Frequency Response and Polarization of ELF/VLF Signals Generated via Ionopsheric Modification

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ELF/VLF signals generated via HF heating of the ionosphere are known to exhibit an amplitude dependence on modulation frequency with a well documented maximum in ELF radiation around 2 kHz. Currently there are multiple explanations for this 2 kHz observed maximum and the general frequency dependence of observed amplitudes. One of the first theories put forth during the first experiments at the Tromso facility involves the formation of resonances at these frequencies as waves reflect in the Earth ionosphere cavity. The second hypothesis claims that the 2 kHz maximum originates from ionospheric physics where heating and cooling rates are such that modulation at this frequency is favored. The third hypothesis applies more to long distance propagation and is based on 2 kHz being just above the cutoff frequency for the qTE1 and qTM1 modes of the Earth-ionosphere waveguide. In this work we use the High Frequency Active Auroral Research Program (HAARP) heating facility to generate ELF/VLF waves using amplitude modulation. To obtain a clearer understanding of the frequency dependence of both amplitude and polarization of generated ELF/VLF waves, observations are made at multiple sites at varied distances from the HAARP facility. At distances >700 km the effective radiation pattern of HAARP generated ELF signals is known to resemble that of a linear dipole dominated by modulation of the ionosphere Hall conductivity. However, closer to the HAARP array (<100 km) the relative role of Hall vs. Pederson conductivity modulations has not been fully quantified. There is also some disagreement among researchers as to whether the signals observed in the Earth ionosphere wave guide are due primarily to horizontal currents directly modulated by the HAARP array or if the so called vertical 'loop-back' currents also play a role. By observing the amplitude and ELF polarization at multiple sites, a more complete picture of the current patterns that are modulated by HAARP can be obtained. The three locations used for receiver placement were: Chistochina at a distance of 36 km and azimuth of 47.7, Paxson at a distance of 50.6 km and an azimuth of -20.0, and Paradise at a distance of 99 km and an azimuth of 80.3. The format chosen to run at the HAARP facility consisted of one second tones increasing from 500 Hz to 8.3 kHz over a 40 second interval followed by a 20 second ramp. This format was repeated for 30 minutes at different dates and times representing different ionospheric conditions during the campaign. It is found that ELF amplitude and polarization as a function of ELF frequency is different for each site.