CALCULATING GREYLINE PATHS **by David G3ZPF**

FIG1 shows the border of daylight and darkness following a great circle around the earth. The exact position varies throughout the year because the attitude of the Earth changes with respect to the Sun. The rotational axis of the Earth swings back and forth through an angle of roughly 24 degrees each side of the vertical, and it is that “wobble” which causes the seasons of the year.

When the northern hemisphere is leaning away from the Sun we have our winter because the Sun is lower in the sky and the heating effect of its rays is reduced. Conversely when the northern hemisphere is tilted towards the Sun we have our summer and the southern hemisphere has its winter. Equatorial regions have very little seasonal variations because the Earth tilts about its centre and the Sun will always be high in the sky around the equator.

Surprising though it may seem, during winter in the northern hemisphere the Earth is actually a little closer to the Sun than it is in our summer.

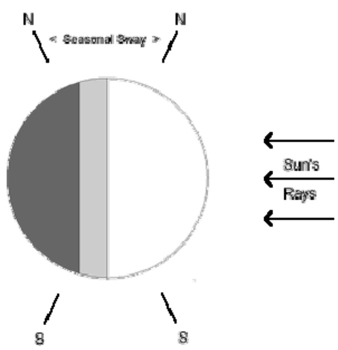


FIG 1

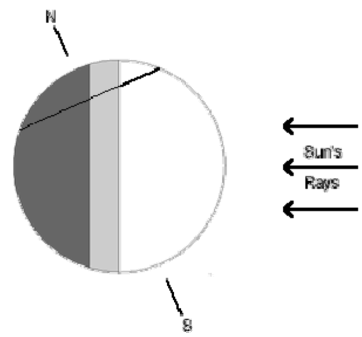


FIG 2

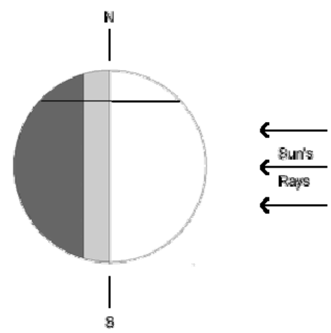


FIG 3

The transition from daylight to darkness does not take place instantly so there is a band of twilight around the earth. In arctic and Antarctic regions the sun never quite sets in the summer, nor fully rises in the winter, hence the familiar expression “land of the midnight sun”.

The line cutting across the twilight region in FIG2 and FIG3 represents the latitude of the UK in December and April respectively. The latter is around the time of the vernal equinox. The earth is ‘vertical’ so the periods of day and night are pretty much equal. In December (FIG2) it is easy to see that because the northern hemisphere is tilted away from the Sun, the period of daylight will be much shorter than the period of darkness.

The combination of the Sun being lower in the sky, plus the longer periods of darkness gives greater heat loss and heralds the onset of winter. Enhanced propagation conditions can occur for a QTH in the band of twilight (often referred to as the “Grey line”) especially if the station at the other end of the QSO is also in twilight.

PROPAGATION ENHANCEMENT

Most reader will be familiar with the various layers in the ionosphere, and their respective effects on radio waves at different frequencies. To visualise how twilight conditions can enhance propagation, consider FIG4, which shows locations in daylight, twilight, and darkness.

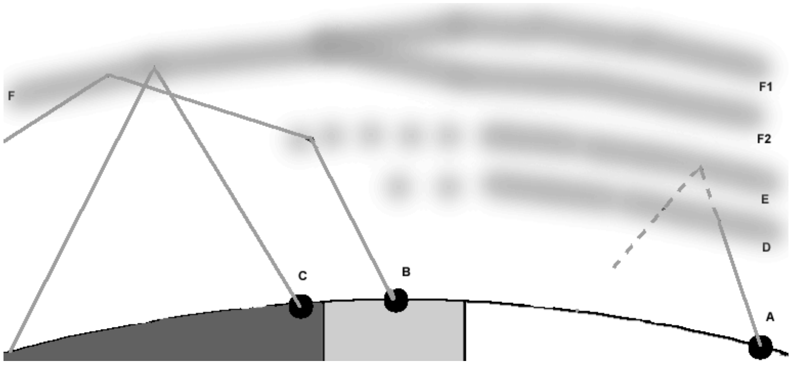


FIG 4

Station A will only be able to communicate at groundwave distances on LF because any skywave radiation will be severely attenuated, if not totally absorbed, by the D layer. Any signal that does get past the D layer will be reflected by the E layer, but will be further attenuated by a second passage through the D layer on its way back to the earth. Under daylight conditions at LF, any signal that does finally get back to the surface will be well below the detection threshold of any amateur equipment.

