A Novel Design Technique for Beam-Waveguide Antennas

W. A. Imbriale, M.S. Esquivel, and F. Manshadi
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

JPL has recently built a new 34-meter beam-waveguide (BWG) antenna at Goldstone's Deep Space Station 13 site (DSS-13). The design of the center-fed BWG consists of a beam magnifier ellipse in a pedestal room located below ground level that transforms a 22-dB gain feedhorn into a high-gain 29-dB gain pattern for input to a standard four-mirror (two flat and two paraboloid) BWG system. The design of the upper section of the BWG is based on a Geometrical Optics (G. O.) criteria which guarantees a perfect image from a reflector pair. The system was initially designed (Phase 1) for operation at 8.45 GHz (X-band) and 32 GHz (Ka-band) and has less than 0.2-dB loss (determined by comparing the gain of a 29-dB gain horn feeding the dual-shaped reflector system with that obtained using the BWG system). In Phase 2, S-band (2.3 GHz) is to be added.

If a standard 22-dB S-band horn is placed at the input focus of the ellipse, the BWG loss is greater than 1.5 dB, primarily due to the fact that, for low frequencies, the diffraction phase centers are far from the G. O. mirror focus, resulting in a substantial spill over and defocusing loss. This defocusing is especially a problem for the magnifier ellipse, where the S-band phase center at the output of the ellipse is 3 meters from the G.O. focus.

A straightforward design by analysis would prove cumbersome because of the large number of scattering surfaces required for the computation. Rather, a unique application was made of the conjugate phase-matching techniques to obtain the desired solution, A plane wave was used to illuminate the main reflector and the fields from the currents induced on the subreflector propagated through the BWG to a plane centered on the input focal point. By taking the complex-conjugate of the currents induced on the plane and applying the radiation integral, the far-field pattern was obtained for a theoretical horn that maximizes the antenna gain.

To synthesize a horn quickly and inexpensively, the theoretical horn was matched as well as possible by an appropriately sized circular corrugated horn. The corrugated horn performance was only 0.2-dB lower than the optimum theoretical horn but 1.4 dB above the standard 22-dB horn. A system employing the corrugated horn was built and tested and installed in the 34m BWG antenna as part of a simultaneous S/X-band receiving system,

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