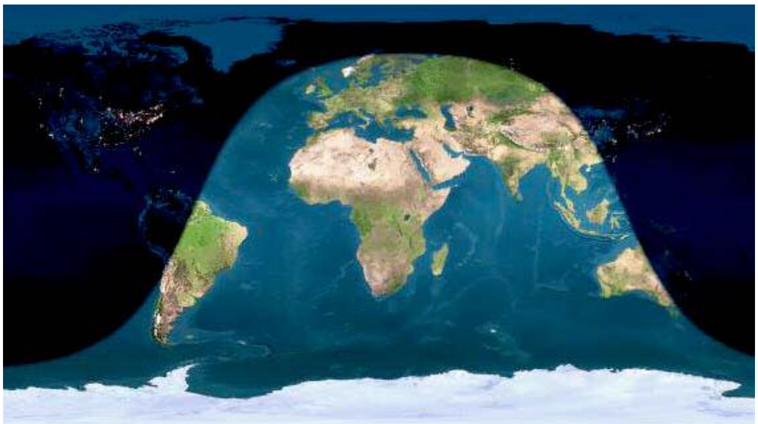
The Twilight Zone revisited – recent grey-line research (July 2005)

Steve Nichols G0KYA
7, Quebec Close
Cringleford
Norwich NR4 6XU
E-mail: steve@infotechcomms.co.uk
Tel: 01603 503076



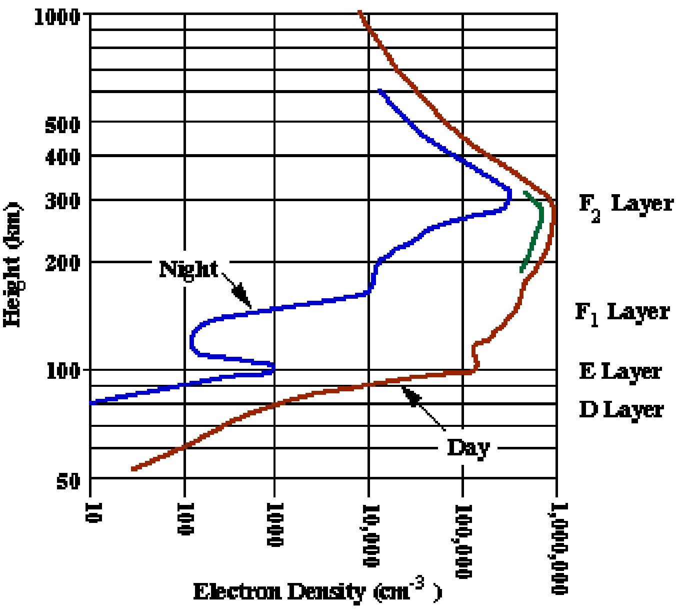
In the July 2002 edition of RadCom I outlined the mechanics, facts and probable fiction surrounding grey-line propagation – the term used for the highly efficient propagation that can occur between two stations experiencing mutual sunrise and/or sunset.

In that feature I said that although many books extol the virtues of grey-line, very few actually talk about its effectiveness on each of the common amateur bands. In other words, they talk generally about enhanced grey-line propagation occurring on a regular basis, but which bands are best? At what times of year? How big is the enhancement and how can we best utilise it?

Before we go any further we must recap on what grey-line is and why it is likely to be so useful.

Worldwide communication using the LF and HF bands is dependent on radiation coming from the sun. 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 reflective (more correctly, refractive) 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.

Another theory maintains that at sunrise/sunset the ionosphere can be "tilted" which can lead to ducting, reflective and directional characteristics.

We know that D layer absorption is inversely proportional to the square of the frequency. This means that in practice grey-line effects, if they exist, should be more pronounced at 160m than say 80m, and even less evident at 40m. By the time we get to 20m and above D layer absorption is not the major factor it is at LF – which is why you can't generally work DX on 160m during the day and yet 20m can be wide open.

The effects of grey-line are well documented with many examples of such propagation being logged on 160 and 80m over the years. At the 2004 RSGB HF convention delegates were shown an animation of 160m contacts into the USA from the 3B9C DXpedition to Rodrigues Island in March/April2004.

The animation clearly showed the band of 160m contacts crossing the USA as the sunrise terminator moved across the country – you couldn't ask for a more visual example of the importance of sunrise enhancements on top band! Whether the signals actually "followed" the grey-line or took another path is another story! It is also doubtfl if this pattern could be repeated night after night as conditions can vary wildly.

