Optimum placement of direction finding antennas on aircraft for accurate DOA estimation

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Military aircrafts usually have direction finding (DF) systems with array antennas to detect and analyze signals coming from arbitrary angles. These systems typically estimate the direction of arrival (DOA) using eigenstructure-based methods, such as MUSIC, whose performance strongly depends on the accuracy of the array manifold. In most cases, the array manifold is calibrated by measuring signals received by the antennas. However, this measurement can be time-consuming and expensive, especially for such large aircraft structures. Therefore, much research has focused on making an accurate array manifold while saving both time and costs. EM simulation of array antennas, which is commonly used to calibrate the array manifold as a replacement of the measurement, shows a superior performance in the presence of the mutual coupling effect among the array elements. However, the mutual coupling effect is not the only consideration for aircraft applications. The wave blockage effect and wave scattering by the aircraft structure should also be taken into account. In addition, there exist certain positions where some specific geometry, such as landing gears, radomes, and vertical fins, blocks the antenna’s field of view, which disturbs the direct signal path to the antennas. To consider all of these possible effects, the entire aircraft geometry should be included in the EM simulation, when calibrating the array manifold.

In this paper, we propose a method for finding an optimum placement of DF antennas on aircraft using the EM simulation. The DF system is assumed to use a 5-element UCA array operating in the VHF band and has an average signal-to-noise ratio (SNR) of 20 dB for all the incoming signals. The array can be placed only in a designated area, located at the bottom of the aircraft, because of the structural complexity. The entire aircraft geometry is included in the simulation as piecewise mesh triangles having a length of around one-seventh wavelength, which is the most appropriate length found from the simulating time and accuracy standpoint. The array manifold is then calibrated by estimating the phase on each input port of the array from the signal incidence at all possible angles. Based on the calibrated array manifold, the accuracies of the DOA estimation are evaluated by varying the positions of DF antennas on the aircraft. The optimum placement of the DF arrays according to the DOA accuracy will be discussed. The effect of the structural parts of the aircraft, such as wings, front and rear body, and tails, on the DOA estimation will also be examined in this paper.