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Research Paper

Propagation and Ionization of Electromagnetic Waves in Plasma Due to HF Waves Caused by HAARP

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ABSTRACT

The ionosphere plays a unique role in the Earth's environment. The ionosphere is an example of naturally occurring plasma formed by solar photo-ionization and soft x-ray radiation. The most important feature of the ionosphere is to reflect the radio waves up to 30 MHz. Especially, the propagation of these radio waves on the HF band makes the necessary to know the features and the characteristics of the ionospheric plasma media. Because, when the radio waves reflect in this media, they are reflected and refracted depending on their frequency, the frequency of the electrons in the plasma and the refractive index of the media and thus, they are absorbed and reflected by the media. HAARP (High Frequency Active Auroral Research program) is an investigative project aimed to realize, simulation and controlling the ionosphere processes that can violate application of connective and monitoring systems and has installation to lead to spearhead experiment in basis of phenomenon related to ionosphere layer that this experiments are used to analysis the basic characteristic of ionosphere and also current potential evaluation to extend ionosphere technologies used in telecommunication and monitoring aims. This project sends and enters the 3.6 MW signal in the frequency range of 2.8-10 MHz in HF band to atmosphere layer. Frequency range of 3-30 MHz that is equivalent to 10-100 meter length of wave is called HF. Changes from HF to ULF and ionization due to HAARP project in the ionosphere have been investigated in this paper.

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I. Introduction

The understanding of the existence of a conductive layer in the upper atmosphere has been emerged in a century ago. The idea of a conductive layer affected by the variations of the magnetic field in the atmosphere has been put forward by the Gauss in 1839 and Kelvin in 1860[1]. Newfoundland Radio signal from Cornwall to be issued by Marconi in 1901, at the first experimental evidence of the existence of ionospheric, respectively. In 1902, Kennely and Heaviside indicated that the waves are reflected from a conductive layer on the upper parts of the atmosphere. In 1902, Marconi stated that changing the conditions of night and day spread. In 1918, high-frequency band has been used by aircraft and ships. HF band in the 1920s has increased the importance of expansion. Then, put forward the theory of reflective conductive region, has been shown by experiments made by Appleton and Barnet. The data from the 1930s started to get clearer about the ionosphere and the radio research station, Cavendish Laboratory, the National Braun of Standards, the various agencies such as the Carnegie Institution began to deal with the issue. In the second half of the 20th century, the work of the HF electromagnetic wave has been studied by divided into three as the full wave theory, geometrical optics and conductivity. Despite initiation of widespread use of satellite-Earth communication systems, the use of HF radio spectrum for civilian and military purposes is increasing. Collapse of communication systems, especially in case of emergency situations, communication is vital in this band [1]. In the ionosphere, a balance between photo-ionization and various loss mechanisms gives rise to an equilibrium density of free electrons and ions with a horizontal stratified structure. The density of these electrons is a function of the height above the earth's surface and is dramatically affected by the effects of sunrise and sunset, especially at the lower altitudes. Also, the many parameters in the ionosphere are the function of the electron density [2]. The ionosphere is conventionally divided into the D, E, and F-regions. The D-region lies between 60 and 95 km, the E-region between 95 and 150 km, and the Foreign lies above 150 km. During daylight, it is possible to distinguish two separate layers within the F-region, the F1 (lower) and the F2 (upper) layers [3]. During nighttime, these two layers combine into one single layer. The combined effect of gravitationally decreasing densities of neutral atoms and molecules and increasing intensity of ionizing solar ultraviolet radiation with increasing altitudes, gives a maximum plasma density during daytime in the F-region at a few hundred kilometers altitude.

During daytime, the ratio of charged particles to neutral particles concentration can vary from 10^{-8} at 100 km to 10^{-4} at 300 Km and 10^{-1} at 1000 km altitude. The main property of F-region consists of the free electrons. As known, the permittivity and permeability parameters are related to electric and magnetic susceptibilities of material, on account of medium and moreover, the speed of electromagnetic wave and the characteristic impedance depend on any medium and the refractive index of medium gives detail information about any medium. Because of all of these reasons, ε is a measure of refractive index, reflection, volume and wave polarization of electromagnetic, impedance of medium.