Because the D layer is so low in the atmosphere it dissipates almost immediately when no longer in sunlight, but the E layer, at a height of about 70 miles, takes rather longer. The station at C will have increased range over the station at A, because skywave reflections can take place from the F layer, once the E and D layers have dissipated. The F layer will be at a height of about 175 miles, having combined from the daytime F1 and F2 layers at 140 and 200 miles up, as darkness fell, where it dissipates slowly throughout the night. As it dissipates, so the MUF falls gradually.

Now consider the station at B, who's skywave strikes the partially dissipated E layer. Although there will be insufficient energy to divert the RF sufficiently to return it to the surface, it will be turned to a lower upward angle whereupon it will continue upwards to reach the F layer. When it reaches the F layer it will be returned to the earth at a greatly increased range, especially if the station at the other end of the QSO is also in twilight, with the E layer lowering the angle of his skywave too. When both stations are in twilight, the signal travels in twilight for the whole of its path.

Because real aerials are unable to focus RF into a single line, some amount of RF will leave the grey line path at an angle and enter either daylight or darkness. In daylight the D layer will be present and LF signals will suffer severe attenuation on their downward path. HF signals would pass through, however, so do not think that grey line DXing is an exclusively LF event. Any RF that passes into darkness on leaving the grey line enters into a domain where the F layer is dissipating and lowering the MUF. HF signals will be lost to space although LF signals will be returned to earth.

CURVED PATHS

Since the twilight zone will lie along a great circle it follows that signals should arrive on the 'normal' beam heading, assuming you are lucky enough to have a beam at LF. There have, however, been any number of reported instances where this has not been the case. To explain why requires a re-appraisal of the terms in which simple RAE theory depicts the ionospheric layers.

The D, E, and F layers are generally depicted as RF mirrors which reflect skywaves back to earth but in fact they are 'clouds' of charged particles which *refract* the skywave downwards. Even though the nett result is the same it is significant to note the difference between the gradual turning of an RF wave within the depth of the ionospheric layer and the reflection of light from the surface of a mirror.

Once the layers are thought of as clouds it only takes one further step of the imagination to realise that they will be very unstable regions for RF, and that any 'swirling about' of particles as they split and recombine could well curve a signal off a straight line path. The fact that ionised layers do move about is well known to VHF types who have exploited sporadic-E propagation. It is generally thought that curved paths on HF or LF are confined to signals passing through the auroral regions but that the side scatter off irregularities on the earth's surface also contribute to the effect. Few people will have highly directive aerials at LF, and many of those that do are unable to steer them precisely, so there is the possibility that an inferior aerial with a much broader radiation pattern would fare better than expected in certain conditions.

Although the mechanics of RF propagation contain a large number of variables and uncertainties, the chances of DX contacts will obviously increase if it is possible to find the sunrise and sunset times for any point on the earth on a given date. Even if those times are known, there will be some areas of the globe that will never fall on a grey line path with some QTHs because the 'wobble' of the earth is only +/- 24 degrees. If it was 45 degrees then sooner or later any point on the earth would have a grey line path with any other, but then our winters would be very bleak indeed.

OTHER SUNRISE & SUNSET ENHANCEMENTS

While searching the internet during the preparation of this article I came across some information published by N4KG of which I was not previously aware. There is a peak in signals from westerly directions at sunrise which are often attributed to greyline propagation but which are thought to be a focussing effect from normal F layer refractions, plus another from the E layer. They can combine to produce gains of 10dB or more, over periods ranging from a few minutes on 160 metres, up to 20 mins on 80m and up to 60 mins on 40 metres. These enhancements always occur *after* sunrise on 80 and 40 metres, and a few mins either side of sunrise on 160 metres.

