Platform-Based, Electrically-Small HF Antenna with Switchable, Directional Radiation Patterns

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Practical vehicle-mounted antennas operating at the high frequency (HF) band usually have very small electrical dimensions. In the HF band, due to the large wavelength of electromagnetic waves, these antennas tend to be extremely small compared to the wavelength of the electromagnetic waves that they radiate or receive. Hence, they tend to have very narrow bandwidths and omni-directional radiation patterns. While, in theory, achieving superdirectivity from an electrically-small aperture is possible, its implementation in practice is extremely challenging (R. C. Hansen, Proceedings of the IEEE, 69(2), 170-182, 1981). A practical way to achieve a directional radiation pattern from an electrically-small aperture is to create a cardioid-shaped radiation pattern by combining a figure-eight-shaped radiation pattern and an omni-directional one with the same magnitudes. This idea can be implemented by feeding a dipole and a co-located loop using the same magnitude and phase of excitation. However, conventional electrically-small dipoles and loops still suffer from narrow bandwidth.

In this work, we present a platform-based electrically-small antenna operating at the HF band with a switchable cardioid-shaped radiation pattern and enhanced bandwidth. This is achieved by employing the platform's natural resonant modes as the main radiation mechanism and using the antennas mounted on the platform as means of exciting the characteristic modes of the platform. In the proof-of-concept design, we use an Amphibious Assault Vehicle (AAV) as the platform. The AAV has a dimension of 7.6 m $\times$ 3.3 m $\times$ 2.0 m. The antenna is designed to operate at 10 MHz, and is composed of low-profile, electrically-small coupling elements. These coupling elements are chosen to excite a dipole mode of AAV with vertical polarization and two orthogonal loop modes of the platform that have vertical polarizations in the azimuth plane. The dipole mode creates an omni-directional radiation pattern in the azimuth plane, and the loop modes create two perpendicular figure-eight-shaped radiation patterns. To achieve a cardioid-shaped radiation pattern, we excite the dipole and one of the loop modes using the same excitation coefficients. By giving the dipole mode additional 180° phase shift, we can rotate the direction of maximum radiation of the cardioid-shaped pattern by 180°. To point the cardioid-shaped pattern towards the perpendicular directions, we combine the dipole mode with the second vertically-polarized loop mode of the platform.

In the presentation, we will detail the design of the coupling elements and implementation of the feed network. At 10 MHz, the feeding network consists of lumped elements (inductors and capacitors). We will also discuss the achieved bandwidth and theoretical limits of the bandwidth. Moreover, the performance of the antenna when the platform is placed on different realistic ground planes (e.g. wet earth, dry earth, and sea water) will be examined. Finally, measurement results of a scaled-model prototype will be presented and discussed.