Propagation of electromagnetic waves in the atmosphere is influenced by the spatial distribution of the refractive index of the ionosphere [4-10]. The theory of ionospheric conductivity was developed by many scientists and is now quite well understood, though refinements are still made from time to time. The ionosphere carries electric currents because winds and electric fields drive ions and electrons. The direction of the drift is at right angles to the geomagnetic field [5]. Furthermore, electrical conductivity is an important central concept in space science, because it determines how driving forces, such as electric fields and thermosphere winds, couple to plasma motions and the resulting electric currents. The tensor of electrical conductivity finds application in all the areas of ionospheric electrodynamics and at all the latitudes [6]. On the other hand, the most important parameter determining the behavior of any medium is the dielectric constant, which at any frequency determines the refractive index, the form of wave in medium, to be polarized, the state of wave energy and the propagation of wave. The behavior of electromagnetic waves emitted from within the ionospheric plasma and the analytical solutions are necessary to understand the characteristics of the environment will be defined. Problems in plasma physics at the conductivity, dielectric constants and refractive index will be defined according to the media parameters. When these expressions, using Maxwell's equations expressed in the wave dispersion equation, wave propagation, depending on the parameters of the environment will be examined.

These statements are expressed in terms of Maxwell's equations using the wave dispersion equation, wave propagation, depending on the parameters of the environment will be examined. By examining of the dispersion relation, the types of wave occurred in the media and relaxation mechanisms, polarizations and conflicts caused by ionospheric amplitude attenuation of these waves will be obtained analytically. Thus, resolving problems of ionospheric plasma in the emitted radio waves, the basic information that will be understood [2].

From the beginning of electromagnetic waves usage in wireless telecommunication, HF is used radio aims. Popularity on HF systems is not limited to its wireless application and also radar systems use this band. The location, finding system using echo radio, were HF band systems that in 1920 were used for ionosphere height measurement. First plane discovery radar system also applied in 1938 in HF band. Also HF band radars using the reflectivity of the ionosphere as a solution for ultra horizon radar monitoring.

HAARP is a transmitter of electromagnetic waves that hitting the one particular area of the sky, and changes free electrons of ionosphere layer above atmosphere in about 275Km height that has temperature equivalent 1400°C, and this way transfers too much amount of energy to them. Thus, temperature can increase as far as 20%, this region gets extended. Hence use of HAARP technology causes ionosphere layer to be red and molten or microscopic. Whole of technologies utilized in HAARP are based on transmission of long waves to ionosphere, and then observation of its results. Local bombardment of ionosphere with long waves is creation of a great virtual mirror that acts like an aerial. These virtual aerial transmits ultra low frequencies to ground [5-8].

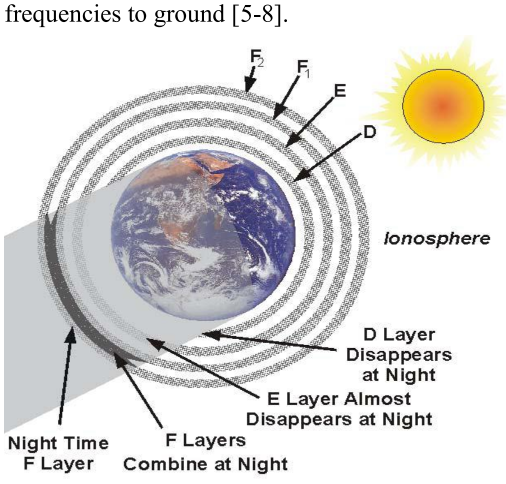

Fig. 1. Regions of atmosphere [2]

II. Ionization and Recombination

Only the E, F_1 and F_2 regions refract HF waves. The D region is very important though, because while it does not refract HF radio waves, it does absorption or attenuation of them. The F2 region is the most important region for HF radio propagation because:

- It is present 24 hours of the day.
- Its high altitude allows the longest communication paths.
- It reflects the highest frequencies in the HF range.

The lifetime of free electrons is greatest in the F_2 region which is one reason why it is present at night.

Typical lifetimes of electrons in the E, F_1 and F_2 regions are 20 seconds, 1 minute and 20 minutes, respectively. Because the F_1 region is not always present and often merges with the F_2 region, it is not normally considered when examining possible modes of propagation. Spread F occurs when the F region becomes diffuse due to irregularities which scatter the radio wave. The received signal is the superposition of a number of waves reflected from different heights and locations in the ionosphere at slightly different times.

