NORTOWN AMATEUR RADIO CLUB • TORONTO •

Sir Edward Appleton

The Discovery of the Properties of the Ionosphere

The Ionosphere

A collection of ionized particles and electrons in the uppermost portion of the earth's atmosphere which is formed by the interaction of the solar wind with the very thin air particles that have escaped the earth's gravity.

These ions are responsible for the reflection or bending of radio waves occurring between certain critical frequencies with these critical frequencies varying with the degree of ionization.

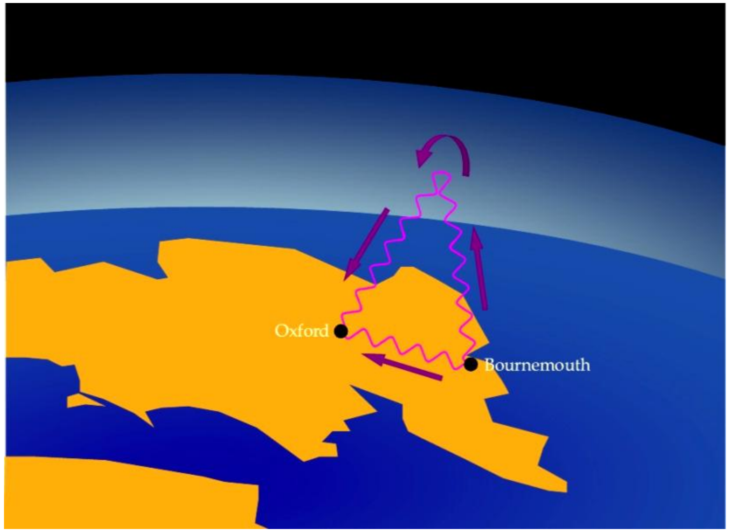

SIR EDWARD
VICTOR APPLETON
(PHYSICIST)
G.B.E., K.C.B., M.A., D.Sc., Sc.D.
LL.D., Litt.D., F.R.C.S.E., F.R.S.E.
F.R.S.
NOBEL LAUREATE
1892-1965
DISCOVERED THE APPLETON LAYER
1926
PRINCIPAL & VICE-CHANCELLOR
UNIVERSITY OF EDINBURGH
1948-1965
AND HIS BELOVED WIFE
HELEN LENNIE
DIED 29TH OCTOBER 1983

Edward Victor Appleton was born on 6 September 1892 in Bradford, England.
He studied natural sciences at Cambridge University and during World War One served in the Royal Engineers. After the war, he returned to Cambridge to conduct research on atmospheric physics mainly using radio waves.

In 1920 he was appointed assistant demonstrator in experimental physics at the Cavendish Laboratory.
In 1924, Appleton became professor of physics at London University, returning to Cambridge in 1936 as professor of natural philosophy.

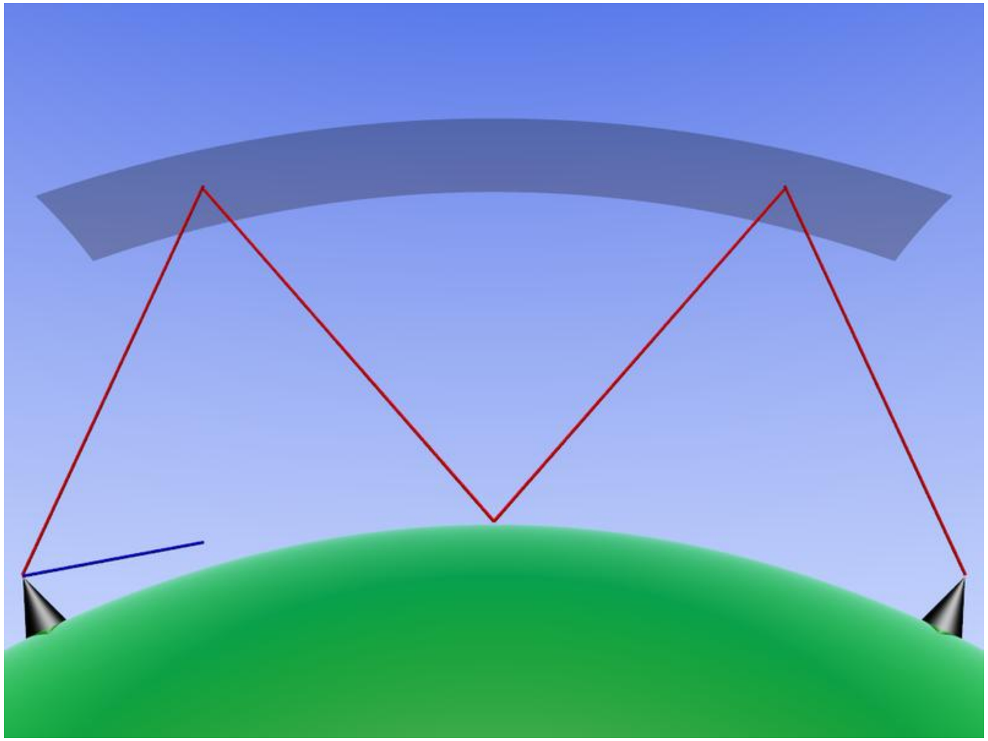
In his work, Appleton had observed that the strength of the radio signal from a transmitter on a frequency such as the medium wave band and over a path of a hundred miles or so was constant during the day but that it varied during the night. This led to him to believe that it was possible that two radio signals were being received. One was traveling along the ground, and another was reflected by a layer in the upper atmosphere. The fading or variation in strength of the overall radio signal received resulted from the interference pattern

