Chapter 1 : Propagation of Long Wavelength Disturbances in a Plasma : Richard L Liboff :

The problem of uncovering the modes of excitation of a plasma in a uniform magnetic field has been extensively studied in the literature. For the most part these endeavors were constructed about a macroscopic, phenomenological theory. In addition, one'is able to find many problems which yield solu.

Sixty years later, Guglielmo Marconi received the first trans-Atlantic radio signal on December 12, , in St. The message received was three dits, the Morse code for the letter S. To reach Newfoundland the signal would have to bounce off the ionosphere twice. Jack Belrose has contested this, however, based on theoretical and experimental work. In , the U. Congress imposed the Radio Act of on amateur radio operators , limiting their operations to frequencies above 1. The government thought those frequencies were useless. This led to the discovery of HF radio propagation via the ionosphere in In , Scottish physicist Robert Watson-Watt introduced the term ionosphere in a letter published only in in Nature: In the early s, test transmissions of Radio Luxembourg inadvertently provided evidence of the first radio modification of the ionosphere; HAARP ran a series of experiments in using the eponymous Luxembourg Effect. Appleton was awarded a Nobel Prize in for his confirmation in of the existence of the ionosphere. Lloyd Berkner first measured the height and density of the ionosphere. This permitted the first complete theory of short-wave radio propagation. Ratcliffe researched the topic of radio propagation of very long radio waves in the ionosphere. Vitaly Ginzburg has developed a theory of electromagnetic wave propagation in plasmas such as the ionosphere. In , the Canadian satellite Alouette 1 was launched to study the ionosphere. On July 26, the first operational geosynchronous satellite Syncom 2 was launched. The rotation of the plane of polarization directly measures TEC along the path. Australian geophysicist Elizabeth Essex-Cohen from onwards was using this technique to monitor the atmosphere above Australia and Antarctica. It exists primarily due to ultraviolet radiation from the Sun. Above that is the stratosphere , followed by the mesosphere. In the stratosphere incoming solar radiation creates the ozone layer. The number of these free electrons is sufficient to affect radio propagation. This portion of the atmosphere is partially ionized and contains a plasma which is referred to as the ionosphere. Ultraviolet UV , X-ray and shorter wavelengths of solar radiation are ionizing, since photons at these frequencies contain sufficient energy to dislodge an electron from a neutral gas atom or molecule upon absorption. In this process the light electron obtains a high velocity so that the temperature of the created electronic gas is much higher of the order of thousand K than the one of ions and neutrals. The reverse process to ionization is recombination , in which a free electron is "captured" by a positive ion. Recombination occurs spontaneously, and causes the emission of a photon carrying away the energy produced upon recombination. As gas density increases at lower altitudes, the recombination process prevails, since the gas molecules and ions are closer together. The balance between these two processes determines the quantity of ionization present. Ionization depends primarily on the Sun and its activity. The amount of ionization in the ionosphere varies greatly with the amount of radiation received from the Sun. Thus there is a diurnal time of day effect and a seasonal effect. The local winter hemisphere is tipped away from the Sun, thus there is less received solar radiation. The activity of the Sun is associated with the sunspot cycle , with more radiation occurring with more sunspots. Radiation received also varies with geographical location polar, auroral zones, mid-latitudes , and equatorial regions. There are also mechanisms that disturb the ionosphere and decrease the ionization. There are disturbances such as solar flares and the associated release of charged particles into the solar wind which reaches the Earth and interacts with its geomagnetic field. The ionospheric layers[edit] Ionospheric layers At night the F layer is the only layer of significant ionization present, while the ionization in the E and D layers is extremely low. During the day, the D and E layers become much more heavily ionized, as does the F layer, which develops an additional, weaker region of ionisation known as the F1 layer. The F2 layer persists by day and night and is the main region responsible for the refraction and reflection of radio waves. Ionization here is due to Lyman series -alpha hydrogen radiation at a wavelength of

