# The Twilight Zone

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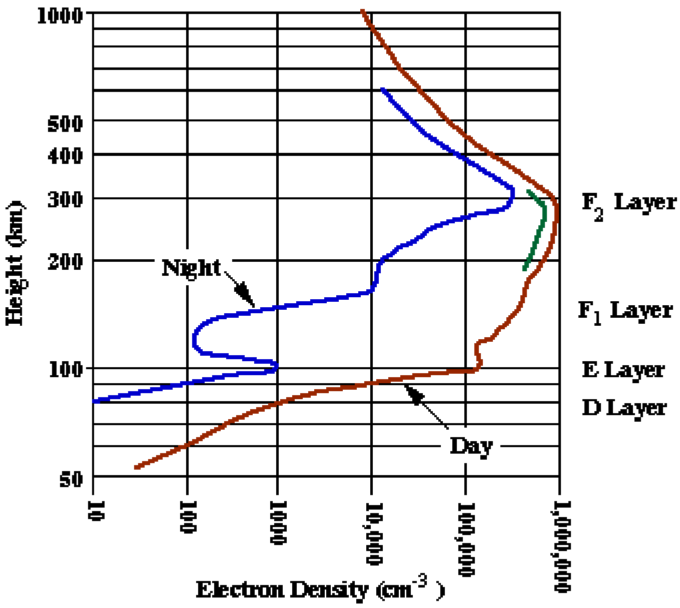
Intro: Steve Nichols G0KYA, of the RSGB's Propagation Studies Committee, believes that propagation around sunrise and sunset is not fully understood. Here he outlines the mechanisms behind grey line and other twilight propagation modes and a research project to help us understand them.

Worldwide communication using the HF bands is dependent on radiation coming from the sun. In general, and to grossly oversimplify reality, at LF (160, 80 and 40m) we need a night-time path between the two stations. At 28MHz, a daylight path is generally needed. But twice a day, at sunrise and sunset, the ionosphere undergoes dramatic changes, giving enhanced propagation in some directions.

In terms of radio propagation, the D and E layers are responsible for most of the absorption of radio waves that pass through them, but the absorption is frequency dependent. The D layer can completely absorb signals on 160, 80 and 40 metres during the day, and can attenuate signals on 20m too. Hence the reason you don't hear much, if any, DX on the low bands during the day as sky-wave signals are absorbed before they can reach the E and F layers.