To prove his theory, in 1924 Appleton used the British Broadcasting Corporation (BBC) radio broadcast transmitter at Bournemouth, England. This transmitted a signal towards the upper reaches of the atmosphere. He received the radio signals near Cambridge, proving they were being reflected. By making a periodic change to the frequency of the broadcast radio signal he was able to measure the time taken for the signals to travel to the layers in the upper atmosphere and back. In this way he was able to calculate that the height of the reflecting layer was 60 miles above the ground.

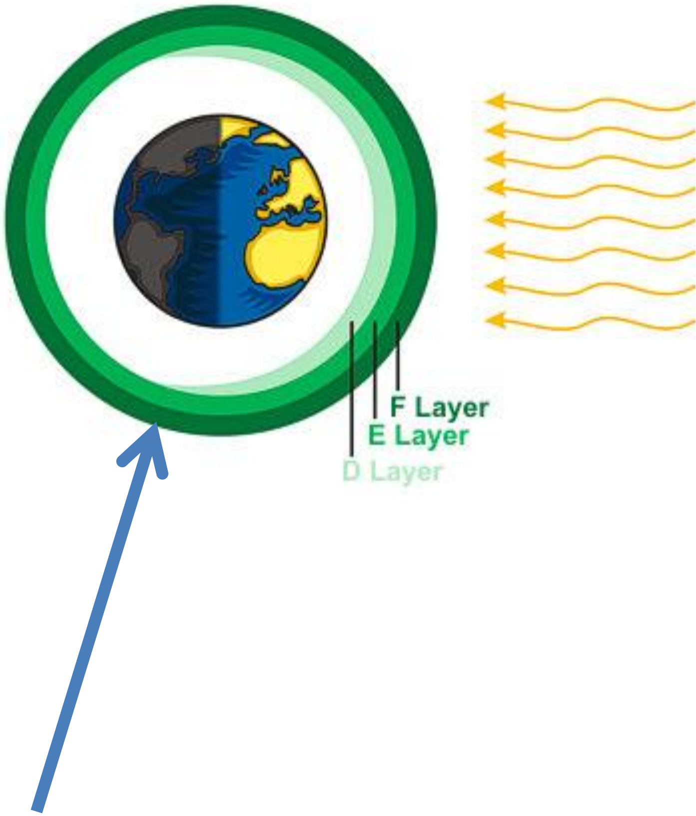


In 1924 Appleton was able to demonstrate the existence of the electrified reflecting layer in the upper atmosphere.
The existence of a reflecting layer had first been postulated around forty years earlier by Balfour Stewart, who suggested that the small daily changes detected in the earth's magnetic field might be due to electric currents in the upper atmosphere. Marconi had then demonstrated that, as radio signals could be sent from Cornwall to Newfoundland, something must cause them to 'bend' around the earth. In 1902 Oliver Heaviside and A.E.Kennelly had independently postulated the theory of a conducting layer of the atmosphere: the

