Analysis of Antenna Loss and Receiving Efficiency for High-Sensitivity Scanned Phased Arrays

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For phased arrays used in satellite communications and radio astronomy, high-sensitivity is required. A typical noise budget for a state-of-the-art L-band radio telescope receiver with 19 K system noise temperature. A small increase in added noise due to antenna loss leads to a relatively large degradation in system performance. Losses for single antennas can be minimized by using high conductivity metals, low dielectric loss materials and evenly distributing currents. These considerations certainly apply to array antennas, but for a multiport antenna system, antenna loss is also influenced by mutual coupling effects and the beamformer weights applied to the signal from each element.

To better understand the relationship between array antenna loss, mutual coupling, and beamformer weights, losses for a coupled array can be lumped into an array effective resistance similar to the loss resistance of an equivalent single antenna. Antenna loss for active receiving phased arrays and focal plane phased array feeds is studied using the active array receiving efficiency. Since the array effective loss resistance is close to zero for high-efficiency antennas, the modeling of array receiving efficiency is challenging. An accurate full-wave model is used and the results are verified by the reported test results.

Antenna loss for an isolated single array element is close to zero, that for the array antenna, however, can be largely exacerbated by the decrease of array element spacing in wavelength and the steered beams with large scanned angles. Since the array antenna loss is usually referred to the single antenna loss in traditional thought, the array antenna loss might be underestimated for phased array feeds applied for radio telescopes due to mutual coupling effects. These results help to illustrate the distributed nature of losses in antenna arrays and will help to advance the development of high-sensitivity array receivers for satellite communication and radio astronomy applications.