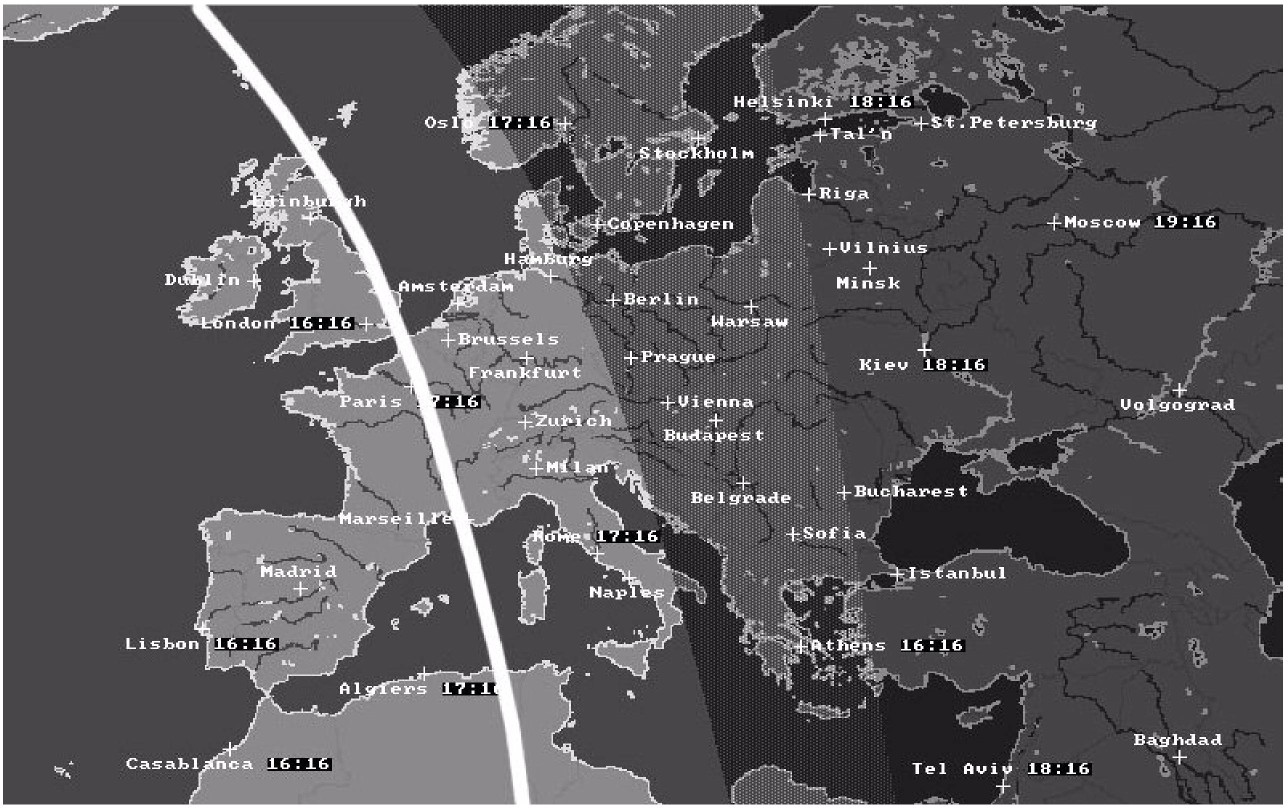

The ionosphere undergoes a dramatic change in ionisation at the transition from day to night. The electron (and ion) density in the E-layer decreases by a factor of 200 to 1 and the F1 by nearly 100 to 1 (see graph). At sunset, the D layer disappears rapidly.

Around the other side of the world other regions that are entering into daylight have yet to form any significant D layer and the E layer has not built up from its night-time low. Therefore, for a short period propagation between two regions simultaneously experiencing sunrise and sunset can be highly efficient. Signals on the lower bands can theoretically travel over great distances with little attenuation.

This is well documented with many examples of grey line propagation being logged on 160 and 80m over the years.

Many amateurs will be familiar with this so-called grey line propagation (the term was coined in 1975 - see Ref 1) – propagation that occurs along a line separating night from day. The line is called the terminator but it is diffuse, due largely to the earth's atmosphere that scatters the light over a large area. In radio terms, the radio terminator is not the same as the visual one. The latter refers to the point when we see the sunrise or sunset at ground level on the earth and the period of visual twilight that either precedes or follows. The former refers to the way the sun illuminates the ionospheric D, E and F layers.

For example, the PC program Geoclock defines the point at which the sun starts/stops illuminating the D-layer as being offset from the visual sunrise/sunset by 6.596 degrees longitude. As the earth rotates 15 degrees per hour this could be as much as 24 minutes before or after sunrise or sunset, although the actual figure will depend upon the time of year and latitude (see diagram – the white line shows the physical sunset and the two subsequent shaded areas show loss of D and then F layer illumination at each
location).




The HF “twilight” zone –the region on earth between the loss of the D layer and where the sun starts/stops illuminating the F layer (roughly defined as being offset from sunset by 14.165 degrees longitude) can therefore be almost one hour before and after sunrise and sunset.

E layer illumination starts/finishes somewhere in between these two, but the average height is much closer to that of the D layer.

To confuse matters, these values are based on average D- and F- layer heights and the apparent heights of these can change too. So it is no good looking for grey line DX exactly at your visual sunrise/sunset – you could be out by up to an hour depending on the band, your respective locations, and the time of year (see diagram).