My 2002 article on grey-line was an introduction to the technique, but left a lot of unanswered questions. The ones that stuck in my mind were:

- How can grey-line be a sunrise/sunset effect (as seen on the earth) when the D and E/F layers involved in grey-line are actually illuminated much earlier/later than sunrise/sunset due to the layers' height above the earth?
- What degree of enhancement can we expect via grey-line?
- Is grey-line apparent on the higher bands such as 80m and 40m and if so how significant is it?

I also announced that a new Yahoo internet group was to be formed with the aim of undertaking some grey-line research. This is an update on that group's activities and what we found.

The first problem with conducting any form of grey-line tests is finding suitable stations. This proved to be very difficult indeed as the station must be a) on a suitable grey-line path to the UK, which changes on a weekly basis b) be willing to set up a suitable beacon transmission for a period of two weeks or so c) not vary their power and d) be "workable" in the first place.

This last statement sounds blindingly obvious, but while a Geoclock plot will show that there is a grey-line path at sunrise from G to ZL on 30 December, the propagation Gods will also tell you that life isn't so simple.

If you don't believe me take a look at the searchable DX Summit logs at http://oh2aq.kolumbus.com/dxs/. There wasn't a single G to ZL contact logged on 160m in December 2004.

To be fair there are numerous contacts with ZL2BSJ logged by a number of Western European stations on 80m that could be grey-line and one or two on 40m that could also qualify.

In fact. I did an analysis of every G to ZL contact for the month of September 2001 and it showed that statistically you were more likely to make contact with ZL on 17m or 20m than the low bands.

Purists would say that the DX cluster is not a fair way to judge propagation as it relies on every possible contact being logged correctly and at the exact time they occurred. I agree – which is why more scientific tests were required.

Also, just because you have worked a station at mutual sunrise/sunset doesn't necessarily indicate a great grey-line enhancement – you might have been able to work the station two hours before or after with the same signal strength. Much more data is needed.

The first hunt for suitable beacon stations started with shortwave broadcasters like Radio New Zealand and the BBC's relay station at Meyerton in South Africa. These turned out to be a disastrous choice as either a) the station couldn't be heard or b) it shared a frequency with other stations that meant you ended up logging the wrong one.

I had another brainwave after reading about the Globe Wireless Sitor data network. This seemed ideal with plenty of stations throughout the HF spectrum. A search on the internet will soon turn up a list of the stations and where they are.

Unfortunately, this wasn't terribly successful either as the stations apparently vary their power output according to conditions, have a strange signal that has a very variable bandwidth and do not transmit continuously.

Back to the drawing board!

But one solution soon arose thanks to the generous help of Mike Harris VP8NO at Port Stanley in the Falkland Islands. The Falklands experiences a mutual grey-line sunrise with the UK at the end of November and again in January.

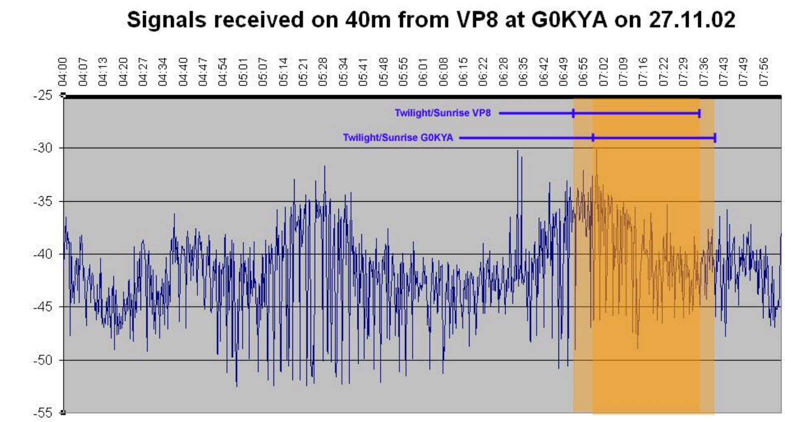
Using his Elecraft K2 radio with 12 watts output on 40m, Mike agreed to put out a QRSS (slow morse) signal up for us in November 2002. The keying software would send “VP8FI QRSS BEACON” with 10sec dots.

Reception stations in Euope, which included myself G0KYA, Johan Smet ON5EX in Belgium, Stan G3DSS, and Alan G4ZFQ, soon realised that the signal was going to be weak to hear and opted to use the SpectrumLab program to graphically “see” the signals. This also meant that relative dB signal strengths could be obtained (with the rig’s AGC turned off).

