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电离层人工调制激发的VLF波在磁层的传播特性及应用研究

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Propagation and application of VLF waves generated by HF heating of ionosphere in the magnetosphere

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摘要

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摘要 电离层人工调制可以激发甚低频(VLF)波, 其中向上传播进入磁层的VLF波, 不但能够用来研究磁层中的各种物理现象, 且具有人工沉降高能粒子, 消除辐射带等实际用途. 本文使用射线追踪方法, 模拟电离层调制激发的VLF波在磁层的传播路径, 分析激发纬度和调制频率对传播路径和传播特性的影响; 并基于低频波的色散方程和波粒共振条件, 分析VLF波传播路径上与磁层高能粒子的最低共振能及其分布. 研究表明, VLF波通过在磁层来回反射向更高的L-shell传播, 最终稳定在某一L-shell附近. 以较低的调制频率或者从较高的纬度激发的VLF波能够传播到更高的L-shell, 但是, 当激发纬度过高时, 低频波也可能不发生磁层反射而直接进入电离层和大气层. 低频波在磁层的传播过程中, 在较高的纬度或者较低的L-shell能够与较高能量的电子发生共振相互作用, 在较高的L-shell并且低纬地区, 能够与较低能量的电子发生共振相互作用. 共振谱数越高, 能发生波粒共振的电子能量越高.

关键词 电离层人工调制, VLF波, 射线追踪, 波粒共振

Abstract: It has been proposed that VLF radiations, resulting from high-frequency (HF) transmitter heating of the ionosphere, can be potentially used for artificial radiation belt remediation. In the present study we first perform a parametric study of these VLF wave propagation paths and characteristics in the near-Earth magnetosphere, using our own developed ray tracing code. Then, based on the resonance condition and dispersion equation, we make an analysis about the energy of electrons resonating with these artificial VLF waves. The results indicate that VLF waves can propagate outward by magnetospheric reflection and finally settle down at certain higher L-shells in the inner magnetosphere. The waves can propagate further when the frequency is lower or the initial latitude is higher. But, it is also possible that VLF waves touch the ionosphere and get absorbed there without any magnetospheric reflection, if the waves are launched at very high latitudes. In the magnetosphere, VLF waves at higher latitude or lower L-shell can resonate with higher energy electrons and at lower latitude and higher L-shell can resonate with lower energy electrons. For higher harmonic, resonance interaction needs higher energy electrons.

Keywords Ionosphere modulation heating, VLF wave, Ray tracing, Wave-particle interaction

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