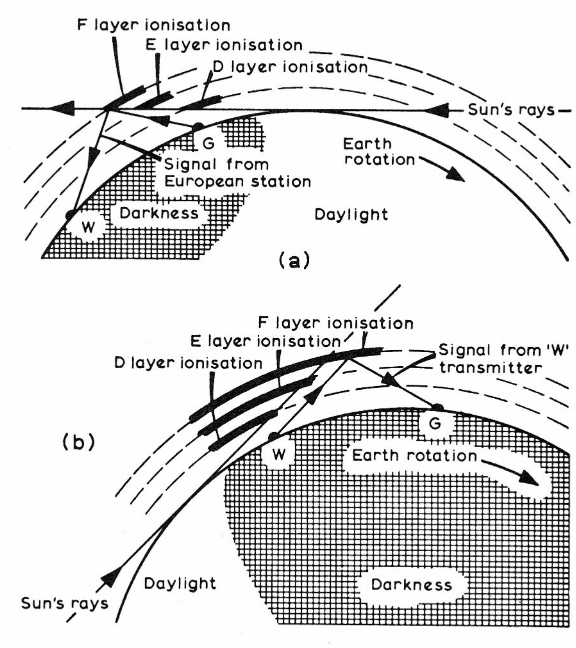



**Fig 4. The North America-Europe path, (a) at European sunrise, ie just prior to sunrise in the UK, (b) at North American sunset – note that in this case the F layer ionisation is persisting for a much longer period than the E and D layer ionisation**

And even worse, for signals at an angle to the terminator we are interested in where the first ionospheric refraction or hop actually occurs once you radiate a signal, which is likely to be many hundreds of miles to the east or west of you – where the sun may still be illuminating the F layer. This is well illustrated on page 93 in the book “HF Antenna Collection” by Erwin David, G4LQI – see refererence 7.

Most books relating to HF propagation give a brief description of grey line propagation, and how and why it works. What they don't tell you is the actual frequencies affected, other than a vague idea that 80/160m are definite bands for grey line, and "some" HF bands also exhibit grey line enhancements.

Either way, all these books tell you that grey line enhancements occur along the terminator. That is, when both stations are at the sunrise/sunset condition.

John Devoldere’s book "ON4UN's Low-Band DXing". suggests that his own experience shows paths perpendicular to the terminator may enjoy the greatest signal enhancement. That is, on the low bands, as sunset occurs at the receiving station, you may get grey line enhancements at right angles to the terminator in the direction towards the dark side of the earth - not along the terminator.

He also points out that the width of the terminator will vary according to the season and your position on the earth, and cannot be thought of as a fixed entity - the grey line will be narrower at the equator and wider at the poles. So the time-span available for grey line conditions will also vary depending upon the time of year, and the locations of the two stations, which is what I proved earlier.

Likewise, the width of the grey line will depend upon frequency as D layer absorption is frequency dependent - you may still be able to work DX on 40m 24hours a day in mid-winter, while DX on 160m will fade out quite quickly after sunrise to the greater D layer absorption.

But what of HF? There appears to be little hard research of grey line propagation at higher frequencies. The vague suggestion in most books appears to be that grey enhancements can and do occur on 20m. Ten metres is theoretically too high for the effect to appear as D layer absorption is virtually non-existent normally at these high frequencies, although I have read more than one article about how to work grey line on 10m! See the graph of frequency -dependent D-layer absorption predictions at http://www.sec.noaa.gov/rt_plots/dregion.html .

My own studies show that enhancements on 10m do occur. On many occasions I have heard signals from Indian, Indonesian and other stations on 10m just after their local sunset - these stations were not audible before. I have also worked a Brazilian (PT2GTI) station on 10m just after his local sunrise, receiving a 59+ report using just 10 Watts into an indoor dipole. I have also heard a station in Puerto Rico (KP4NU) at 59, one hour after his local sunrise in November. Both stations were still audible later that morning but at reduced signal strengths – down 10-15db.