At sunset, the enhancement is on signals coming from easterly directions. Again thought to be due to combined F and E layer conditions, and occurring *before* sunset with durations similar to the sunrise enhancements previously mentioned. The important thing to note is that these effects require the presence of daylight at one end of the path in order to produce enhanced signals.

Thinking back I have seen reference to, and experienced first-hand, DX openings on 40 metres well into full daylight in the UK. It would seem prudent not to assume that conditions will always tail off as dawn approaches.

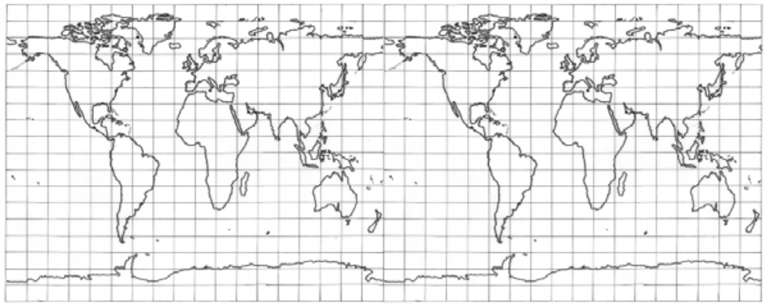
FOR THOSE WITHOUT COMPUTERS

The calculation of sunrise and sunset times has occupied amateurs for decades and several mechanical aids have been produced during that time. In the late 70's microcomputers started to appear in shacks. This made more accurate predictions possible, but the limited power of these machines meant that solutions were still predominantly text based.

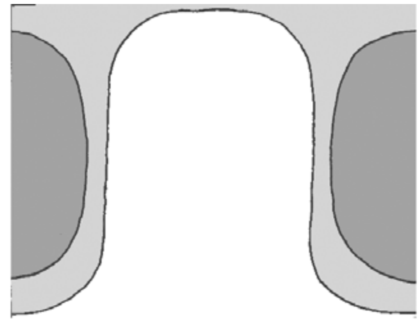
In recent years the increasing power of domestic PCs has increased to the point where elaborate algorithms and detailed graphical displays are practical, but this is of academic interest to the large number of RAOTA members neither have, nor want, a PC in their shack. Before discussing my favourite PC program for grey line paths I will present a series of tables that will enable members without any computer available to construct grey line overlays for any map that they have to hand.

Before doing that, I'd like to bring to your attention something to look out for at junk sales. Although no longer manufactured, a USA company called XANTEC used to make a device called the "DX EDGE", the design of which is shown in FIG5.

It consists of a double Mercator projection world map, plus a transparent overlay for each month of the year. By placing either the sunrise, or sunset, side of the curve over the UK, all other locations on the earth in twilight at the same time can be seen. The world map has to be a double one, so that all locations can be covered by the overlay.



WORLD MAP



TRANSPARENT OVERLAY

FIG 5

The overlay shown is for the month of October, and when you first see a full set of them it is surprising just how much the shape of the curves varies. Obviously you'd need to check your 'find' at the junk sale to make sure the complete set of overlays were present. Later versions of this product had colour overlays, but the early ones were monochrome. The only limitation is that only one overlay is available for each month. Around the turn of the year, which is when you are most likely to be using it on LF, the times of sunrise and sunset change quite quickly on a day-by-day basis, which limits the accuracy. By looking out of the window you can make adjustments of the position of the overlay to compensate for time changes, but bear in mind the shape of the twilight zone is changing too. Comparing adjacent overlays for the winter months shows how significant this is.

