**Shaped Reflectors for Toroidal Beams**

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We propose a novel technique for single-reflector, single-feed toroidal beam antenna systems. The reflector surface is shaped so as to provide a doughnut-like beam pattern with desired peak, beam width, and null depth at pattern center. The feed element is simply a rectangular pyramidal horn. Reflector design is achieved as an exact, closed form solution, derived from Maxwell's equations and the associated boundary conditions, and specifically adapted to producing a desired far field pattern.

Spurred on by increasing demands for doughnut-shaped beams, typically for radar surveillance and satellite communication, a variety of toroidal antennas is frequently encountered. In one common embodiment for the annular antennas with equal transmit/receive power, the gain increases as the look angle departs further and further away from the center, in order to maintain the same power level by compensating for the longer path length. The null depth at the center is dictated by the distance between antenna and target, while the beam peak is related to the size of the coverage area. In this way, the far field pattern becomes fully specified once the beam peak, null depth, and edge roll-off requirements have been set. This far field requirement having been fixed, the design of a shaped reflector illuminated by a single feed horn is arrived at via an exact, closed form solution. The CPU required to generate a thousand points of the shaped reflector surface amounts to merely a few minutes of real time. No optimization algorithms whatsoever are involved in producing this closed form solution. For the purpose of demonstration, we have also fabricated on our 3D printer a toroidal beam antenna for equal power reception at geostationary orbit. Test results are presented as part of the validation data.

Beam performance verification was carried out by software simulations as well as by outright hardware measurements. Four different antenna designs are presented herewith for demonstration, their key parameters being beam peak, beam width, and null depth. The far field patterns of these four shaped reflectors were obtained as numerical simulations on commercial software. Good correlation is evident between the required and calculated far field performance. Furthermore, one of the shaped reflectors has been fabricated using a 3D printer, providing thus an opportunity for actual near-field measurements, measurements subsequently propagated numerically through standard methods into the far zone. Excellent test results in this category will likewise be shown.