Design of Platform-Based, Compact HF Direction Finding Antenna Array Using the Characteristic Mode Theory

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Vehicle-mounted direction finding (DF) systems usually require compact-size antenna arrays. This problem is especially exacerbated in the high-frequency (HF) band. In this frequency band, because of the large wavelength of the electromagnetic waves, practical vehicle-mounted antenna arrays are usually electrically small. This small aperture issue causes extremely narrow bandwidth and low direction-of-arrival (DoA) estimation accuracy. One way to compensate this issue is to utilize the metallic platform as part of the radiating element, to facilitate radiation by the electrically-small antennas. Corbin achieved enhanced bandwidth and DoA estimation accuracy by placing regular small monopoles to the locations where the platform's natural resonant modes are the strongest (C. F. Corbin, Air Force Inst of Tech, No. AFIT/GE/ENG/11-06, 2011). In our previous work, we proposed a systematic method of employing the platform's characteristic modes (CM) for DF (R. Ma and N. Behdad, Applied Computational Electromagnetics Society Symposium (ACES), 2018 International. IEEE, 2018). In this method, we selected and excited the combination of the platform's CMs that provides the lowest Cramer Rao lower bound (CRLB). Therefore, the method can produce an antenna array that approaches the optimal DoA estimation accuracy provided by the platform's CMs. While the antenna elements of these works are electrically small, they have to be placed faraway from each other. In some applications, however, it may be desirable to place the entire DF array at a single location on the hosting platform.

In this work, we report a platform-based, compact antenna array for HF DF applications. The platform considered in this proof-of-concept demonstration work is a typical mid-size aircraft (e.g. similar to a Boeing-737 airplane), and is 42 m long and 37 m wide. The DF array is mounted at a single location on the rear end of the aircraft. It is composed of four antenna elements. These antenna elements are closely placed so that the entire array can be enclosed in a very small volume with dimensions of 3 m $\times$ 3 m $\times$ 1.6 m. The proposed array is coupled to multiple CMs of the metallic body of the airplane. At 30 MHz, this array has a $ka \approx 0.9$, where a is the radius of the sphere and k is wave number. The array has four ports and achieves an instantaneous fractional bandwidth of $\geq 2\%$. The proposed design surpasses the DoA estimation limitation (per port) of the sphere enclosing the array (S. Nordebo et al., IEEE Transactions on Signal Processing, 54(10), 4055-4061, 2006). In the presentation, we will discuss the design details. To show the enhancement of bandwidth and DF accuracy, we will compare bandwidth and CRLB of our design and those of other designs in the absence of the platform, as well as the theoretical limitation. We will also present simulation results and measurement results of a scaled fabricated prototype. Based on these results, numerical DF experiments with Monte Carlo method will be discussed.