So started the hunt for these very weak CW signals from the South Atlantic. It is hard to describe, but effectively you are looking for a near invisible signal using a bandwidth of just a few Hertz and using a system that once set up has to be used every night for a week without being touched.

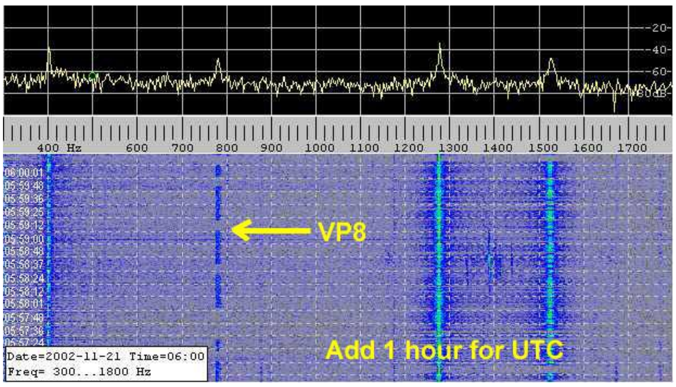
Although we were all on a steep learning curve the results were worth it and showed that the signals showed a fairly consistent peak every morning of around 6-10dB. There was sometimes a dip in the signal strength before the enhancement. The peak appeared to come around the start of the twilight period – that is around 30 minutes before mutual sunrise, dipping down to a minimum at sunrise.

Johan’s results were less conclusive and he thought that more tests were required, although the differing types of receive antennas might have accounted for the differences – I used a horizontal dipole and Johan used a vertical.



As November wore on, the mutual sunrise times for Norwich (my own QTH and Port Stanley) started to come closer together, and the enhancement was still there on my results. I do have to say that at these times the signal was often little stronger than it was in the night time period, showing that if you want to work DX on 40m you may do as well with a totally dark path between you and the DX station.

Or as Johan put it: “Why should I leave my cosy bed and rise at 7:30am work Mike on 40 if he's just as strong at midnight!“



What was also obvious was the variable nature of the propagation – no two nights were quite the same.

Mike was given the Christmas off and the experiment started again in January 2003 as the earth’s orbit around the sun brought a mutual sunrise to the stations once again. This time my results were not quite as clear, but still showed an enhancement at around 30mins before sunrise.

Another way of putting it is that the signal enhancement was in the civil twilight period, which runs to and from the point at which the sun is six degrees below the horizon and sunrise/sunset and where it is “bright enough to work outdoors”.

I had originally played with the Geoclock program settings to show the times when the D and E layers are actually illuminated. I thought that this would help identify grey-line openings as it more accurately depicted what is happening in the ionosphere. Unfortunately it didn't really help as there is a delay factor in the way the ionisation builds up and decays. It turns out that modelling the grey-line in terms of twilight and sunrise works just as well, if not better.

Conventional wisdom also says that the window for working grey-line is narrowest on 160 and increases in size as you increase frequency. It's also narrower at the Equator and wider near the poles.

I had another brainwave. If you think about it, at sunset and sunrise you have a grey-line path … all the way back to yourself. Could it be possible to send a signal right around the world and hear it a split second later at these times? Richard G3CWI offered to listen for such signals on 3.8MHz using his chirp sounding equipment, but no RTW signals were detected.

The next step of the research was to try again on 80m and Mike VP8NO graciously agreed to reconfigure his station for that band.

Tests on 3549kHz started in the middle of January 2003 and I soon realised that my magnetic loop antenna wasn't going to hear Mike's signal and a W3EDP end-fed was hastily erecting with its 85ft end secured at the top of a large oak tree in the back garden. Unfortunately, neither I nor any of the other stations were able to detect Mike's signals and we had to call it a day as the mutual sunrise period passed.

In May 2003 we were able to try the path again only this time with a mutual sunset between G and VP8 and tests started again on 40m. The trick here was to track Mike's signal during the night to ensure it was correctly identified and then watch for it to appear at sunset the next day – easier said than done.

The process wasn't helped by appalling HF conditions at the time with a geomagnetic Kp index of around 7 – storm conditions.

By 17 May Mike's signal was starting to appear in the UK around 20:30hrs, but it was weak and there was no enhancement at sunset or during twilight – in fact, it wasn't there at all.

