Approximate Analysis of Curvature Effects on the Input Impedance of Axial Slots on Circular Cylinders

D. Chatterjee*, 570-F Flarsheim Hall, CSEE Department, UMKC
5100 Rockhill Road, KC, MO 64110, e-mail: chatd@umkc.edu

Abstract

The method of calculating active element pattern in slotted conformal (or flush-mounted) phased arrays on non-planar surfaces entails the determination of self (Y_{11}) and mutual (Y_{12}) admittances. Analysis of array antenna characteristics on doubly curved or variable curvature surfaces can be accomplished by rigorous numerical approaches such as finite element of finite difference techniques that are otherwise known to be computationally intensive for convex surfaces with electrically large radius of curvatures [R. Mittra, *IEEE Antennas. Prop. Mag.*, v. 46, no. 5, pp. 18-32, Oct. 2004]. In such situations, to calculate the source-excited surface fields on convex surfaces, the *Uniform Theory of Diffraction* (UTD) [P. H. Pathak, *Antenna Handbook*, Y. T. Lo & S. W. Lee (eds.), Van Nostrand, NY, 1988, (ch. 4)] appears to be the only alternate, computationally efficient solution for PEC (perfect electrical conductor) convex surfaces. While the UTD has been successfully (and extensively) applied to calculate Y_{12} between antennas flush-mounted on electrically large surfaces, its application to calculate Y_{11} has not been thoroughly investigated. Preliminary investigations reported in [D. Chatterjee, *IEEE Antennas. Wireless. Prop. Lett.*, vol. 4, pp. 71-74, 2005] showed that the singular behavior near the source region can be reasonably approximated by the corresponding planar approximations to the UTD Green's function. This analysis further suggested that the Y_{11} of a narrow axial slot on an electrically large curved convex surface can be computed with reasonable accuracy from the high-frequency UTD Green's function only. Since the calculation of the surface fields for arbitrary, smooth convex surfaces are essentially ray-optical generalizations of the asymptotic Green's functions for PEC circular cylinders and spheres, a comparative study of the Y_{11} of axial slots on electrically large ($\mathrm{ka} \to \infty$) PEC circular cylinders against the exact results for the Y_{11} of a slot on an infinite ground plane, appears most appropriate. This is accomplished by starting with a new form of the PEC circular cylinder Green's function in [C. Tögkoz *et. al.*, *IEEE Trans. Antennas. Prop.*, pp. 1435-1443, Apr. 2005] which is specialized near the paraxial region via different approximation to the Hankel function in the original exact solution, resulting in a final form distinct from the conventional UTD Green's function [Pathak, *op. cit.*]. The special feature of the paraxial Green's function, G_{zz}, is that for collinear source and observation locations on the cylinder generator axis, the surface field varies with $\frac{1}{\mathrm{ka}}$, where ka is the electrical radius of the circular cylinder. This facilitates the analysis of the effects of the electrical size of the cylinder on the Y_{11} of a narrow axial slot of vanishing width (*i.e.*, axial slit). The Y_{11} of such narrow slot of vanishing width, on a PEC circular cylinder, is calculated from the paraxial G_{zz} following the general formula in [R. F. Harrington, *Time Harmonic Electromagnetic Fields*, IEEE Press, NY, 2001, p. 429, Eq. (8-156)]. Furthermore, the expression for Y_{11} of a narrow slot was reduced to a simple one-dimensional integral, and unlike the double spectral integrals in an earlier work [S. W. Lee, *Electromagnetics*, no. 2, 1982, p. 117, Eqs (10.10a, b)]. The axial slot Y_{11} was numerically compared against the well-known Booker relationship [Harrington, *op. cit.*, p. 380] which calculates the slot Y_{11} from the knowledge of the dipole input impedance, Z_{d}, via the relationship $\mathrm{Z}_{\mathrm{d}}\mathrm{Z}_{\mathrm{s}} = \frac{\eta^2}{4}$, for a slot in an *infinite* ground plane. (Here the slot impedance $\mathrm{Z}_{\mathrm{s}} = \frac{1}{\mathrm{Y}_{\mathrm{s}}} = \frac{1}{\mathrm{Y}_{11}}$.) These Y_{11} results, for comparative analysis, will be made available at the time of the presentation.