At low latitudes, spread F occurs mostly during the night hours and around the equinoxes. At mid-latitudes, spread F is less likely to occur than at low and high latitudes and is more likely to occur at night and in winter. At latitudes greater than about 40, spread F tends to be a night time phenomenon, appearing mostly around the equinoxes, while around the magnetic poles, spread F is often observed both day and night. At all latitudes there is a tendency for spread F to occur when there is a decrease in F region maximum frequencies (reduced electron density). That is, spread F is often associated with ionospheric storms.

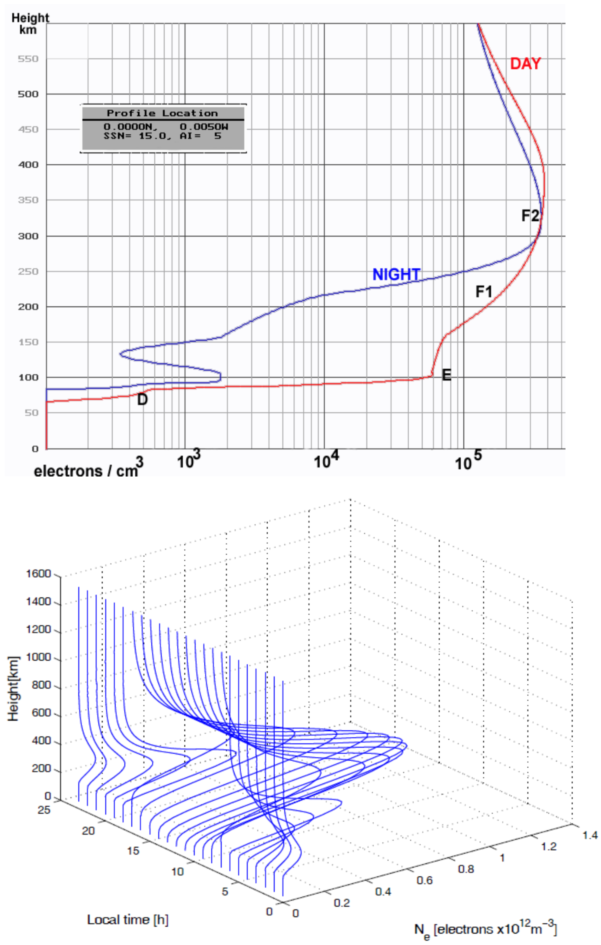

Fig. 2. Variation of reactions with day and night

Ionization and recombination is the process in which electrons, which are negatively charged, are removed from neutral atoms or molecules to leave positively charged ions and free electrons. At the same time, however, an opposing process called recombination begins to take place in which a free electron is captured by a positive ion if it moves close enough to it. Ionization has threshold energy, recombination has not but is much less probable. The free electrons in the ionosphere cause HF radio waves to be refracted (bent) and eventually reflected back to earth. The greater density of electrons means the higher frequencies that can be reflected. However, not all radiations from the sun produce the same effects on the ionosphere. But in all cases, charged particles and ionizing radiations are events that affect the strongest the ionosphere, some carried by geo-magnetospheric currents to polar caps and to the equator via ring currents, other striking directly the upper atmosphere without embellishment. Threshold is ionization energy (13.6eV, H) X. The Integral over Maxwellian distribution gives rate coefficients. Because of the tail of the Maxwellian distribution, the ionization rate extends below T = Xi and in equilibrium when:

$n_{ions} / n_{neutrals} = <\delta_i> / <\delta_r> \upsilon$

The percentage of ions is in the range of 100% if electron temperature:

$T_e \geq X_i / 10$ e.g. H_2 is ionized for $T_e \geq 1eV$

As the gas density increases at lower altitudes, the recombination process accelerates since the gas molecules and ions are closer together. The point of balance between these two processes determines the degree of ionization present at any given time. The 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. After sunset the molecular ions e.g. H2 and He in the D, E and F_1 layer vanish quickly through dissociative recombination of the type,

$XY^+ + e^- \rightarrow X + Y$

Which on yielding two atoms these processes have high reaction probabilities.

The F2 is a much harder process because

$X^+ + e^- \rightarrow X + \hbar\omega$

and

$X^+ + e^- + M \rightarrow X + M$

for $\hbar\omega$ being a photon and M a third reactant which is much slower and hence the F_2 layer more stable at night. Generally ionization and combination reactions play an important role in conductivity of the ionosphere. With lower collision frequencies, resulting in lower conductivities but also depending on the proportion of neutral molecules that abound.

