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Ground-based transmitter signals observed from space: ducted or nonducted?

Mark A. Clilverd (1), Craig J. Rodger (2), Rory Gamble (2), Nigel P. Meredith (1), Michel Parrot (3), Jean-Jacques Berthelier (4), Neil. R. Thomson (2)

(1) Physical Sciences Division, British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, England, U.K., (2) Physics Dept., University of Otago, Dunedin, New Zealand, (3) M. Parrot, Laboratoire de Physique et Chimie de l'Environnement, 3A Avenue de la Recherche Scientifique, 45071 Orleans Cedex 2, France. (4) J-J Berthelier, Centre d'Etudes des Environnements Terrestre et Planétaires, 4 Avenue de Neptune, Saint Maur des Fosses, France (macl@bas.ac.uk)

The principal loss mechanism for electrons from the inner radiation belt ($1.2<L<2.0$) and slot region ($2.0<L<3.0$) is atmospheric precipitation driven by several processes, including coulomb collisions, plasmaspheric hiss, lightning-generated whistlers, and man-made transmissions. Several studies have shown that ducted and nonducted VLF waves can precipitate radiation belt energetic electrons into the upper atmosphere. Here we investigate the propagation of VLF communication transmitter signals by combining the observations from plasma wave instruments onboard the CRRES and DEMETER satellites, in order to determine if nonducted transmitter signals are significant in radiation belt loss processes. We investigate the regions where strong transmitter signals are observed in the ionosphere directly above the transmitter, in the magnetosphere near where the signals cross the geomagnetic equator, and in the ionospheric region geomagnetically conjugate to the transmitter. For very low L-shell transmitters ($L<1.5$) there is evidence that a significant proportion of the wave energy propagating into the plasmasphere is nonducted. However, at higher L-shells the waves become highly ducted in the plasmasphere. Strong evidence for this comes from the lack of significant wave power propagating above the electron half gyro-frequency limit for inter-hemispherically ducted waves. We conclude that man-made transmissions in the frequency range (18-25 kHz) will be restricted to driving electron precipitation pri-

marily from the inner radiation belt (L=1.3-2.5).