Sailing the Ionosphere

Fred Backer VK2JFB

1. A little help from the sun

One of the most fascinating aspect of HF amateur radio to me is that we can reach so far with so little technology and so much help from nature.

In this hi-tech age we are surrounded by sophisticated consumer equipment with which we can contact just about anybody on the globe by international phone, internet, satellite or what-not. And yes, we can do it cheaply and reliably. There is, however, a very special thrill to me in contacting fellow amateurs around the world using nothing but a modest 100 watts or so transmitter and a fairly simple antenna. All this thanks to the effect of solar radiation on the ionosphere which, given the right conditions, will bounce HF radio signals back to earth.

In this respect radio amateurs are somewhat akin to amateur sailors. They also could reach just about any destination in the world much faster by jumping on a jumbo jet. Instead they get their thrills by using a sailing vessel and rely on favourable winds and fair seas to get there eventually.

2. An ionospheric weather eye

Any ocean sailor should be a competent weather man. Similarly HF amateurs - DX amateurs in particular - should become competent at understanding ionospheric conditions and interpreting solar index figures.

There is a lot of propagation information about these days, especially on the internet. For a taste, have a look at the marvellous website:

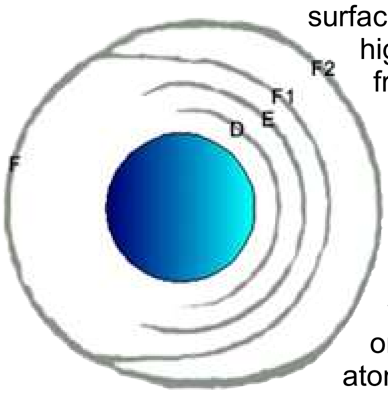
http://dx.qsl.net/propagation

Here you can find the latest index figures and a lot more, including some stunning pictures of the sun.

Most information is given in terms of solar index figures (SFI, A and K indices etc.). You've probably heard these figures bandied around on the bands many times. Let us explore what these terms mean so we can do something useful with them.

3. The good stuff

The ionosphere is a region of the atmosphere from about 60km to about 400km above the earth's surface. Ionisation in the extremely thin atmosphere here is caused by high-energy extreme ultraviolet radiation from the sun. When photons from this radiation hit an atmospheric gas atom they knock an electron free, the atom then changes into a positively charged ion and a negatively charged electron. The free electrons then interact with HFradio waves and refract them back towards earth.



Ionisation occurs only during daylight hours and is strongest in the middle of the day, the strength of the ultraviolet radiation varies with the solar activity. The rate at which ionisation occurs depends on the intensity of the ultraviolet radiation and and on the density of atoms in the atmosphere which, in turn depends on the altitude.

Recombination is the opposite of ionisation: ions and free electrons recombine to form normal atoms. Recombination occurs continuously 24 hours a day. The speed at which recombination occurs depends on the density of the atmosphere. The thinner the atmosphere - i.e. the higher from earth - the slower the speed of recombination.

4. Layers of goodies

Ionisation doesn't take place continuously throughout the ionosphere but in distinct layers.

The depth to which the the ultraviolet radiation penetrates the atmosphere depends on its frequency. Lower frequency ultraviolet waves penetrate the atmosphere the least, they produce ionised layers at the highest altitude.

Working from the top, we find the following layers:

- The F Layer
The F layer exists from about 130 to 400 km above earth. During daylight hours there are actually two separate layers: F1 (about 130 – 210km) and F2 (about 250 – 400km). Radiation is intense at these altitudes and the ionisation is quite high. The atmosphere is very rare, recombination therefore occurs very slowly. Therefore the F layer is always present to a variable degree and this makes it the most useful layer for HF radio communication.

The free electrons in the ionosphere interact easier with lower frequency HF signals than with higher ones. This makes long distance communication on the 1.8MHz (160m), 3.5MHz (80m) and 7 MHz (40m) possible at night when ionisation is low. A higher degree of ionisation is required to refract signals in the 10MHz (30m) and 14MHz (20m) bands. This is why these bands work best during daytime and evening hours. Still higher degrees of ionisation are required to refract signals in the 21MHz (15m) and 28MHz (10m) bands. These bands therefore work during daytime, ionisation levels are not often strong enough to refract signals in the 50MHz (6m) bands.

- The E Layer
This layer occurs from about 90 to 130km above earth. Because the atmosphere is denser here recombination occurs fairly rapidly after sunset. During the day the E layer refracts HF signals down to the 7MHz band back to earth, providing “short skip” communication ranging up to about 2 500km. Higher frequencies pass through this layer with some absorption. The higher the frequency the less the absorption.[1)]

- The D layer
This layer occurs from about 50 to 90km. Ionisation rates are low here, even during the day, and recombination happens very rapidly after sunset. Ionisation is not strong enough to refract HF radio waves back to earth. The D layer’s main effect is to absorb lower frequency HF signals, particularly in the 1.8MHz and 3.5MHz bands. These bands will be typically dead during the day as a result of D layer absorption.