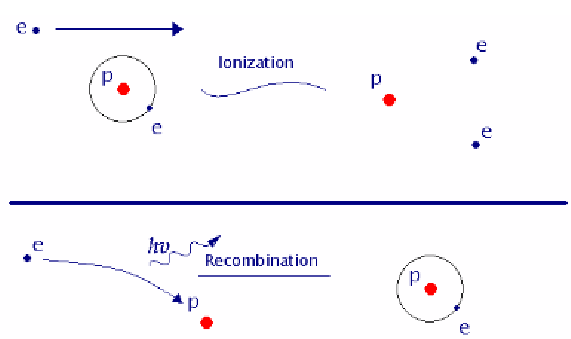

Fig. 3. Ionization and recombination

In D layer during the night cosmic rays produce a residual amount of ionization. Re-2 combination is high in this layer, thus the net ionization effect is very low and as a result the high frequency (HF) radio waves aren't reflected by the D layer. The frequency of collision between electrons and other particles in this region during the day is about 10 million collisions per second! The D layer is mainly responsible for absorption of HF radio waves, particularly at 10 MHz and below, with progressively smaller absorption as the frequency gets higher. The absorption is small at night and greatest about midday. The layer reduces greatly after sunset primarily due to recombination, but remains due to reionizing galactic cosmic rays. A common example of the D layer in action is the disappearance of distant AM broadcast band stations in the daytime [6].

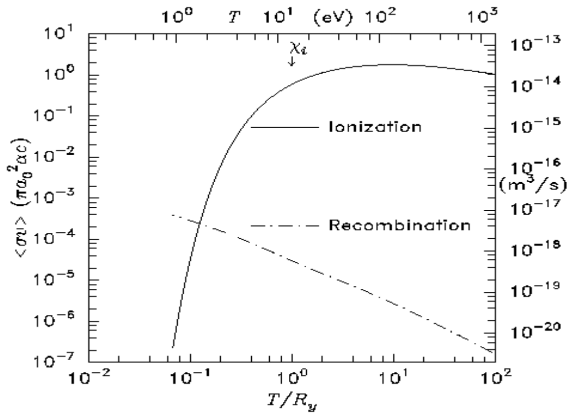

Fig. 4. Ionization and recombination rates

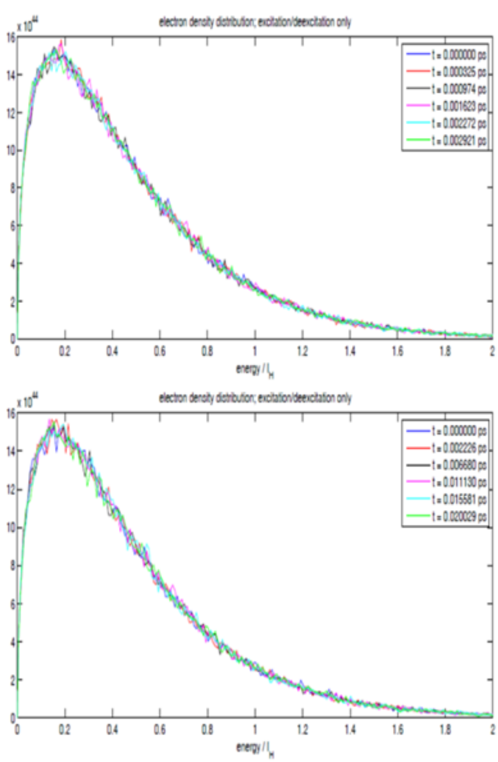

Fig. 5. Electron density function at various times starting from equilibrium, with excitation/de-excitation only (top), and ionization/recombination only (bottom) These results show that the simulation method does preserve the equilibrium distribution as required. 100000 sample for free electrons.

A. E Layer

After covering a distance of about 30km we encounter the E layer which is the middle layer, 90km to 120km above the surface of the Earth. Ionization is due to Soft X-Ray (1-10 nm) and far ultraviolet (UV) solar radiation ionization of molecular oxygen (O). This layer can only reflect radio waves having frequencies less than 10 MHz. It has a negative effect on frequencies above 10 MHz due to its partial absorption of these waves. During the daytime the solar wind presses this layer closer to the Earth, thereby limiting how far it can reflect radio waves. On the night side of the Earth, the solar wind drags the ionosphere further away, thereby greatly increasing the range which radio waves can travel by reflection.

