D Region

When a sky wave leaves the Earth's surface and travels upwards, the first region of interest that it reaches in the ionosphere is called the D layer or D region.

It is present at altitudes between about 60 and 90 kilometres and the radiation within it is only present during the day to an extent that affects radio waves noticeably. It is sustained by the radiation from the Sun and levels of ionisation fall rapidly at dusk when the source of radiation is removed.

The D layer is chiefly generated by the action of a form of radiation known as Lyman radiation which has a wavelength of 1215 Angstroms and ionises nitric oxide gas present in the atmosphere. Hard X-Rays also contribute to the ionisation, especially towards the peak of the solar cycle.

The D layer or D region mainly has the affect of absorbing or attenuating radio communications signals particularly in the LF and MF portions of the radio spectrum, its affect reduces with increasing frequency.

At night the fall in the level of ionisation means that it has little effect on most radio communications signals although there is still sufficient for it to refract VLF signals.

This region attenuates the signals as they pass through. The level of attenuation depends on the frequency. Low frequencies are attenuated more than higher ones. In fact it is found that the attenuation varies as the inverse square of the frequency, i.e. doubling the frequency reduces the level of attenuation by a factor of four. This means that low frequency signals are often prevented from reaching the higher regions, except at night when the region disappears.

$$\text{attenuation} = \frac{k}{f^2}$$

attenuation=��2

Where:
k = constant
f = frequency of operation (Hz)

The D region attenuates signals because the radio signals cause the free electrons in the region to vibrate. As they vibrate the electrons collide with molecules, and at each collision there is a small loss of energy. With countless millions of electrons vibrating, the amount of energy loss becomes noticeable and manifests itself as a reduction in the overall signal level. The amount of signal loss is dependent upon a number of factors.

- ***Number of gas molecules present:*** One factor is the number of gas molecules that are present. The greater the number of gas molecules, the higher the number of collisions and hence the higher the attenuation. At the altitude where the D region exists, there is still a relatively high level of gas molecules and hence there is a sufficiently large number of ion-molecule collisions to absorb a large amount of the energy under many circumstances.
- ***Level of ionisation:*** The level of ionisation is also very important. The higher the level of ionisation, the greater the number of electrons that vibrate and collide with molecules.
- ***Signal frequency:*** The third main factor is the frequency of the signal. As the frequency increases, the wavelength of the vibration shortens, and the number of collisions between the free electrons and gas molecules decreases. As a result signals lower in the radio frequency spectrum are attenuated far more than those which are higher in frequency. Even so high frequency signals still suffer some reduction in signal strength.

In practical terms it is found that the level of attenuation is sufficient to prevent signals in the MF portion of the spectrum from reaching the higher layers. However at night when the ionisation in the D region falls away, they are able to reach the higher layers and signals from further away may be heard. This is evident on the medium wave band and higher frequencies where the signals are absorbed by the D region.

Signals at higher frequencies that are "reflected" by higher regions int he ionosphere will also be attenuated to some extent, although this will be dependent upon the frequency. It is worth noting that for each reflection the signal will need to pass through the D region twice, being attenuated each time. Therefore signals that are reflected multiple times can suffer significant degrees of attenuation.

E Region

The E region or E layer is above the D region. It exists at altitudes between about 100 and 125 kilometres. Instead of attenuating radio communications signals this layer chiefly refracts them, often to a degree where they are returned to earth. As such they appear to have been reflected by this layer. However this layer still acts as an attenuator to a certain degree.

At the altitude where the E layer or E region exists, the air density is very much less than it is for the D region. This means that when the free electrons are excited by radio signals and vibrate, far fewer collisions occur. As a result the way in which the E layer or E region acts is somewhat different. The electrons are again set in motion by the radio signal, but they tend to re-radiate it. As the signal is travelling in an area where the density of electrons is increasing, the further it progresses into the region, the signal is refracted away from the area of higher electron density. In the case of HF signals, this refraction is often sufficient to bend them back to earth. In effect it appears that the region has "reflected" the signal.

The tendency for this "reflection" is dependent upon the frequency and the angle of incidence. As the frequency increases, it is found that the amount of refraction decreases until a frequency is reached where the signals pass through the region and on to the next. Eventually a point is reached where the signal passes through the E layer on to the next layer above it.

Like the D region, the level of ionisation falls relatively quickly after dark as the electrons and ions re-combine and it virtually disappears at night. However the residual night time ionisation in the lower part of the E region causes some attenuation of signals in the lower portions of the HF part of the radio communications spectrum.

The ionisation in this region results from a number of types of radiation. Soft X-Rays produce much of the ionisation, although extreme ultra-violet (EUV) rays (very short wavelength ultra-violet light) also contribute. Broadly the radiation that produces ionisation in this region has wavelengths between about 10 and 100 Angstroms. The degree to which all of the constituents contribute depends upon the state of the Sun and the latitude at which the observations are made.

