by disturbances in the solar atmosphere known as coronal holes. Whilst flare associated events are more prevalent in years of high sunspot activity, coronal hole events occur throughout the solar cycle including periods when the visible face of the Sun is totally devoid of spots.

The most familiar effects of these disturbances are intense aurora. A rarer, but more serious, problem is that these events can induce massive currents in long northern power distribution systems. Canada suffered a power black-out for several hours some years ago due to one such event. Submarine cables and satellite communications systems can also be disabled. The arrival of a CME can herald the onset of a period of poor HF communications and absorption, due to the enhanced ionisation of the D-layer by the trapped electrons, causes all the bands to go 'flat'. Again the effect at LF is different. The daytime signals up to about 2000km can be significantly enhanced by up to 10 or 12dB above normal levels. The effect on night-time paths is more dramatic with absorption at LF increasing significantly above normal and signal levels on long paths dropping as much as 20dB below normal levels.

Next month we'll look at whether we can predict good conditions.

Understanding LF Propagation

Can we predict good LF conditions?

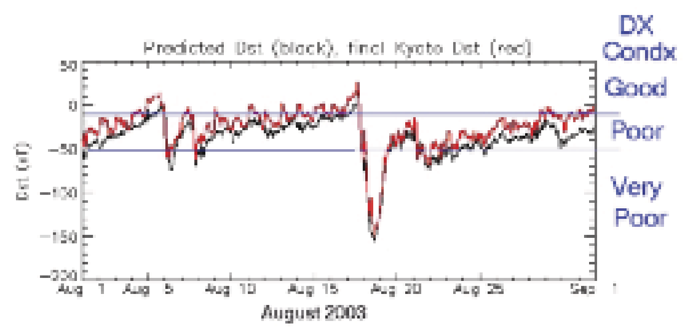


FIGURE. 1: Plot of Dst from Colorado University.

PREDICTIONS. It might seem that with the knowledge built up it should be possible to predict good LF conditions. This can be done to some extent, but it is much easier to predict bad conditions, particularly for night-time paths. There will be severe reduction in signal levels at LF about 24 hours after a major geomagnetic storm. Flares cannot easily be predicted and the best that NOAA will say is that there is a likelihood of a flare of particular strength in the next three days. However, by carefully watching the background levels via the NOAA SEC internet site, it is possible to see the solar X-ray flux, measured by the GEOS satellites, increasing. This gives a good indication that a predicted flare is imminent. Flares are more likely around the sunspot maximum and their likelihood is directly related to the sunspot number, which is a measure of solar activity.

Coronal Mass Ejections are detected as they form and their impact on Earth can be predicted about two days ahead of their arrival, which is denoted by a large increase in the geomagnetic index Kp, known as a geomagnetic 'storm'. One problem is that a CME will sweep past Earth, the Kp will indicate the storm and return to a 'quiet' state in a matter of hours. The effect of the storm is not felt for about two days, at mid latitudes, despite aurora occurring on the night of the impact. This may be due to the time taken for electrons trapped in the ionosphere to diffuse down and spread out at lower latitudes. It may also be due to the fact that the charged particles are collected in the magnetosphere 'tail' as the plasma cloud sweeps past the Earth and these must travel back, under the influence of the magnetic field, into the Ring Current. Then 'precipitation' from the Ring Current takes place mainly at the 'dawn edge'.

An intense storm will produce a depression in night-time signal levels that can last for 21 to 28 days and the Kp index is no indicator of the return of good conditions. This is where the Dst, which acts as a measure of the quantity of electrons still trapped from the CME, is useful. A correlation between this index and signal levels of well known commercial stations suggests that the Dst index mirrors the return of good radio propagation. The index has a range from small positive values (-20 to +40) for quiet conditions and up to -100 to -400 for intense storm condition. The units are nanotesla (nT) because this is a magnetic field. Unlike the Kp index it will show the effect of small events following a major storm that tend to extend the recovery time to good radio conditions, because of the 'reservoir' being topped up.

SOLAR CYCLES. Radio amateurs have had access to LF for almost a whole solar cycle now and we can say what the effect of the 11 year solar cycle on LF conditions might be. The cycle is usually defined in terms of sunspot numbers, and solar flares will be directly related to the sunspot number. Geomagnetic events seem to peak a year or two past the sunspot maximum. Geomagnetic storms still occur during the quiet years but the period between them becomes longer allowing more time for propagation conditions to recover. Perversely it would seem that the best results are not achieved in dead quiet solar conditions and a small amount of geomagnetic activity can be an advantage.

We can now see that the higher level of daylight solar flux during the years around the maximum produce stronger daylight sky-wave signals. On average, the daylight path of in excess of 1000km, can be 10dB lower at the solar minimum. There is a further effect, which cannot yet be quantified, that shows that night-time signals seem to decline below expectation levels in a long geomagnetically quiet period in the solar minimum. This may be due to the lack a sufficient radiation to retain the necessary level of ionisation in the lower E layer. In effect, the E-layer may be becoming slightly transparent to 136kHz signals and some is 'leaking away'. It is noticeable that there can be a dramatic recovery to good levels following immediately after a small geomagnetic disturbance that only measures at a Kp of 4. During a long quiet spell in January 2003, a minor geomagnetic storm raising Kp to only 4, produced record levels on transatlantic paths.

ALL YEAR ROUND. There is a mythology that LF propagation only exists in the winter months, between the autumn and spring equinoxes. This is not true; daytime levels are better in summer because the sun is stronger at mid-day and the ionisation for daytime sky wave is higher. The darkness period is shorter in summer and some paths may not have a period of total darkness for a month around the summer solstice. What normally limits operation in summer is the level of 'static', interference from lightning crashes. This makes listening very uncomfortable and tiring, but data modes and QRSS can be operated successfully through this period on nights when the 'static' is not continuous.

The best information about the state of propagation is derived from listening to reliable commercial stations and logging their strength. Propagation is very frequency dependent and it is only really useful to listen to stations in the same frequency area. Unfortunately there are no LF broadcast stations in North America.

The Canadian Naval Station CFH at Halifax Nova Scotia on 137.00kHz is ideal, at a distance of about 4500km from the UK, but it does have long periods of inactivity. The Greek Naval Station SXV located near Athens on 135.75 is one choice at a path length of 2200km from the UK, but it is difficult to understand the strength variations. This may be due to the long reach up the Adriatic followed by a passage over the Alps, but it is also suspected that the transmitter power is reduced at times. Under generally good conditions, the received level from SXV can swing violently up and down, probably due to multi-hop fading. Because fading is a function of the path distance, it can be very dependent upon the location of the receiving station. Two stations just 50 miles apart may experience what seems like totally different conditions, if one is ideally situated to benefit from constructive (additive) 'interference' between paths with numbers of different hops. Since 2007, a utility station near Budapest (HGA22) transmitting a long spacing signal, at constant power, on 135.430kHz makes a slightly better LF propagation beacon.

REFERENCES

I.A.Daglis, R.M.Thorne, W.Baumjohann, S.Orsini. The Terrestrial Ring Current: Origin, Formation, and Decay, Review of GeoPhysics, 37, Nov. 1999, pp 407-438.

NOAA Space Environment Centre (SEC): www.sec.noaa.gov.

Colorado Univ. real-time Dst estimates are available at http://lasp.Colorado.edu/space_weather/dsttemeric/dsttemeric.html.