Research started up again in October 2003 when we switched our attentions to the precision beacons of Murray ZL1BPU and Dave ZL3J on 80m. These were very stable transmissions of around 4W to a dipole coming from Timaru.

In mid-October, the UK has a mutual sunset grey-line into New Zealand. But if we had struggled to find a 12w signal from The Falklands how were we going to get on with an even weaker signal from the other side of the world?

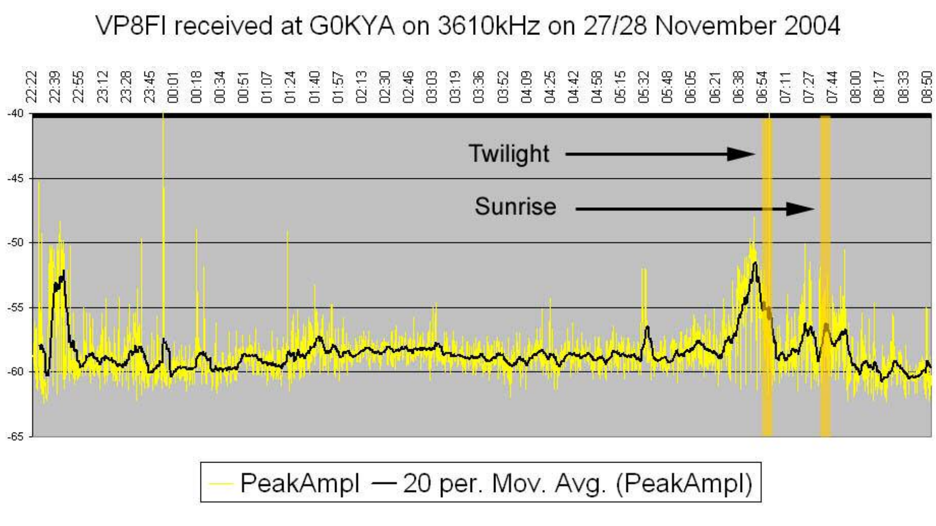
The answer was not very well and the group didn't have a single report of the beacon being copied. Murray did however get one report of incredibly week copy from DL6NL who was not in the grey-line group unfortunately.

Undeterred the group turned back to Mike VP8NO who agreed to commence 80m sunrise grey-line tests again in November 2004 on 3610kHz. For this round Mike used a 40W into an 80m inverted "L".

Soon the signals were being spotted during the night with strong traces. I started to see a peak at 07:31hrs – two minutes before sunrise in the UK and 11 minutes before sunrise in Port Stanley.

The group was joined by fellow RSGB Propagation Studies Committee members Chris Deacon G4IFX and Gwyn Williams G4IKH. Chris confirmed a peak at around 07:20 - 07:30hrs.

With mutual sunrise at 07:37hrs the plot also suggested that there was a strong signal at 06:50hrs, a dip and then an enhancement before a dip again at sunrise - in



other words a double peak.

Rather like the 40m tests, the enhancements were only of the order of 4-10db – nothing spectacular. To put that in perspective, that is around one to two S-points. The day-to-day results were again, variable.

There were also signs at times of the signals peaking at around 03:40hrs. In November, the Falklands has a much shorter night than we do. With sunrise at 07:30hrs and sunset at 23:50hrs that puts the mid point of darkness at 03:40hrs hours. This probably explains the peaking as D layer absorption fell to a night time minimum.

Results changed on a daily basis, probably as a result of changing band conditions. It is very easy to concentrate on the grey-line aspects of a particular path and forget the seasonal, ionospheric and geomagnetic factors, as Gwyn G4FKH – RadCom's HF propagation contributor – pointed out.

I mentioned in my previous article that you may be more likely to see good propagation on 40m/80m on paths that go INTO the dark zone, not along the terminator. This is echoed by John Devoldere's ON4UN book *"Low-Band DX-ing"* – an absolute bible for anyone venturing south of 14MHz!

Some quick tests by Alan G4ZFQ using a station in Nashville, TN on 3210kHz failed to show any sunrise enhancement at sunrise in January 2005, but this needs more study later this year. Alan did report that he saw a sunset enhancement on signals from Alice Springs on 2310KHz, but this is well before the sunrise in Alice Springs and may point to the perpendicular effect rather than signals travelling along the grey-line. As always, more work needs to be done this winter.

So what have we learned about grey-line since the project started?

