Beam Scan Angle Dependence of Array Antenna Loss and Receiving Efficiency

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The key figure of merit for active receiving arrays for satellite communications and radio astronomy is sensitivity (G/T_{sys}), which is directly proportional to signal to noise ratio (SNR). Antenna loss is critical to the noise budget for a high-sensitivity receiver system. A state-of-art radio telescope receiver achieves a system noise temperature at L-band of less than 20 K, and even small losses would lead to an unacceptable reduction in sensitivity. Losses for single antennas can be minimized by using high conductivity metals, low dielectric loss materials and evenly distributing currents. It is less well understood that loss for array antennas is also influenced by mutual coupling between array elements and the beamformer weights applied to the signal from each element.

Antenna loss for active receiving phased arrays and focal plane phased array feeds is studied using the active array receiving efficiency. 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. Using a full-wave model, we have found that strong mutual coupling and large variation of beamformer weights lead to a decrease of array effective resistance and an increase of the array effective loss resistance due to concentrated surface currents on the array elements.

In addition to aperture arrays, we also consider phased array feeds located at the focal plane of a large reflector. Compared to phased array antennas, antenna loss for phased array feeds is more sensitive to mutual coupling and beam steering angle. This study shows that receiving efficiency and array effective resistance can be used to understand the behavior of array radiation and loss properties of high sensitivity array designs.