These are not grey line paths, but there were definite enhancements.

Reports of sunset/sunrise enhancements at 50MHz over long distances have also been logged, notably between the UK and USA. One suggestion (see Ref 6) is that that this is due to E or Es enhancements as the E layer increases in altitude at sunset.

The increase in altitude of the E layer needs further explanation. As the sun sets the lower regions of the E layer are not illuminated so the effective height of the reflecting layer appears to increase. Likewise, at this time we can imagine the radio ionosphere as being tilted as it is being illuminated at an angle. This is probably the vehicle for the enhanced propagation at 28MHz and 50MHz – D layer absorption probably has nothing to do with it.

If the theory holds, look for enhanced signals during local daytime in G from stations along their terminator – from the west at their local sunset and from the east at their local sunrise. The signals should be strongest at roughly right angles to the terminator – the same as ON4UN's prediction of propagation on LF, but from the illuminated parts of the globe, not dark.

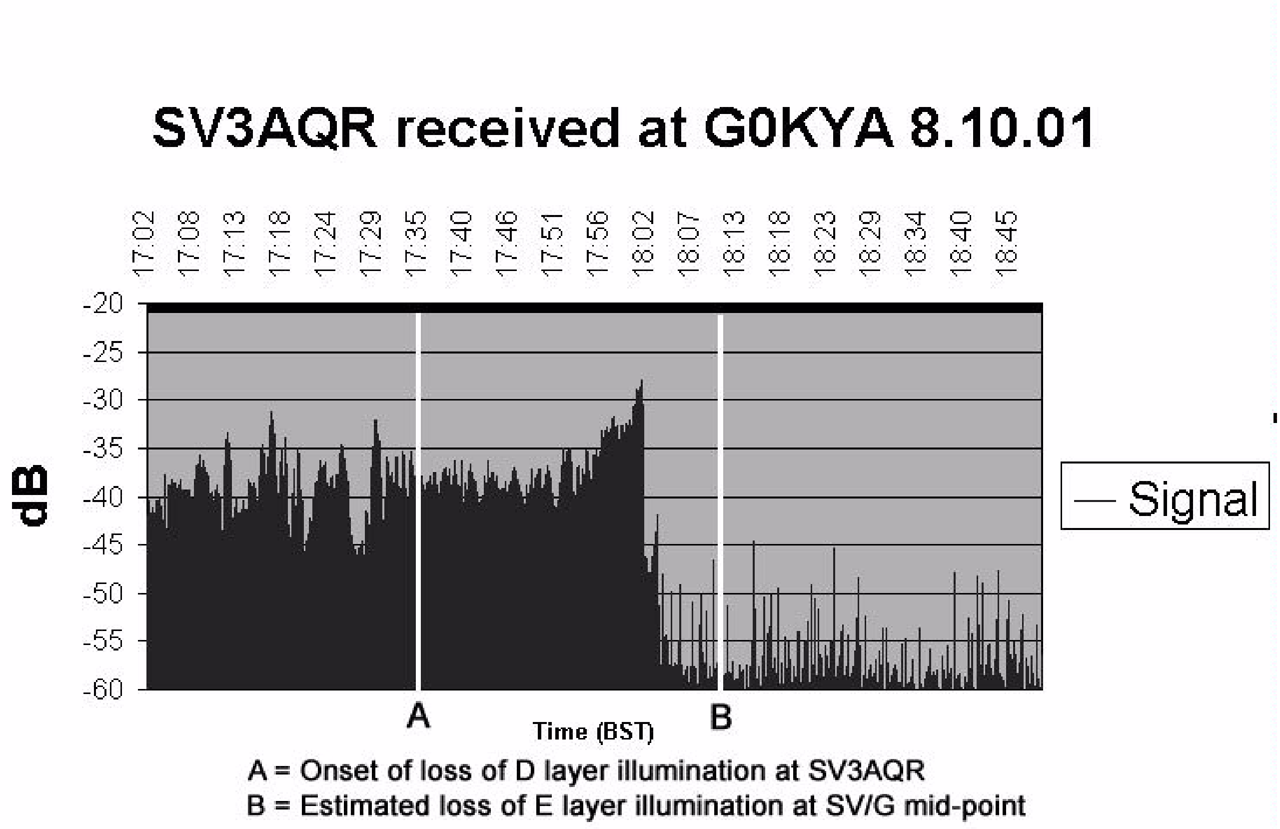
There is an alternative way of looking at grey line conditions on 7MHz and 10MHz connected with the critical frequency (fof2). At frequencies above fof2 a radio wave travelling vertically upwards would pass through the f2 layer into outer space. Below f0f2 it would be reflected back to earth. Now imagine a radio wave hitting the ionosphere at about 75-85 degrees to the earth - a near vertical incidence wave (NVIS). Below the critical frequency it would be returned. If it is some way above fof2 it will pass into space. At some frequency close to fof2 it could be refracted through a large angle and could end up travelling almost parallel to the earth, giving a very long first skip distance. This is the condition for the Pedersen (see Ref 2) or critical ray, discovered in 1927, characterised as being high angle, long distance and close to and probably above the fof2 frequency. As there would be no intermediate ground hops the signal strength could be very high indeed.

