Experimental Demonstration of a Superdirective Horn Antenna Designed by Poynting Streamline Method

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Antennas are commonly modeled and understood as transmitters, and the reciprocity theorem is used to obtain the receiving properties of the antennas. The goal of this work is to directly analyze antennas as receivers in terms of the influence of antennas on received fields and consider whether this approach can lead to unique insights or new design method.

A receiving antenna can be considered as a device that concentrates electromagnetic energy at the load. The interaction between the receiving antenna and incident electric field can be analyzed using streamlines of the Poynting vector field, which we refer to as Poynting streamlines. The field energy absorbed by the antenna load is represented by the Poynting streamlines that terminated on the antenna load. By calculating the Poynting streamline distribution near a receiving antenna, the area of the locus of captured streamlines by the antenna load can be considered as the geometrical shape of the antenna effective area.

High-gain electrically large aperture antennas such as horn antennas commonly use corrugated internal surfaces, metamaterials and dielectric lenses to make the aperture field distribution close to uniform. Alternatively, the aperture field distribution could be optimized using the Poynting streamline approach to make the antenna effective area larger than the antenna physical aperture size. We have designed a screen consisting of rows of metal rods in front of the horn antenna in such a way that Poynting streamlines are drawn towards the antenna aperture. The enlongated Poynting streamlines area associated with a dipole is used to compensate for a notch shape in the Poynting streamlines area for the horn antenna and thereby achieve a more convex streamline area shape. In simulations, the metal screen structure increased the aperture efficiency of a 1.5 $\lambda\times$ 2 λ horn antenna from 85% to 127%. The screened horn antenna was fabricated and characterized in an antenna test chamber. The measured gain increase relative to the bare horn was consistent with a peak aperture efficiency of 115%.