Application of the Radio-Window Concept to the Propagation of VLF and MF Waves through Night Time Ionosphere Above Powerful VLF Transmitters

Francois Lefeuvre
LPC2E / CNRS, 3A, Avenue de la Recherche Scientifique, 45071 Orléans cedex 2, France
lefeuvre@cnrs-orleans.fr

Keywords: VLF transmitter, MF waves

Abstract: Surprisingly, the propagation of radio waves through the ionosphere is still not completely understood. This has been recently pointed out from night time observations made by the DEMETER satellite (~700 km altitude) over powerful VLF ground-based transmitters used for communications with submarines. If it seems quite reasonable to observe high-power densities of VLF waves over geographical areas located at latitudes slightly below the ones of the VLF transmitters and their conjugated regions, it is difficult to explain: (i) the geographical extension of the VLF observations, and (ii) high-power densities of MF waves (lightning-generated whistlers) observed in the ~2. – 2.5 MHz band, over the same geographical areas than for VLF waves. The mechanism proposed to explain those observations is based on the radio-windows concept. The propagation characteristics of radio waves are derived from the Appleton-Hartree formula. The refractive index n2 is a function of the X = fpe2/f2 and Y= fce/f parameters (with f the wave frequency, fpe the electron plasma frequency and fce the electron gyrofrequency). Under given conditions for propagation, upgoing rays which reach the altitude of the X = 1 plasma cut-off are not reflected but converted to another propagation mode. As an example, for a propagation from below the ionosphere up to the 700 km altitude, assuming a given night time electron density profile, numerical simulations show that a 25 kHz VLF waves crosses a X = 1 plasma cut-off at ~ 90 km altitude (the entry into the ionosphere) whereas a 2.2 MHz MF wave crosses a first X = 1 plasma cut-off at ~ 250 km altitude (entry into the ionosphere) and a second one at ~ 400 km altitude (output from the ionosphere). The half angles of the transmission cones at the X=1 plasma cut-offs depend on the level of wave heating at those altitudes and so on the increases in collision frequencies generated by powerful VLF ground-based transmitters. Numerical simulations show that: (1) in the VLF frequency range, the wave heating being maximum at the altitude of the Ordinary mode resonance region, i.e. just above the X = 1 plasma cut-off, the half angle of the transmission cone may reach several dozens degrees, (2) in the MF frequency range, the wave heating being maximum at the altitude where the product of the electronic density and the collision frequency is maximum, the opening of the transmission cones strongly depend on the relative altitudes of the maximum heating and of the X=1 plasma cut-offs.

Brief Bio François Lefeuvre is a CNRS Research Director Emeritus at the LPC2E laboratory (Laboratoire de Physique et Chimie de l'Environnement et de l'Espace) of the French National Centre for Scientific Research (CNRS) and the University of Orleans. He is presently Past President of URSI (International Union of Radio Science). He obtained his first thesis in 1970 at the "Groupe de Recherche Ionospherique", Saint-Maur des Fossés, received a fellowship from ESRO (now ESA) for studying natural ELF and VLF emissions in the magnetosphere at the Physics Department of

Lefeuvre F.
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DOI: 10.5220/0005420400030004
In *Proceedings of the Third International Conference on Telecommunications and Remote Sensing (ICTRS 2014)*, pages 3-4
ISBN: 978-989-758-033-8

the Sheffield University in UK (1970), got a permanent position at CNRS in 1972 and obtained is second thesis (thèse d'état) in 1977 at the University of Orleans. In 1979/1980 he was a visiting scientist in the Radio Science Group at the Stanford University. He has published scientific papers in several domains including radio wave propagation within the ionosphere and the magnetosphere, inverse problems, signal analysis, risk management. He was Co-Investigator for several space missions (GEOS, AUREOL 3, INTERBALL, DEMETER), Principal Investigator for a wave experiment on the INTERBALL mission, and PI mission for the TARANIS project. He was Director of LPCE (Laboratoire de Physique et Chimie de l'Environnement) from 1994 to 2003, chaired the ESA Space Weather Working Team (2002-2005) and was President of URSI (International Union of Radio Science) from 2005 to 2008 then from 2009 to 2011