F Region

The most important region in the ionosphere for long distance HF radio communications is the F region. During the daytime when radiation is being received from the Sun, it often splits into two: the lower one being the F1 region and the higher one, the F2 region. Of these the F1 region is more of an inflection point in the electron density curve (seen above) and it generally only exists in the summer.

Typically the F1 layer is found at around an altitude of 300 kilometres with the F2 layer above it at around 400 kilometres. The combined F layer may then be centred around 250 to 300 kilometres. The altitude of the all the layers in the ionosphere layers varies considerably and the F layer varies the most. As a result the figures given should only be taken as a rough guide. Being the highest of the ionospheric regions it is greatly affected by the state of the Sun as well as other factors including the time of day, the year and so forth.

The F layer acts as a "reflector" of signals in the HF portion of the radio spectrum enabling world wide radio communications to be established. It is the main region associated with HF signal propagation.

The action of the F layer on radio signals is the same as it is for the E layer, although with the air density being less, there are fewer collisions and less energy is lost. As a result, signals being reflected by the F layer, and in particular the F2 later are subject to low levels of attenuation. As a result, even low power signals can be heard at great distances.

Like the D and E layers the level of ionisation of the F region varies over the course of the day, falling at night as the radiation from the Sun disappears. However the level of ionisation remains much higher. The density of the gases is much lower and as a result the recombination of the ions and electrons takes place more slowly, at about a quarter of the rate that it occurs in the E region. As a result of this it still has an affect on radio signals at night being able to return many to Earth, although it has a reduced effect in some aspects.

The F region is at the highest region in the ionosphere and as such it experiences the most solar radiation. Much of the ionisation results from ultra-violet light in the middle of the spectrum as well as those portions of the spectrum with very short wavelengths. Typically the radiation that causes the ionisation is between the wavelengths of 100 and 1000 Angstroms, although extreme ultra-violet light is responsible for some ionisation in the lower areas of the F region.

Ionospheric variations

It has already been seen that the time of day causes some very significant changes in the state of the ionosphere as the level of ionisation falls at night. However there are many other factors that have an affect on the ionosphere as well. The main one is the Sun itself, but other factors include the season, and the position on the globe.

- ***Seasonal changes:*** In just the same way that the amount of heat places on the Earth receive vary with the seasons, so does the amount of radiation received by the ionosphere. This results from the fact that in summer the radiation received spreads over a smaller area as the Earth's surface is closer to being at right angles to the direction of the radiation. In winter, the Earth's surface is at a greater angle and the radiation has to spread over a larger area. As a result the ionosphere receives less radiation in winter than summer.
  The D and E regions respond as expected with lower levels of ionisation in winter than summer, and the F_1 region also follows a similar pattern. However for the F_2 region there are other influencing factors and it responds in a different way.
  For the F_2 region, the heating effect of the Sun plays a crucial role in the way it responds. The temperature during the winter is much less than in the summer as a result of the heat from the Sun is spread over a larger area because the sun is lower in the sky. In summer the gas temperature rises in the F2 region so the activity in the air rises and a greater number of molecules rise higher up into the atmosphere. In winter as the temperature falls, so the heavier molecules fall, leaving the lighter atoms to rise to the top.
  This means that in winter there is a higher proportion of atoms at the higher altitude of the F2 region. Atoms are easier to ionise than gas molecules, and so the number of suitable targets for the radiation to ionise also rises. As a result the levels of daytime ionisation are actually higher in winter than they are in the summer. The overall effect is that the peak daytime levels of ionisation rise higher in winter than summer, but they fall away to a lower level as the Sun's radiation is present for a smaller proportion of the time.
- ***Geographical variations:*** The levels of ionisation are also affected by the position on the globe. There are naturally variations arising from the latitude where Polar Regions that receive less radiation and the equatorial regions enjoy much higher levels of radiation. Broadly this results in higher levels of ionisation for the D, E and F_1 regions in equatorial areas than towards the poles.
  The F_2 region has a number of other factors that affect its level of ionisation including the Earth's magnetic field and it also receives ionisation from other sources. As a result of these it is found that the levels of ionisation are higher around Asia and Australia than they are over the western hemisphere, including Africa, Europe, and North America.

Summary

The ionosphere is a continually changing area of the atmosphere. Extending from altitudes of around 60 kilometres to more than 400 kilometres it contains ions and free electrons. The free electrons affect the ways in which radio waves propagate in this region and they have a significant effect on HF radio communications.

The ionosphere can be categorised into a number of regions corresponding to peaks in the electron density. These regions are named the D, E, and F regions. In view of the fact that the radiation from the Sun is absorbed as it penetrates the atmosphere, different forms of radiation give rise to the ionisation in the different regions as outlined in the summary table below: