Optimum Placement of Array Antenna Elements on Aircraft for Accurate DOA Estimation in a Wide Frequency Range

Gangil Byun[(1)], Seulgi Park[(2)], Ikmo Park[(3)], and Hosung Choo[(1)]
[(1)] Hongik University, Seoul, Korea
[(2)] LIG Nex1 Co., Ltd., Seongnam, Korea
[(3)] Ajou University, Suwon, Korea

In recent warfare, direction finding (DF) systems have been widely adopted on military aircraft to detect and prevent potential enemy threats in hostile areas. These DF systems usually use antenna arrays to estimate the direction of enemy radio transmissions by comparing amplitude differences and phase delays among the received array signals. Thus, the spacing between antenna elements should be carefully determined for accurate direction of arrival (DOA) estimation, and it becomes more important when the DF systems are working in a wide frequency range. For example, when the spacing between antenna elements is greater than a half wavelength, the first-order ambiguity for DOA estimation is significantly increased in a higher frequency band. On the other hand, a narrow spacing of roughly less than 0.1 wavelength does not give high enough resolutions for distinguishable differences of the amplitude and phase in a lower frequency band. These ambiguities become even more significant when the antenna elements are mounted on a huge platform, such as aircrafts, due to the wave scattering and coupling effects caused by the platform. A great deal of effort has been made from various standpoints to mitigate these platform effects and achieve accurate DOA estimation. From the signal processing standpoint, normalization techniques for the power of each steering vector have been adopted with DF algorithms to minimize the ambiguity, e.g., Bartlett's method and eigen-space methods. However, these algorithms generally ignore the electromagnetic behavior of the antennas by assuming that they are ideal and isotropic point sources. In addition, mutual coupling and multiple reflections caused by the platform are also neglected; thus, such an approach may not be applicable in practice. In searching for a more practical approach, the position optimization of array antenna elements has recently been studied to minimize the platform effects, but this approach is commonly limited to a specific beamforming application of smart antennas which only operates within a specific frequency band. Therefore, DOA estimation in a wide frequency range has not been thoroughly taken into account.

In this paper, we propose an optimization method of placing array antenna elements to maintain DOA estimation accuracy over a wide frequency range. In our approach, we will include the entire aircraft geometry to take into account the actual antenna characteristics, such as radiation patterns and mutual coupling, as well as the platform effect. Then, the positions of omni-directional antenna elements operating from 20 MHz to 500 MHz will be optimized by using a genetic algorithm (GA) in conjunction with the FEKO EM simulator developed by EM Software and Systems. Array manifolds of given positions will be obtained from amplitudes and phases of induced currents on each antenna element. We will then estimate DOAs with a signal subspace multiple signal classification (MUSIC) algorithm, and the average root mean square error (RMSE) for all angles of interest will be averaged to evaluate each array design. Based on the results obtained from the above, the optimized results will also be analyzed using various standpoints to verify the suitability of the optimization method proposed in this paper.