1. It is a well-documented phenomenon on 160m – because of very heavy D layer absorption the only way that two stations on opposite sides of the world can contact each other on 160m is via grey-line when there are only a few minutes of mutual darkness.
2. On 40m we recorded a grey-line enhancement of an average 3-6dB about 30 minutes before the mutual sunrise on a path between the UK and Falkland Islands, but this was variable depending upon conditions.
3. On 80m we also recorded a grey-line enhancement of an average 3-10dB on the same path and at the same time, although there was some evidence of a double peak, the first occurring 30-40 minutes before sunrise and then another smaller one at sunrise.
4. No signals were seen on 80m at the mutual sunset and they didn't normally appear until the path had been in darkness for some time. This doesn't surprise me, but it would be interesting to try again at the bottom of the sunspot cycle.
5. Greyline propagation, like all other types of ionospheric propagation, is extremely variable. You cannot say with any certainty that you will be able to country "x" on any given night. All you can say is that there may be an increased probability of a path. Solar flux numbers and A/K indices do not tell the whole story either.

These findings are backed up by the experience of some Dxpeditions. In the book "*Contesting in Africa – Multi-Multi on the Equator*" Robert Ferguson, GM3YTS of the VooDoo Contest Group outlines several Top Band QSOs that took place 25-30 minutes before and after the other stations' sunrise/sunset. The 30-minute period is obviously a "sweet" spot for LF working, although this can reduce to mere minutes for some paths, depending on their location and time of year.

The VP8 test was obviously on a mutual sunrise/sunrise path. Further tests on mutual sunrise/sunset paths involving stations on other sides of the world still need looking at.

And what can you deduce for your own operating:

1. Don't rely just on grey-line to make contacts on 40m and 80m – you might stand a better chance of making a contact during the night if you have a dark path between you and the station you wish to work.
2. Typical enhancements while working stations along the terminator and experiencing a mutual sunrise might be of the order of a few dB on 40m and 80m – not the 20-30dB we might wish for!
3. Don't ignore conventional wisdom about HF propagation – For example, DX paths on 80m are more likely to be open during low sunspot years and in the winter, but look for a dark path.

4. The period around 30 minutes before your sunrise or 30 minutes before a DX station’s sunrise if east of you is well worth looking at, especially on Top band.
5. You can’t really expect to see true grey-line enhancements on 20m and above. You might see some twilight enhancements, but these are likely to be due to skip focussing and not depressed D layer absorption – look for signals coming out of the noise from stations to the east at their local sunset on 10m during times of high sunspot numbers for example.

Further work is obviously needed and will likely start again this autumn. We have learned that is actually very hard to find reliable amateur signals on 40m/80m that can be used for trials like these. One answer is to set up dedicated beacons. Another is to use broadcast stations, but you need to plan ahead, find out their operating schedules and ensure they don’t turn their beams half-way through the transmission as one potential target did! More data are obviously needed and even then it is unlikely whether the golden “rule book” of grey-line propagation can ever be written.

I would like to thank all the amateurs who have taken part in the grey-line studies so far. At times it has been frustrating to say the least. We are particularly indebted to Mike VP8NO who had to virtually give up amateur radio operating while his Elecraft K2 was pushed into service as a long-term beacon.

If you are interested in taking part in grey-line research go to http://uk.groups.yahoo.com/group/grey-line . I am also presenting these results at the 2005 RSGB HF Convention.

Steve Nichols G0KYA QTHR
steve@infotechcomms.co.uk
RSGB Propagation Studies Committee

Useful Software
GeoClock (www.geoclock.com)
Grayline 1.2 by PA3CGR
SpectrumLab - http://www.qsl.net/dl4yhf/spectra1.html

Useful References:
1. Dale Hoppe, K6UA et al, "They Grayline Method of Dxing," CQ, Sept 1975, P27.
2. J. G. Lee, "An Introduction to Radio Wave Propagation", Babani BP293, 1991.
3. Ian Poole, G3YWX, "Your Guide to Propagation," RSGB, 1998.
4. Jacobs, Cohen and Rose, "The New Shortwave Propagation Handbook", CQ Communications, 1995.
5. John Devoldere, ON4UN, "Low-Band Dxing", ARRL, 1999.
6. Roger Western, G3SXW et al, ”Contesting in Africa – Multi-Multi on the Equator”, Idiom Press.
7. Steve Nichols, G0KYA. “The Twilight Zone – just what is ‘grey-line ’ propagation”, RadCom July 2002 - available as PDF in the files section of the grey-line Yahoo group at http://uk.groups.yahoo.com/group/grey-line .

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