Synthesis of Aperture-Field Distributions for of High-Gain Phased Arrays

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Recent analytical and numerical studies of rather unusual aperture-field distributions for high-gain phased arrays have generated some interesting new results, while leading to a deeper insight, and understanding of the underlying radiation process. The planar, circular-aperture distributions analyzed were synthesized as weighted linear combinations of **TE** and **TM** cylindrical wave-modes with equal azimuth symmetry order $\boldsymbol{m}$. The **TE** and **TM** cylindrical modes used were mathematically defined as linear combinations of the W. W. Hansen's **M** and **N** basis vector-fields, using only Bessel functions of the first kind to express the radial dependence of the five **TE**, and of the five **TM** field-components. The closedform expression of the radial component $\boldsymbol{S}^*_R$ of the Complex Poynting Vector shows that the radial energyflow density of the combined **TE** and **TM** aperture-fields is identically zero, *everywhere* in the half-space above the $\mathbf{z} = 0$ plane of the aperture, for any values of the radial and azimuth coordinates $\boldsymbol{r}$ and $\boldsymbol{\varphi}$, and of the symmetry order $\boldsymbol{m}$. Further, the imaginary part of the vector product $\boldsymbol{S}^*_R$, that represents *reactive power flow* in the radial direction, also becomes identically zero, when the two mode-types are linearly combined with equal weights. At the same time, however, the axial component $\boldsymbol{S}^*_{\mathbf{Z}}$ of the Complex Poynting Vector of the combined **TE** and **TM** fields is non-zero, and is oriented along the positive z-axis, thus generating a broadside high-gain beam. It appears then that the linear combination of **TE** and **TM** cylindrical wave-modes, with equal order $\boldsymbol{m}$, results in the total cancellation of the radial, active-energy flow, *everywhere* in the $\mathbf{z} \geq 0$ radiation half-space, at all radial, azimuth, and axial positions. The results of preliminary computations, with $\boldsymbol{m} = 1$, show that the electric-field components $\mathbf{E_r}$, $\mathbf{E}_\varphi$ and $\mathbf{E_z}$ have a decaying oscillatory radial dependence, while the axial component $\boldsymbol{S}^*_z$ of the Complex Poynting Vector is sharply peaked at the center of the circular aperture. The azimuth component $\boldsymbol{S}^*_\varphi$ of the Complex Poynting Vector is zero a the center of the aperture, and has a mostly non-decaying oscillatory radial dependence. The axial ratio $\rho = \mathbf{E}_\varphi/\mathbf{E_r}$ is exactly equal to **1** on axis (at the center of the aperture), thus representing circular polarization, and goes through poles and zeros with increasing radius. The radiation pattern in the near-, Frenel, and far-field is being determined by using the Green's function, and by combining all the components of the **E** and **H** fields. Present analysis efforts aim at determining an optimum aperturetruncation radius, and an optimum radial *filtering (or windowing)*. As no rigorous procedure is as yet known for determining the optimum combination of truncation radius and radial filter shape, a rather heuristic approach is being used. It has been determined that the new, unusual aperture-distribution may be represented by a continuous spectrum of planar waves, where all the spectrum components have propagation vectors **K** oriented at a constant angle $\boldsymbol{\gamma}$ relative to the broadside z-axis, and phases that are linearly dependent on the azimuth angle $\boldsymbol{\varphi}$. As a consequence, the resulting total phase-front appears to have the shape of a circular helical-surface, similar to a corkscrew. It has been concluded that the radiated beam, generated by that distribution, appears to be the microwave equivalent of an *optical vortex*.

REFERENCES

1. Stratton, J. A., *Electromagnetic Theory*, Chapter VII, 392.