It is likely that these conditions exist around local sunset/sunrise as fof2 passes through the two bands and could account for long distance communications under grey line conditions on 7MHz and 10MHz – see http://www.spacew.com/www/fof2.html for predictions of fof2.

Either way, there is more to grey line and twilight propagation than meets the eye. The effects are different on every band, and the mechanism behind the propagation is probably different too. What we can say is that twilight propagation is not always best along the terminator and there may not be any enhancement at all on some bands. Some books would have you believe that you can just tune up on 20m at sunset and work ZL 59+20dB every day – if you can I would like to hear about it!

I am currently doing some research into twilight propagation on many of the amateur bands, starting with 10m. The early results show that we can and do see enhancements from signals originating from areas experiencing sunrise/sunset.

The graph of the beacon SV3AQR on 28.182MHz is typical. This was produced using SpectrumLab software connected to the audio output from a Yaesu FT-920. With the AGC turned off, the vertical scale indicates signal strength while the horizontal scale shows time. You can quite clearly see a 10db increase in signal strength near the beacon's radio "dusk". The effect has been seen on other beacons, but like all ionospheric effects, it doesn't occur every day and is virtually impossible to forecast.




More monitoring work needs to be done before we can write the definitive guide to grey line and twilight propagation and this is where I need readers' help. If you have a PC with a soundcard, can run the SpectrumLab software (www.qsl.net/dl4yhf/) have a very stable receiver (the software needs stability in the order of a few Hz), and can leave your system monitoring for an hour or more at a time then I would like to hear from you. As part of the Propagation Studies Committee's work I plan to systematically look at twilight propagation on all the HF and LF bands using known, quantifiable signal sources such as beacons and broadcast stations. This is not a five-minute job though, but is essential if we are to finally clear up what has been a grey area of propagation research for a long time – every pun intended!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Useful Software
Beacon Time Wizard by Taborsoft (www.taborsoft.com)
GeoClock (www.geoclock.com)
Grayline 1.2 by PA3CGR

References:

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2. J. G. Lee, "An Introduction to Radio Wave Propagation", Babani BP293, 1991.
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4. Jacobs, Cohen and Rose, "The New Shortwave Propagation Handbook", CQ Communications, 1995.
5. John Devoldere, ON4UN, "Low-Band Dxing", ARRL, 1999.
6. Ken G4IGO, "E layer and Sporadic E - Two Modes of Propagation at 50MHz", UK SMG web site (www.uksmg.org).
7. E David, “HF Antenna Collection”, RSGB, 1991

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