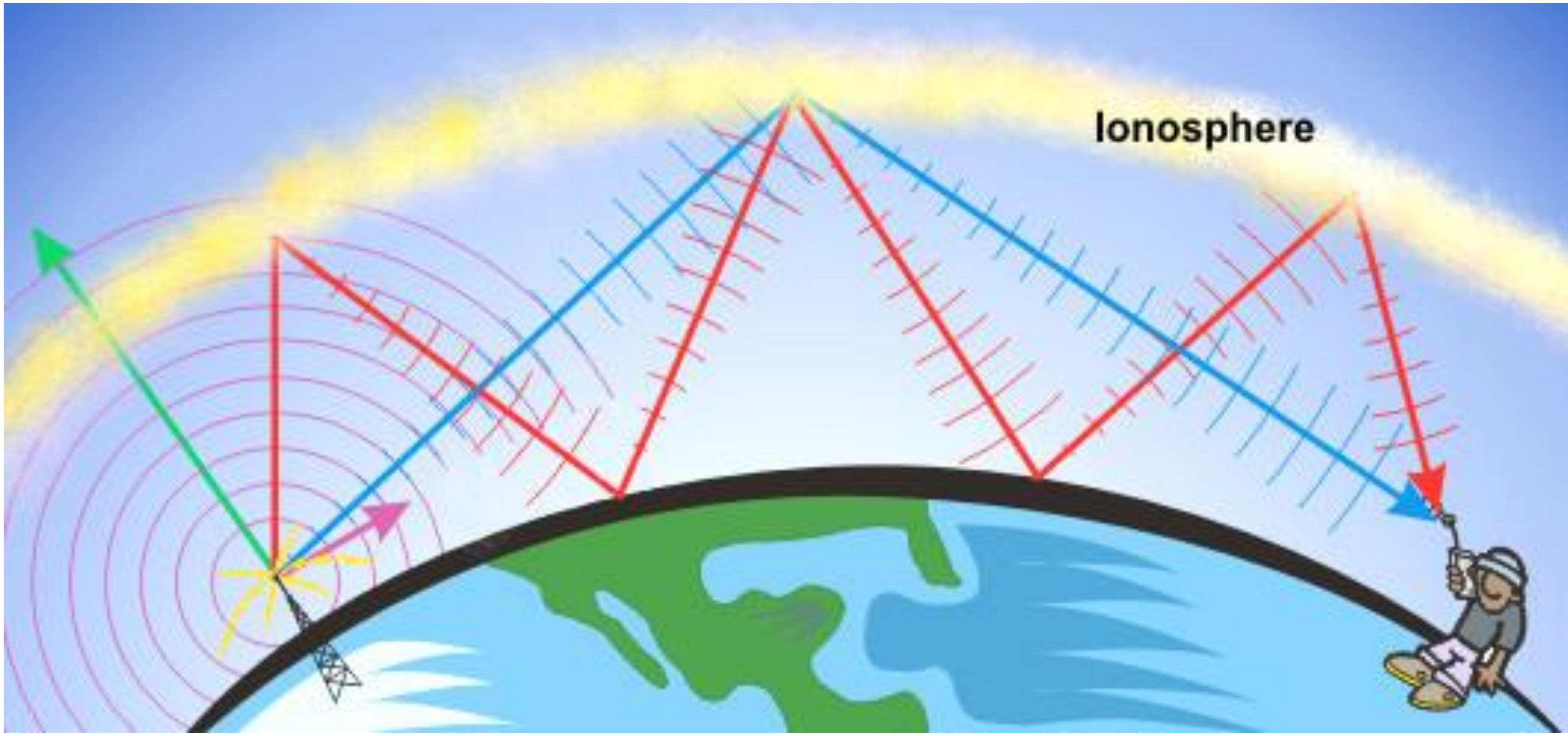
Kennelly-Heaviside Layer.



Using a BBC transmitter, Appleton conducted experiments to prove that this layer existed and its position and height above the ground were determined. However, these experiments produced more questions than answers. In 1926, Appleton discovered another layer 250-350 km high which reflected back shorter wavelengths in daytime as well as at night, and that they were reflected back with greater strength than the Heaviside layer. Appleton realised that this was the layer responsible for reflecting short wave radio round the world - 'the Appleton layer' - that now enables communication with Australia and America.