5. The MUF factor
HF radio amateurs tend to be preoccupied with the “maximum useable frequency” (MUF). Why? The maximum useable frequency (MUF) is the highest frequency which the F layer will refract back to earth. It makes sense to work with frequencies close to the MUF because the higher the working frequency, the less the absorption in the D and E layers. Typically the optimum working frequency will be about 85% of the F2 layer’s MUF.

Intense ionisation of the F2 layer is therefore a bonus for HF communication. As mentioned above, the higher the degree of ionisation, the higher the MUF, and the higher the frequency, the less absorption in the D and E layers.

Ionisation is caused by extreme ultraviolet radiation of the sun. This radiation originates in the hot regions that overlie sunspot areas. Hence the more sunspots there are, the better the ionisation.

Solar activity is not constant: it follows an 11 year cycle. The most recent sunspot maximum occurred in 2002

6. Measuring the good stuff
We just saw that the more sunspots, the better the ionisation. Counting the sunspots on the visible solar surface is therefore a useful exercise. Indeed, the dx.qsl site gives current and recent NOAA (American) sunspot numbers, updated daily.

It has also been found that the solar flux radiated at a frequency of 2.8 GHz correlates closely with sunspots and the intensity of ionisation. The observatory at Penticton in B.C., Canada measures the energy at this frequency and puts out the result in the form of a "Solar Flux Index" (SFI) which you will find on the dx.qsl site and will often hear discussed on air. Once again, the higher the SFI the better the propagation and the higher the maximum usable frequency. In broad terms:

SFI	expected band conditions
< 70	poor above 7 MHz
70-90	poor to fair up to 14 MHz
90-120	fair up to 21 MHz
120-150	fair to good up to 30 MHz
150-200	excellent up to 30 MHz

7. The bad stuff

Whilst increasing sunspot activity does improve F-layer refraction it also increases the likelyhood of solar flares. Solar flares are bad news for amateurs because they can disrupt radio communication in various ways:

-Sudden Ionospheric Disturbances (SID)

These are caused by extreme UV and X-ray radiation emitted by large flares. This results in unusually high ionisation of the D layer causing greatly increased absorption of HF signals. SIDs can reach the earth in about 8 minutes and wipe out the bands immediately. They may take minutes to hours to recover.

-Ionospheric Storms

Very big flares not only produce enormous amounts of radiation - including high energy x-rays, they also eject enormous clouds of plasma mixed with magnetic fields, known as coronal mass ejections (CMEs). These contain billions of tons of highly energetic protons and electrons. CMEs can blast off in any direction. Luckily most of them are directed away from earth.

If directed towards earth the effect of these plasma clouds and x-ray flux can be brutally disruptive. The one first detected on 19th October 2003, for instance, not only wiped out HF radio communication for days but also affected more than 20 satellites and spacecraft, temporarily knocked out the power grid in Sweden and prompted the US Federal Aviation Administration to issue a first-ever radiation exposure warning for air travellers.

CMEs make the F layer expand and diffuse, and - again - greatly increase ionisation of the D layer. They can also produce an event called a geomagnetic storm, a disturbance of the earth's magnetic field causing the field to fluctuate over unusually wide limits. CMEs may take 1 or 2 days to reach earth, their effects can last from a few hours to several days.

8. Measuring the bad stuff

X-ray flux levels are a measure of the likelyhood of SIDs. Monitoring these is the task of two satellites named GOES-8 and GOES-10. The GOES-8 measurements are used to issue *solar alerts* when the X-ray flux levels exceed certain levels.
If the bands suddenly seem to go dead it is a good idead to go to the http://dx.qsl.net/propagation website and check the X-ray flux chart. Flares are considered "significant" when flux levels rise above the "M" level.

Keeping a watch on geomagnetic stability is done by a worldwide network of magnetometers. These are used to generate a number called the Planetary K index. Every 24 hours the K index is summarized in a number called the Planetary A index. In broad terms the index figures mean:

A	K	Geomagnetic Field
0 - 3	0	quiet
4 - 6	1	quiet to unsettled
7 - 14	2	unsettled
15 - 47	3 - 4	active
48 - 79	5	minor storm
80 - 131	6	major storm
> 131	>6	severy to very severe storm

9. Putting it all together

Now we know what the commonly used factors SFI, A and K stand for. Does this mean we now know all about the ionosphere? Not by a long shot.

Chaos theory has taught us that complex processes have so many variables that their future development, whilst by no means random, is beyond our ability to pin down and predict. Some examples: our terrestrial weather, turbulence and the stock market. The processes taking place on the sun are typically chaotic, and all we know are some broad generalities. We know that solar activity generally goes up and in an 11 year cycle, just as we know that seasons follow one another on earth. However, we'll never know just when the next big solar flare will be, just as we 'll never be able to predict whether it'll rain 17 days from now or where the stock market will be this time next year.

And isn't this exciting? It means that there is plenty of adventure left in this world. You will discover new things about ionospheric propagation every time you switch on your HF rig. So go ahead, explore . . . . enjoy!

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[1)] **Sporadic E**. This is a thin –only a few kilometres thick- layer that sporadically occurs in the E region. It can have a very high degree of ionisation and thus a very high critical frequency, refracting HF and sometimes even VHF signals very efficiently. Near the equator sporadic E is usually present around midday. In temperate regions it occurs more often in summer, again around midday.