Recombination rates are high in the D layer, so there are many more neutral air molecules than ions. Medium frequency MF and lower high frequency HF radio waves are significantly attenuated within the D layer, as the passing radio waves cause electrons to move, which then collide with the neutral molecules, giving up their energy. Lower frequencies experience greater absorption because they move the electrons farther, leading to greater chance of collisions. A common example of the D layer in action is the disappearance of distant AM broadcast band stations in the daytime. During solar proton events , ionization can reach unusually high levels in the D-region over high and polar latitudes. Such very rare events are known as Polar Cap Absorption or PCA events, because the increased ionization significantly enhances the absorption of radio signals passing through the region. Such events typically last less than 24 to 48 hours. The vertical structure of the E layer is primarily determined by the competing effects of ionization and recombination. At night the E layer weakens because the primary source of ionization is no longer present. After sunset an increase in the height of the E layer maximum increases the range to which radio waves can travel by reflection from the layer. This region is also known as the Kennellyâ€"Heaviside layer or simply the Heaviside layer. Its existence was predicted in independently and almost simultaneously by the American electrical engineer Arthur Edwin Kennelly â€" and the British physicist Oliver Heaviside â€" However, it was not until that its existence was detected by Edward V. Appleton and Miles Barnett. Sporadic-E events may last for just a few minutes to several hours. Sporadic E propagation makes VHF-operating radio amateurs very excited, as propagation paths that are generally unreachable can open up. There are multiple causes of sporadic-E that are still being pursued by researchers. This propagation occurs most frequently during the summer months when high signal levels may be reached. It is the layer with the highest electron density, which implies signals penetrating this layer will escape into space. The F layer consists of one layer F2 at night, but during the day, a secondary peak labelled F1 often forms in the electron density profile. Because the F2 layer remains by day and night, it is responsible for most skywave propagation of radio waves and long distances high frequency HF, or shortwave radio communications. Above the F layer, the number of oxygen ions decreases and lighter ions such as hydrogen and helium become dominant. This region above the F layer peak and below the plasmasphere is called the topside ionosphere. Ionospheric model[edit] An ionospheric model is a mathematical description of the ionosphere as a function of location, altitude, day of year, phase of the sunspot cycle and geomagnetic activity. Geophysically, the state of the ionospheric plasma may be described by four parameters: Radio propagation depends uniquely on electron density. Models are usually expressed as computer programs. The model may be based on basic physics of the interactions of the ions and electrons with the neutral atmosphere and sunlight, or it may be a statistical description based on a large number of observations or a combination of physics and observations. One of the most widely used models is the International Reference Ionosphere IRI , [10] which is based on data and specifies the four parameters just mentioned. IRI is updated yearly. IRI is more accurate in describing the variation of the electron density from bottom of the ionosphere to the altitude of maximum density than in describing the total electron content TEC. Since this model is "International Standard" for the terrestrial ionosphere standard TS Persistent anomalies to the idealized model[edit] Ionograms allow deducing, via computation, the true shape of the different layers. Winter anomaly[edit] At mid-latitudes, the F2 layer daytime ion production is higher in the summer, as expected, since the Sun shines more directly on the Earth. However, there are seasonal changes in the molecular-to-atomic ratio of the neutral atmosphere that cause the summer ion loss rate to be even higher. The result is that the increase in the summertime loss overwhelms the increase in summertime production, and total F2 ionization is actually lower in the local summer months. This effect is known as the winter anomaly. The anomaly is always present in the northern hemisphere, but is usually absent in the southern hemisphere during periods of low solar activity. Equatorial anomaly[edit] Electric currents created in sunward ionosphere. It is the occurrence of a trough in the ionization in the F2 layer at the equator and crests at about 17 degrees in magnetic latitude. Solar heating and tidal oscillations in the lower ionosphere move plasma up and across the magnetic field lines. This phenomenon is known as the equatorial fountain. Resulting from this current is an electrostatic field directed

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westâ€”east dawnâ€”dusk in the equatorial day side of the ionosphere. Ephemeral ionospheric perturbations[edit] X-rays: As soon as the X-rays end, the sudden ionospheric disturbance SID or radio black-out ends as the electrons in the D-region recombine rapidly and signal strengths return to normal. These particles can hit the Earth within 15 minutes to 2 hours of the solar flare. The protons spiral around and down the magnetic field lines of the Earth and penetrate into the atmosphere near the magnetic poles increasing the ionization of the D and E layers. Coronal mass ejections can also release energetic protons that enhance D-region absorption in the polar regions. In the Northern and Southern pole regions of the Earth aurorae will be observable in the sky. Lightning[edit] Lightning can cause ionospheric perturbations in the D-region in one of two ways. The first is through VLF very low frequency radio waves launched into the magnetosphere. These so-called "whistler" mode waves can interact with radiation belt particles and cause them to precipitate onto the ionosphere, adding ionization to the D-region. These disturbances are called "lightning-induced electron precipitation " LEP events. Wilson proposed a mechanism by which electrical discharge from lightning storms could propagate upwards from clouds to the ionosphere. Around the same time, Robert Watson-Watt, working at the Radio Research Station in Slough, UK, suggested that the ionospheric sporadic E layer Es appeared to be enhanced as a result of lightning but that more work was needed. Johnson, working at the Rutherford Appleton Laboratory in Oxfordshire, UK, demonstrated that the Es layer was indeed enhanced as a result of lightning activity.

Chapter 2 : Ionosphere - Wikipedia

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