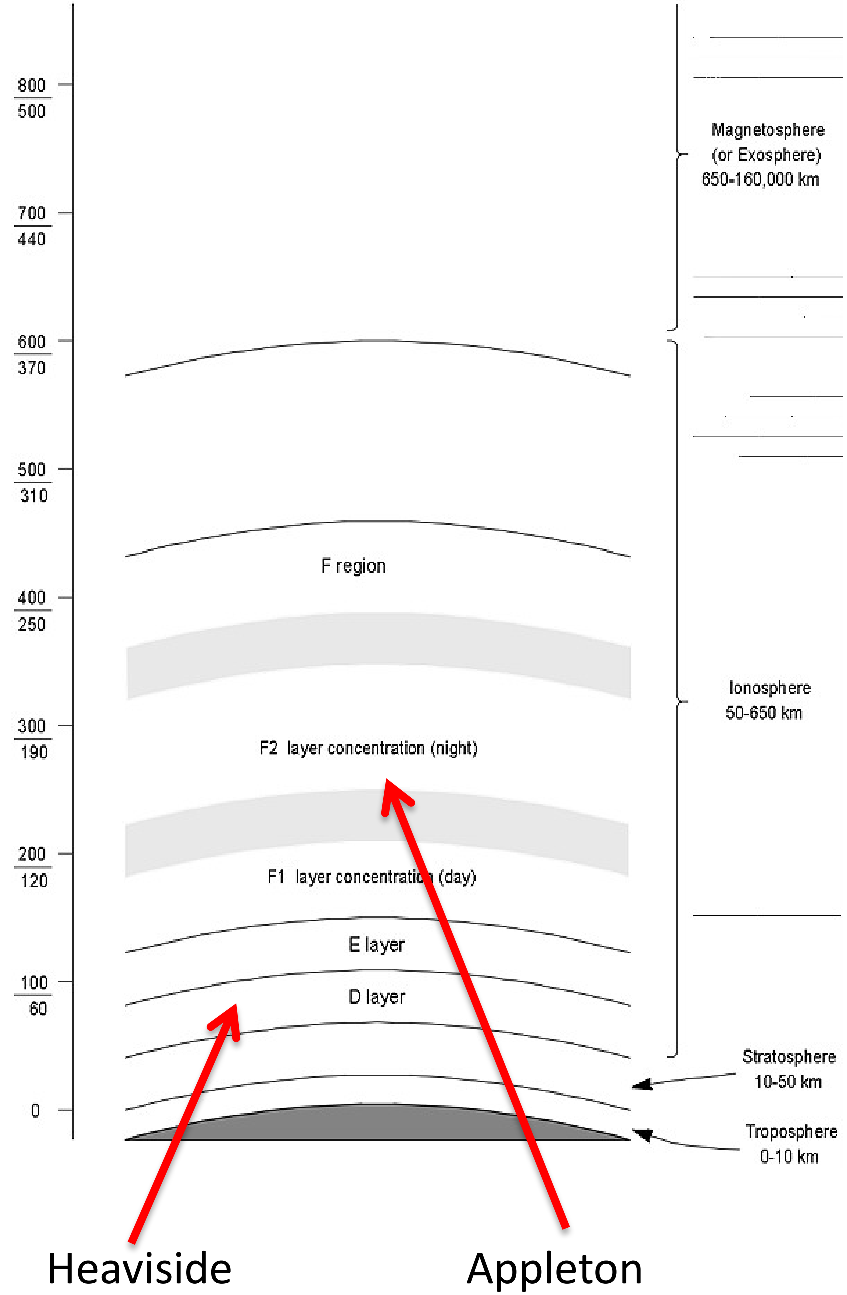
The Appleton Layer



Further experiments which led to the possibility of round-the-world broadcasting were carried out and in 1926 he discovered a further atmospheric layer 150 miles above ground, higher than the Heaviside Layer and electrically stronger. This layer, named the Appleton Layer after him, reflects short waves round the earth.

Edward Appleton confirmed the existence of the Kennelly-Heaviside layer during the early 1920s and used the letter E on his diagrams to designate the electric waves that were apparently reflected from it. In 1924, Appleton discovered two additional layers in the ionosphere, as he and Robert Watson-Watt named this atmospheric region, and noted them with the letters D and F. Appleton was reluctant to alter this arbitrary nomenclature for fear of discovering yet other layers, so it has stuck to the present day.

The basic physics of ionospheric propagation was largely worked out by the 1920s, yet both amateur and professional experimenters made further discoveries through the 1930s and 1940s. Sporadic E, aurora, meteor scatter and several types of field-aligned scattering were among additional ionospheric phenomena that required explanation.



The lowest is D-layer at altitudes ranging from 50 to 90 km. High frequencies (3-30 MHz) penetrate this layer, while low frequency (LF: 30-300 kHz) or medium waves are absorbed by this layer. To some extent LF and Very Low Frequency (VLF: 3 to 30 kHz) are reflected during daytime. It slightly scatter and absorbs HF. This layer subsists only during daytime

The E-layer (Heaviside) extends from an altitude of 100 km. Though sunlight is an important factor for its existence, after sunset also it exists for some time. This layer is responsible for evening and early night time propagation of medium waves (low frequency) up to a distance of about 250 km. Propagation of lower short wave frequencies, e.g. 2 MHz , up to distance of 2000 km at daylight time is due to this layer. It has little effect at night.

F_1 layer exists at an altitude of 200 km during daytime and its characteristics are very similar to E-layer which emerges into F_2 layer at night.

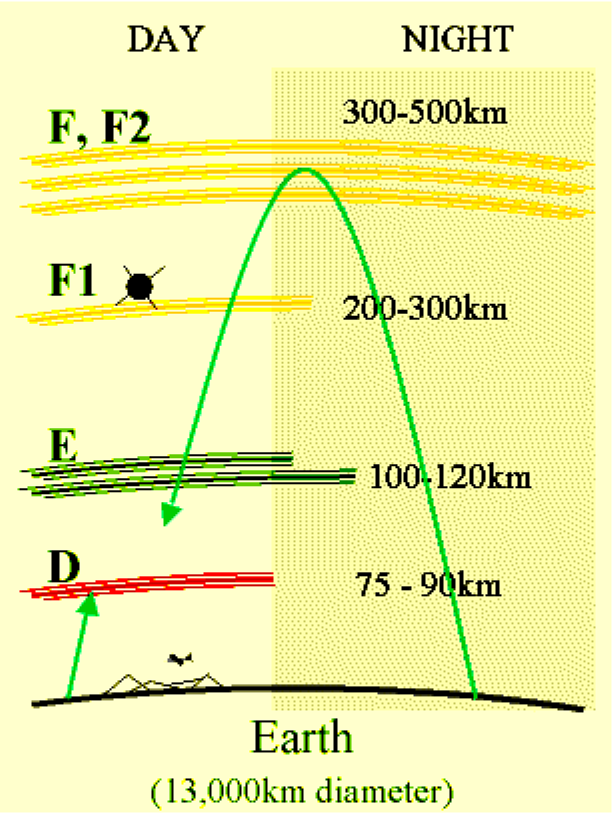
F_2 layer is the most important layer which exists at altitudes ranging from 250 to 400 km and HF long distance propagation round the clock is due to this layer. The behaviour of this layer is influenced by the time of the day, by season and by sunspot activity. F_2 layer was formerly known as Appleton layer. This layer has a high ionization gradient. This layer exists both in the daytime and nighttime.

Since at such an altitude air density is extremely low, the free ions and electrons (due to the action of ultraviolet radiation from the Sun) can not recombine readily and so can store energy received from the Sun for many hours; that is the reason the refractive property of this layer changes only to a negligible extent during day and night.

