Performance Analysis of an Array of High Power Horizontal dipoles at VLF

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This paper discusses the design/analysis techniques used to investigate the performance of an array of high power horizontal dipoles operating near the low end of the VLF band. These techniques were used to analyze an array of dipole antennas operating at 7 KHz above a finite conducting ground plane with a conductivity of 0.0001 S/m. The length of these antennas is 42.8 Km.The application requires upward radiation for the signal to pass though the ionosphere into the magnetosphere, specifically to investigate wave particle interaction in the radiation belts. This research is directed towards developing the ground-based capability to radiate significant power in the frequency range from 1-10 kHz.

Several different configurations of transmitting antennas were examined starting with a baseline of simple practical antennas such as horizontal dipoles similar to the ELF transmitting antennas. For the baseline study, different parameters were varied: length, height, wire diameter, antenna conductor conductivity and ground conductivity. There is a practical height limitation for vertical structures due to the physical parameters of construction materials and cost. For horizontal antennas, efficiency is severely compromised by being electrically close to the finite conducting ground plane. This is due to near field losses in the ground and the significant reduction in radiation resistance caused by the ground reflection. The latter is the dominant effect for horizontal antennas electrically close to ground, which is necessarily the case in this frequency range. For a single element, the maximum efficiency is obtained when the dipole is approximately a full wavelength long and for 7 kHz, with ground conductivity 0.0001 S/m, gives a gain of -13 dBi in the vertical direction. Arraying these antennas increases the efficiency by approximately the number of elements. A 6 dB, increase in gain results from increasing the number of dipole elements to 4. The radiated power for these antennas is limited by voltage, current or transmitter power. This limit also increases with the number of antenna elements. If a separate transmitter is provided for each array element, the power limited ERP for 4 elements is 16 times that of a single element.