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## Excitation of Earth-Ionosphere Waveguide in the ELF and Lower VLF Bands by Modulated Ionospheric Current

Authors: [E. C. Field](#); [R. M. Bloom](#); [PACIFIC-SIERRA RESEARCH CORP SANTA MONICA CA](#)

**Abstract:** In this report we use the principal of reciprocity in conjunction with a full-wave propagation code to calculate ground-level fields excited by ionospheric currents modulated at frequencies between 50 and 100 Hz with HF heaters. Our results show the dependence on source orientation, altitude, and dimension and therefore pertain to experiments using the HIPAS or HAARP ionospheric heaters. In the end-fire mode, the waveguide excitation efficiency of an ELF HED in the ionosphere is up to 20 dB greater than for a ground-based antenna, provided its altitude does not exceed 80-to-90 km. The highest efficiency occurs for a source altitude of around 70 km; if that altitude is raised to 100 km, the efficiency drops by about 20 dB in the day and 10 dB at night. That efficiency does not account for the greater conductivity modulation that might be achieved at altitudes greater than 70 km, however. The trade-off between the altitude dependencies of the excitation efficiency and maximum achievable modulation depends on the ERP of the HF heater, the optimum altitude increasing with increasing ERP. For HIPAS the best modulation altitude is around 70 km, whereas for HAARP there might be marginal value in modulating at altitudes as high as 100 Km. Ionospheric modification, Ionospheric currents, Ionospheric heating.

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