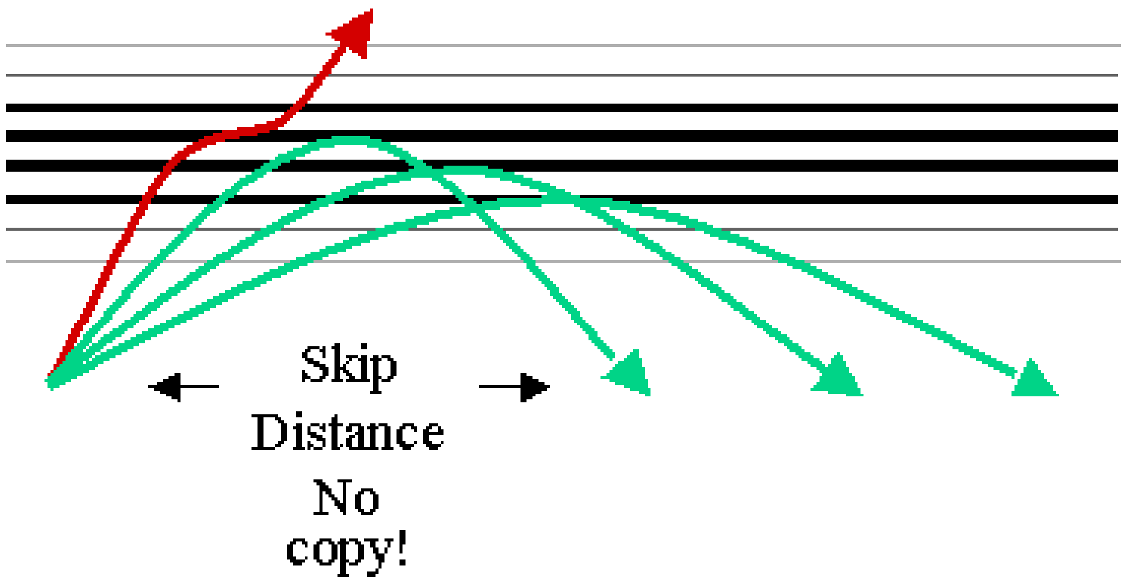
The path which the short wave signal follows through the F_2 layer is in reality a curved one. Degree of the curve depends on the angle of incidence of the wave, ionization gradient of the layer and frequency of the signal.