B. F Layer

The F layer or region, also known as the Appleton layer, is 120km to 400km above the surface of the Earth. Here extreme ultraviolet (UV) (10-100 nm) solar radiation ionizes molecular oxygen (O). The F layer combines into one layer at night, and in the presence of sunlight (during daytime), it divides into two layers, the F1 and F2. The F layers are responsible for most sky wave propagation of radio waves, and are thickest and most reflective of radio on the side of the Earth facing the sun and merges with the magnetosphere, whose plasmas are generally more rarefied but also much hotter. The ions and electrons of the magnetospheric plasma come in part from the ionosphere below, in part from the solar wind.

After knowing how the natural ionizing caused by rays and solar storms on the atmosphere, now we describe how to generation of ULF waves caused by radiation of HF waves to the particular point of ionosphere and changing of this waves from electromagnetic to sound (shock) waves by ionization in that region.

The heating of ions by high frequency electrostatic waves in magnetically confined plasmas has been a paradigm for studying nonlinear wave-particle interactions. The frequency of the waves is assumed to be much higher than the ion cyclotron frequency and the waves are taken to propagate across the magnetic field. In fusion type plasmas, electrostatic waves, like the lower hybrid wave, cannot access the core of the plasma. That is a domain for high harmonic fast waves or electron cyclotron waves, these are primarily electromagnetic waves. Previous studies on heating of ions by two or more electrostatic waves are extended to two electromagnetic waves that propagate directly across the confining magnetic field. While the ratio of the frequency of each wave to the ion cyclotron frequency is large, the frequency difference is assumed to be near the ion cyclotron frequency. The nonlinear wave-particle interaction is studied analytically using a two time-scale canonical perturbation theory.

The theory elucidates the effects of various parameters on the gain in energy by the ions parameters such as the amplitudes and polarizations of the waves, the ratio of the wave frequencies to the cyclotron frequency, the difference in the frequency of the two waves, and the wave numbers associated with the waves. For example, the ratio of the phase velocity of the envelope formed by the two waves to the phase velocity of the carrier wave is important for energization of ions. For a positive ratio, the energy range is much larger than for a negative ratio. So waves like the lower hybrid waves will impart very little energy to ions. The theoretical results are found to be in good agreement with numerical simulations of the exact dynamical equations. The analytical results are used to construct mapping equations, simplifying the derivation of the motion of ions, which are, subsequently, used to follow the evolution of an ion distribution function. The heating of ions can then be properly quantified in terms of the wave parameters and can be conveniently used to find ideal conditions needed to heat ions by high frequency electromagnetic waves.

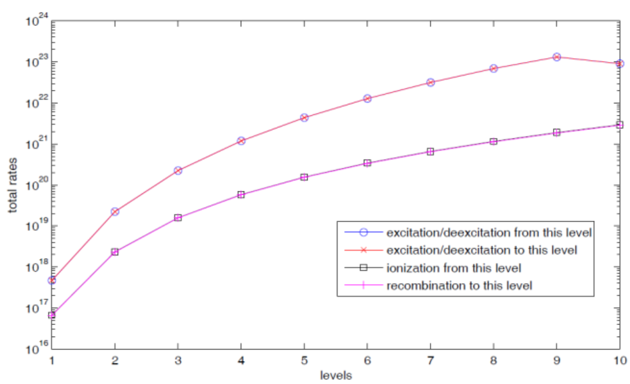

Fig. 6. The total rates for all collisions at equilibrium.

III. Conclusions

Transmission of waves from HF antennas are kind of electromagnetic waves (in electromagnetic wave in publishing mode electric and magnetic fields are perpendicular to each other and move directly) and caused collision with a height of about 250-275 Km layer of the ionosphere, that is the densest part of the ionosphere, According to the produced ionization in that area, reflected waves change to sound (shock) waves and will carry so much energy to the special point on the earth. Because the speed of sound waves is much lower than the speed of electromagnetic waves, so that time of reaching the sound signal from the ionosphere to Earth, according to the primary angle of the beam, it took about 15 to 360 minutes. Sound waves are the kind of mechanical waves that are propagate in environment and Propagation of these waves are due to internal forces caused deformation. These evanescent waves want to restore to the original state (steady state) and to reach steady state, must be emitting energy. Note that, emitted energy is very high, and it can be devastated. So to receive advance notice about the existence of these waves we can establish and using ultra low frequency receiver systems in the critical areas and by measuring the frequency of the sounds that come from the sky, realize these waves.

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