Understanding LF Propagation (Part 2)

Looking at the effect of the Sun on LF propagation

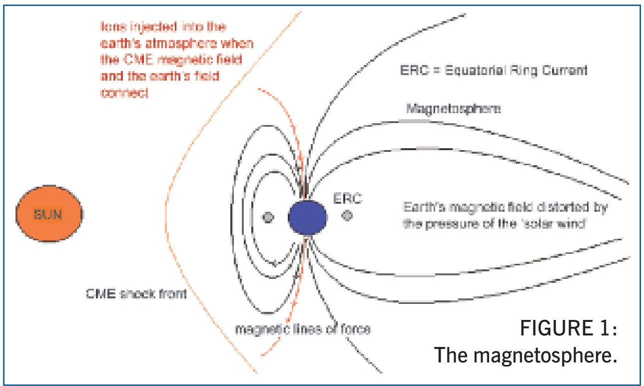

FIGURE 1: The magnetosphere.

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.