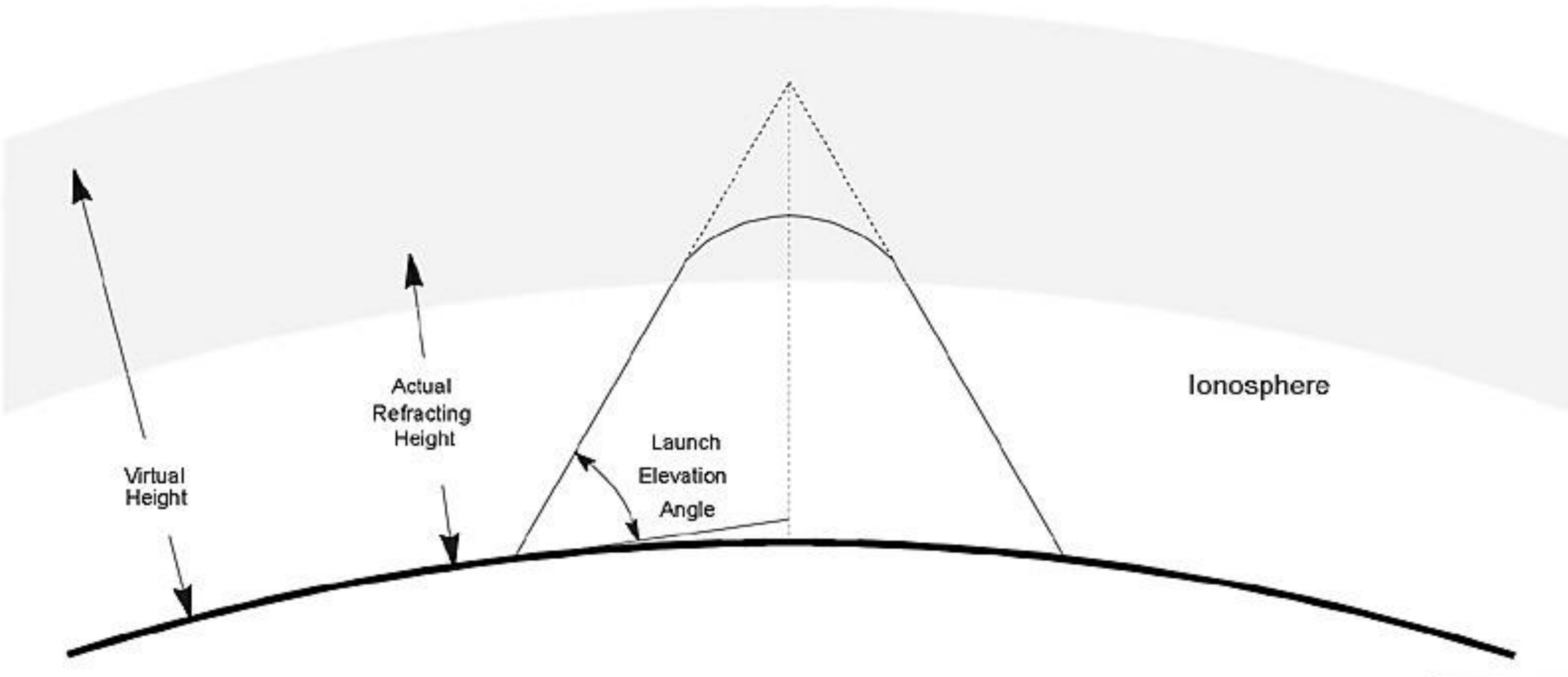
F1 and F2 Layers

The F1 layer is the lower sector of the F layer and exists from about 150 to 220 km above the surface of the Earth and only during daylight hours. It is composed of a mixture of molecular ions O_2^+ and NO^+, and atomic ions O^+. Above the F1 region, atomic oxygen becomes the dominant constituent because lighter particles tend to occupy higher altitudes above the turbopause (at ~100 km). This atomic oxygen provides the O^+ atomic ions that make up the F2 layer. The F1 layer has approximately 5×10^5 e/cm^3 (free electrons per cubic centimeter) at noontime and minimum sunspot activity, and increases to roughly 2×10^6 e/cm^3 during maximum sunspot activity. The density falls off to below 10^4 e/cm^3 at night. The F_1 layer merges into the F_2 layer at night.
Though fairly regular in its characteristics, it is not observable everywhere or on all days. The principal reflecting layer during the summer for paths of 2,000 to 3,500 km is the F_1 layer.



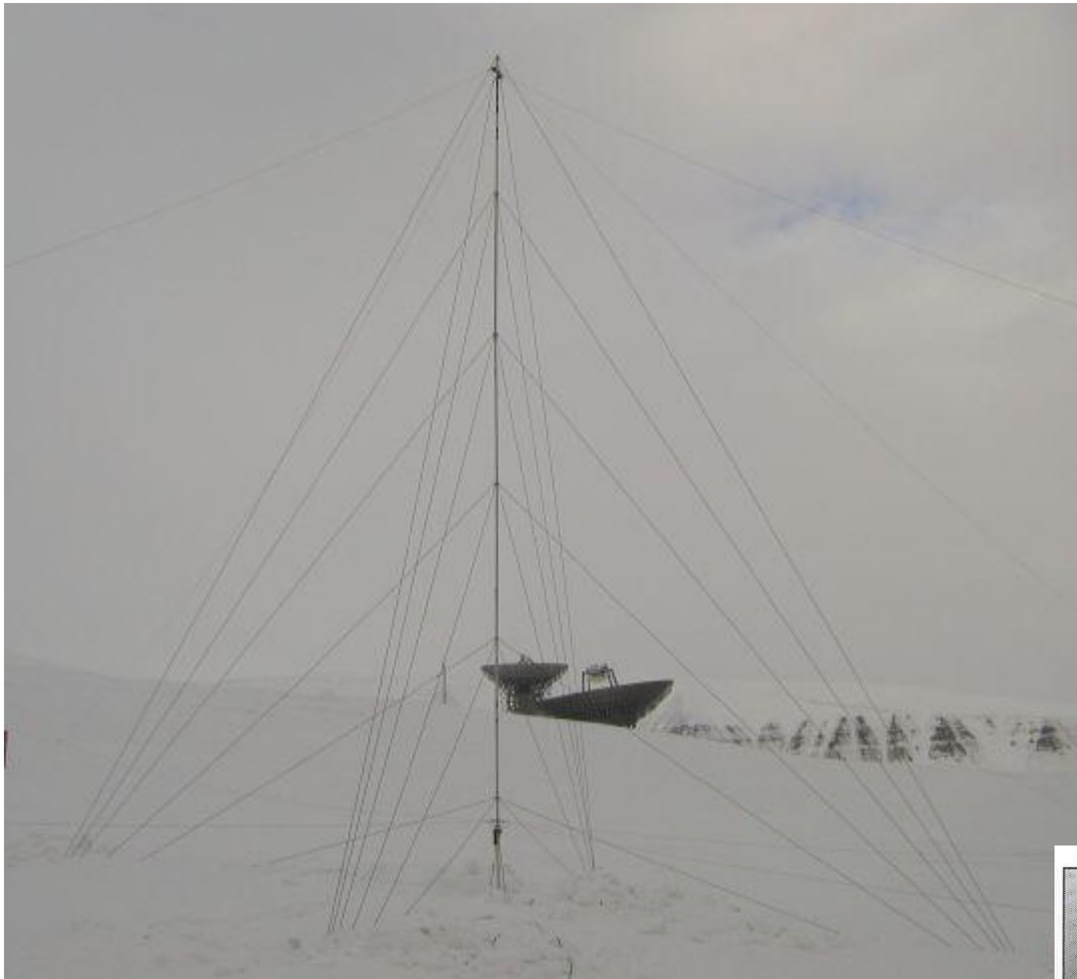
The F_2 layer exists from about 220 to 800 km above the surface of the Earth. The F_2 layer is the principal reflecting layer for HF communications during both day and night. The horizon-limited distance for one-hop F_2 propagation is usually around 4,000 km. The F_2 layer has about 10^6 e/cm^3. However, variations are usually large, irregular, and particularly pronounced during magnetic storms. The F layer behaviour is dominated by the complex thermospheric winds.

