

Antenna Decoupling Based on Metamaterials for Modern Naval Platforms

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The increasing operational requirements of modern naval vessels demand advanced solutions for the physical integration of subsystems. This is particularly evident in the above-deck areas, where the density of RF sensors has grown significantly. The proliferation of sensors is driven by the need for enhanced communication, surveillance, and electronic warfare capabilities. Consequently, many antennas are now positioned in close proximity to metallic superstructures, a challenging environment for ensuring optimal performance. Typical examples include V/UHF communication antennas clustered around the ship's mast, phased-array radar systems designed for long-range surveillance, and Electronic Warfare antennas that detect, intercept, or counteract adversary signals. These systems often operate simultaneously, further complicating their integration due to potential electromagnetic interference (EMI) and mutual coupling effects. Unfortunately, closely spaced antennas can reduce electromagnetic (EM) isolation between them, degrading overall system performance due to the undesirable effects of mutual coupling.

The integration challenge is further intensified by the ongoing effort to minimize the physical dimensions of masts and superstructures, driven by the demand for improved naval vessel performance. Reducing the size of these structures yields multiple advantages, such as lowering the overall weight of the vessel, which improves fuel efficiency and stability. However, these reductions also mean that antennas must often be placed in even closer proximity to one another and to the surrounding metallic surfaces. Such arrangements risk compromising the performance of individual antennas due to factors like increased reflection, diffraction, and scattering of electromagnetic waves. These interactions can lead to undesirable effects, such as a rise in the Voltage Standing Wave Ratio (VSWR), which reflects energy back into the antenna rather than radiating it efficiently, resulting in reduced effective radiated power (ERP).

Several strategies have been proposed to address these challenges. One promising approach involves the use of Electromagnetic Bandgap (EBG) materials and High Impedance Surfaces (HIS). These engineered metamaterials feature periodic structures that inhibit the propagation of surface waves in a specified frequency band, thereby reducing electromagnetic coupling between closely spaced antennas. By strategically positioning EBG structures on the mast or superstructure, unwanted interactions between antennas can be mitigated, improving overall performance. EBG materials operate by reflecting electromagnetic waves in phase and suppressing surface waves, preventing interference from finite ground plane radiation.

This paper presents the design, fabrication, and experimental validation of a metamaterial-based solutions for antenna decoupling in naval applications, based on composite naval materials suited to marine environments. Electromagnetic Bandgap (EBG) materials were developed and tested in the frequency range of 8–11 GHz to mitigate electromagnetic interference and surface wave propagation. Both solutions were evaluated on a scaled-down mock-up of a naval mast, designed to replicate realistic geometric and operational conditions. Measurements were conducted in two configurations: one with the receiver antenna integrated within the mock-up and another with the receiver antenna positioned externally, in the shadow zone of the transmitter. Results demonstrate that both materials structures, effectively reduce antenna coupling and surface currents, achieving an overall improvement of more than 10 dB.

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