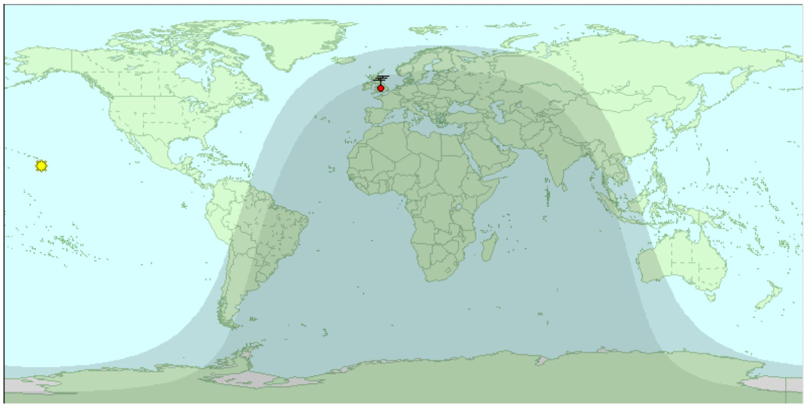
Bear in mind that there are no guarantees of enhancement of grey line signals. As you easily can tell when it is twilight at your own QTH, so you can always take pot-luck at what countries you will find.

Whilst it is possible to produce a homebrew version of the "DX Edge", and indeed I initially intended to include a set of tables for setting out the overlays, it would be a lengthy and fiddly undertaking. Given the average age of RAOTA members I doubt whether anyone would think the effort justifiable, but if anyone does fancy undertaking such a project, I had a set of tables and instructions published in the March 1986 edition of "Amateur Radio" magazine, and could make a copy available.

Mercator projections are not the only maps you can use. Projections where lines of longitude are radii of a circle are available, for which you can produce an overlay which rotates, rather than slides. Bear in mind that most "great circle" maps found in shacks are designed to give true beam headings. The lines of longitude on these maps are curves, not lines, and overlays would be complicated to mark out.

Probably the most practical solution, if you have a local with a PC who owes you a favour, is to utilise graphical printouts from a computer program such as "DX Atlas". You would need a printout for sunrise/sunset over the UK for each month of the year, so you're looking at 24 sheets of A4, or 12 double-sided ones.

FIG6 shows a map image produced by DX Atlas at 22:18 on May 9th, the exact moment I was writing this. If maps like this were produced to fill an A4 sheet they would be quite useable, although obviously you would need to alter the time to put the UK in the centre of either the sunrise, or sunset, twilight zone and print off both.



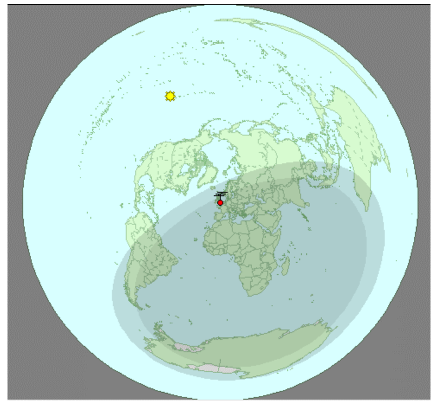


FIG 6 **FIG 7**

For clarity at this small size I have switched off all the Prefix and Zone information, but these can be included to suit your own preference. As mentioned earlier, Mercator map projections are not the only one available, and with a click of the mouse DX Atlas can produce an Azimuth projection instead, as shown in FIG7.

In case it isn't obvious, the DX Atlas maps are re-drawn on the computer screen in real-time, taking the date & time from the system clock, although you can over-ride this and create maps for any date/time you choose. You can also centre the map on any location on the earth too.

In addition you can swap to a "globe" projection. In other words a 'real' view from a point some distance away in space. This shows the twilight zone as a band around the earth (FIG 8) but as you cannot see all the countries without altering the viewpoint to the other side of the earth it is less convenient than the other two projections.

FIG 8

FOR THOSE WITH COMPUTERS

There are alternatives available, such as "Geoclock", or "Ham Radio Deluxe" but my personal favourite is DX Atlas, which is why it was included on the RAOTA "Internet Essentials" CD.

It is available as a 30 day demo, but like WinZip (which pretty well everyone must use) it doesn't stop working after the evaluation period. Instead it produces a "nag" screen every time you start it thereafter. Personally I was so impressed I actually put my hand in my pocket & registered it.

But DX Atlas is rather more than just a greyline program. The maps can be altered to show all kinds of other information, such as MUF, critical freq, (E layer & F layer), D layer density, Aurora, Geomagnetic latitude & dip. The software can link into other packages to increase its usefulness, and contains a full prefix database.

Take a look at **www.dxatlas.com** for full details.