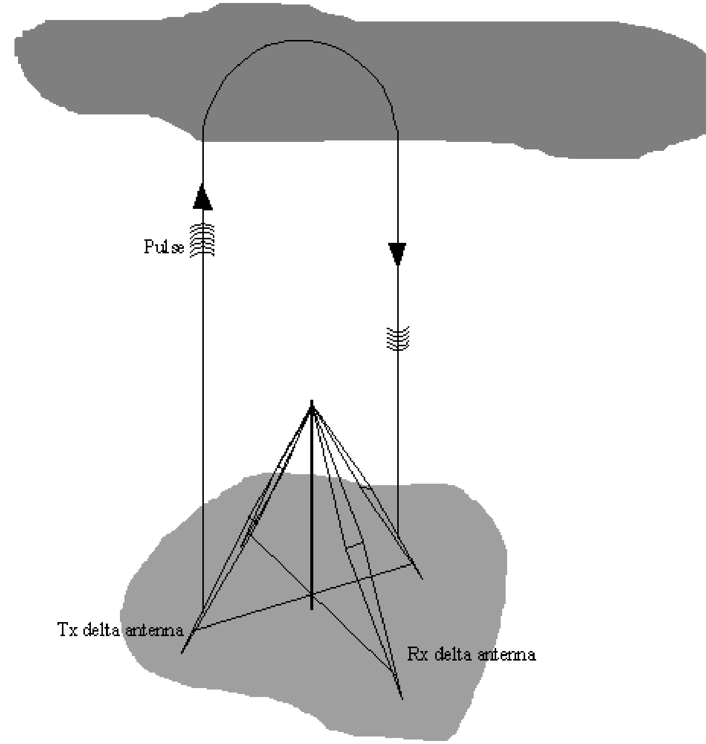




Gradual refraction in the ionosphere allows radio signals to be propagated long distances. It is often convenient to imagine the process as a reflection with an imaginary reflection point at some virtual height above the actual refracting region.

The virtual height of an ionospheric layer is the equivalent altitude of a reflection that would produce the same effect as the actual refraction. The virtual height of any ionospheric layer can be determined using an ionospheric sounder, or ionosonde, a sort of vertically oriented radar. The ionosonde sends pulses that sweep over a wide frequency range, generally from 2 MHz to 6 MHz or higher, straight up into the ionosphere. The frequencies of any echoes are recorded against time and then plotted as distance on an ionogram. The highest frequency that returns echoes at vertical incidence is known as the vertical incidence or critical frequency. The critical frequency is almost totally a function of ion density. The higher the ionization at a particular altitude, the higher becomes the critical frequency. Physicists are more apt to call this the plasma frequency, because technically gases in the ionosphere are in a plasma, or partially ionized state. F-layer critical frequencies commonly range from about 1 MHz to as high as 15 MHz.





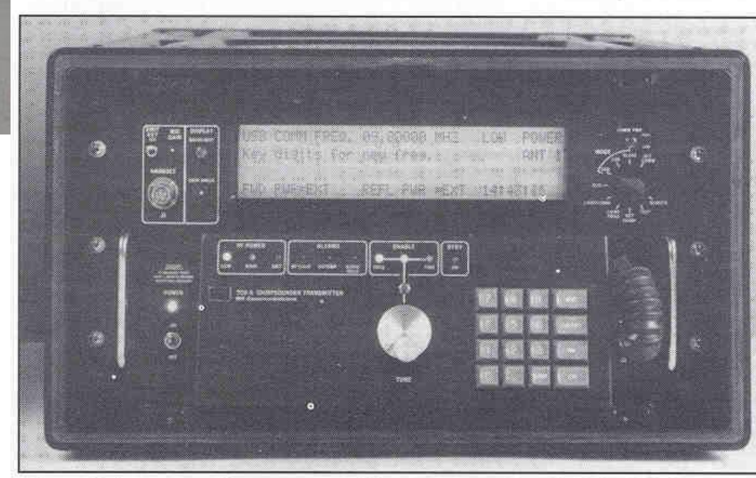
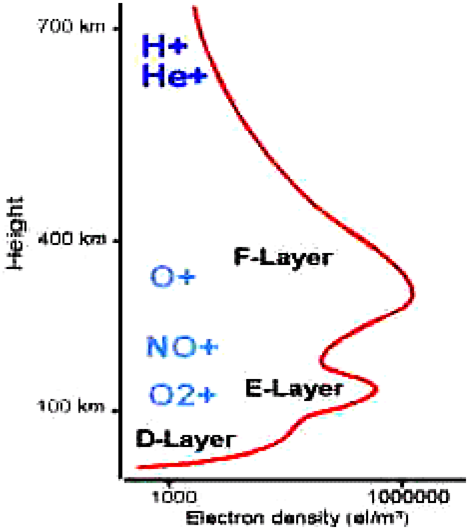


Figure 2. An ionosonde transmitter. Photo courtesy Gerald Oicles/BR Communications, Sunnyvale, CA

The Earth's ionosphere is that part of the high altitude atmosphere, starting at about 90 km, which is strongly ionised. Electrons are stripped off the gas molecules, resulting in ions, by the ultra-violet radiation (1 -10 x 10^{-8} m) of the Sun as well as incident X-rays. The mix of positively and negatively charged ions, negative electrons and neutral gas is called a plasma, which is the most common state of the universe. The most abundant gas molecules are molecular oxygen (O_2) and nitrogen (N_2) below 200 km, atomic oxygen (O) above 200 km, and hydrogen (H) and Helium (He) above 600 km altitude. Although less than 1% of the upper atmosphere becomes ionised the charged particles make the gas electrically conducting, which completely changes its characteristics. The ionosphere can carry electrical currents as well as reflect, deflect and scatter radio waves. It received its name from Sir Robert Watson-Watt in only 1926, although Carl Friedrich Gauss had already speculated about its existence in 1839.

Figure 1: A typical electron density altitude profile, the most important ions, and the various ionospheric layers.

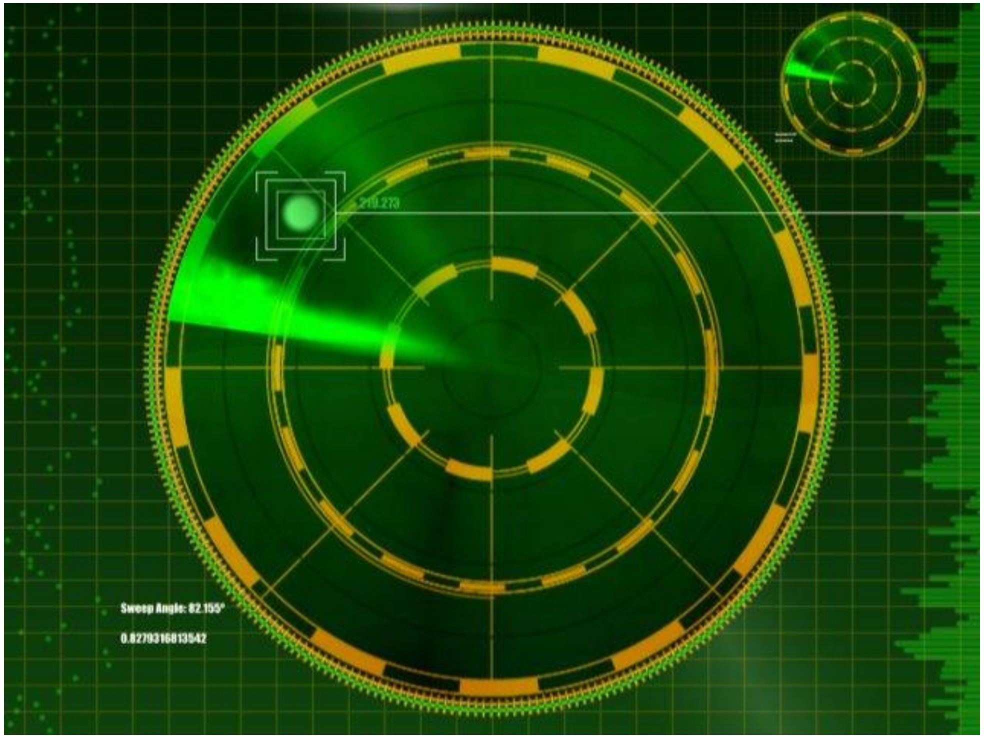


On 29 June 1927, an eclipse provided an opportunity to study the effect of sun on the ionosphere. As soon as the rays of light were cut off, the height of the reflecting layer increased, suggesting that the sun's radiation was required to create the ions in the atmosphere that reflected the radio waves. The resulting Appleton-Hartree equation showed that the charges that actually caused the reflection consist of free electrons.

Appleton went on to discover that the moon as well as the sun affected the height of the layers, and further showed that the layer was strongly influenced by the earth's magnetic field and that the polar blackouts were caused by magnetic storms.

When hostilities broke out in 1939 Appleton was appointed Secretary of the Department of Scientific and Industrial Research - the senior British Government post concerned with physical science.

Working on Appleton's findings, Robert Watson-Watt and his colleagues developed radar, a crucial weapon in the war. Appleton was knighted in 1941.



Sir Robert Watson-Watt has stated that, but for Appleton's scientific work, radar would have come too late to have been of decisive use in the Battle of Britain.

In 1947, the year in which he received the Nobel Prize for Physics, he was also awarded the highest civilian decoration of the United States - the Medal of Merit - and was made an Officer of the French Legion of Honour. He was also awarded the Norwegian Cross of Freedom for his war work. Appleton's work has been recognized by India, Norway and Denmark, and in 1948 he was appointed by the Pope to the Pontificial Academy of Science. He received the Albert Medal of the Royal Society of Arts, in 1950, for outstanding services to science and industrial research and was elected President of the British Association for the Advancement of Science for the Liverpoo1 meeting in 1953. He has been Chairman of the British National Committee for Radio-Telegraphy and Honorary President of the International Scientific Radio Union.

In 1947 Appleton was awarded the Nobel Prize for Physics and, two years later, moved to the University of Edinburgh to become principal and vice-chancellor, a position he held for the rest of his life.

He died on 21 April 1965.

His Favourite Saying:

"I rate enthusiasm even above professional skill."