GTD Annular Slot Antenna Models and Wire Scattering

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ABSTRACT: Antenna patterns were calculated for two computer models of an annular slot antenna using the Basic Scattering Code (BSC) implementation of GTD. The patterns are compared with a measured pattern. The two computer models are a small electric monopole and a ring of rectangular slots. The monopole model showed good agreement with the measured pattern. The monopole was also used to compute GTD scattering from a thin cylinder, and the results compared with a more accurate field calculation using the Method of Moments.

BSC Computer Models for Annular Slot Antenna:

The annular slot antenna, also sometimes called a flush disk capacitor antenna, is sketched in Figure 1. It is excited as a short length of circular waveguide beyond cutoff in the TM01 mode [Johnson & Jasik, pg 6-11]. The cavity is recessed into a ground plane or vehicle, so that the disk and annular slot are flush with the ground plane or skin of the vehicle. Since it can be recessed and does not require any protrusions, this antenna is widely used for aircraft.

For modeling antennas in a GTD computation, the Basic Scattering Code (BSC) from Ohio State provides dipoles, monopoles, and rectangular slot antennas. Using the BSC the two different computer models shown in Figure 2 were investigated for the annular slot: a "wagon train" of rectangular slots, and a small electric monopole. All the default settings for the BSC were used, including slope diffraction.

The "wagon train" of rectangular slots model has an obvious physical similarity to the annular slot. The eight slots are apertures in a ground plane or conducting plate. All the slots are excited in phase with the E field across the narrower dimension of the slot. The "wagon train" of slots computer model is flush with the surface.

The monopole computer model derivation is summarized in Figure 3 as follows. The equivalence theorem allows us to replace a slot in a ground plane with a magnetic current [Milligan pg. 70, Elliott pg 336]. A small magnetic current loop radiates the same pattern as a small electric monopole with uniform excitation

[Balanis pg.169]. Therefore a small monopole antenna with uniform excitation was used to model the annular slot antenna. The monopole protrudes .005 λ above the ground plane.

Figure 4 compares the resulting calculated and measured patterns using the small electric monopole computer model. The antenna was mounted on a circular ground plane with a diameter of 4.186 wavelengths for both the measurements and the computer model. The measured and calculated patterns are normalized to their pattern maxima. Quite good agreement is seen between the calculated and measured patterns using the monopole model.

Using the "wagon train" of rectangular slots computer model, dimensioned to provide the closest fit to the physical dimensions of the annular slot, the resulting calculated antenna pattern over the ground plane is shown in Figure 5. The pattern does not agree very well with the measured pattern which was shown in the previous figure. A much better prediction for the wagon train of slots, as shown in Figure 6, was obtained by halving the radius of the ring of slots and also halving the width of each rectangular slot. However the calculated pattern of Figure 6 is still somewhat less accurate than the monopole antenna pattern of Figure 4. Since there are eight separate slots, the wagon train model also takes eight times as much computer time to run as does the monopole computer model.

Therefore the monopole model is the recommended BSC model for an electrically small annular slot. The accuracy and computational speed of the monopole model makes it highly amenable for use in a much larger GTD computer model such as of an aircraft or ship.

Modeling of Thin Cylinders: BSC vs MOM

High frequency approaches such as GTD and UTD for modeling electromagnetic scattering require that dimensions of scatterers be on the order of a wavelength or larger. However, structures such as aircraft or ships often carry wires or thin cylinders for use as antennas, masts, guy cables, etc. The diameter of these wires and thin cylinders is typically much less than a wavelength when GTD or UTD is being used, yet these thin scatterers can cause some scattering.

Cylinders of about 1/12 wavelength radius near a monopole antenna were modeled using UTD, and the results are compared with a much more accurate low frequency Method of Moments (MOM) approach. The Ohio State Basic Scattering Code (BSC) was used for the UTD analysis, and the Lawrence Livermore National Labs NEC code was used for the moment method (MOM).

The geometries modeled are shown in Figures 7 and 8. If the thin cylinder scatterer were not present, a conical cut about the axis of the monopole would show a uniform pattern. The resulting calculated patterns for the scatterer positioned as in Figure 7 is shown in Figure 9. About 2 dB of ripple is seen in both the MOM and BSC calculations. The angular positions of the peaks of the ripple show some correlation between the two patterns.

Therefore the inclusion of the thin cylinder in the BSC model has resulted in a pattern which is somewhat more accurate than omitting the cylinder altogether. However, the scattering effect is small for this geometry, and so if the cylinder was omitted altogether from the BSC model the level of error introduced would probably not be significant for most computer models of large structures such as ships and aircraft.

For the scatterer positioned as in Figure 8, the UTD-BSC field was uniform with negligible ripple. This was in contrast to the MOM calculation which showed almost total suppression by the cylinder of the radiated field. This total loss of radiation in the MOM model for Figure 8 is most likely because the cylinder acts as a transmission line over the ground plane, and the antenna launches its signal into the transmission line which does not radiate well. Therefore the MOM model is much more accurate than the UTD model for the thin cylinder position shown in Figure 8. These fields were not plotted because they are so easily summarized as practically uniform for the BSC and almost non-existent for MOM.

A more accurate way to model wires or thin cylinder scattering in a BSC computer model is to incorporate results from an MOM calculation into the BSC model. The two computer programs are designed to be used together. Using this approach, the currents on thin cylinders would be accurately computed using MOM, and then these current magnitudes and phases used to excite an antenna in the BSC computer model in the place of the scatterer. This combined MOM and BSC approach is time consuming for the personnel doing the computer modeling and it also takes considerably more computer time to run since the BSC model would have several more antennas. This approach was therefore not tested, but would probably work well for both of the cylinder scatterer geometries shown. The BSC would reproduce the reradiated fields from the cylinder (now included as an antenna) and also from the reflected image of the cylinder. Hybrid MOM-GTD computer codes such as GEMACS were not available for use on this problem.

Acknowledgment

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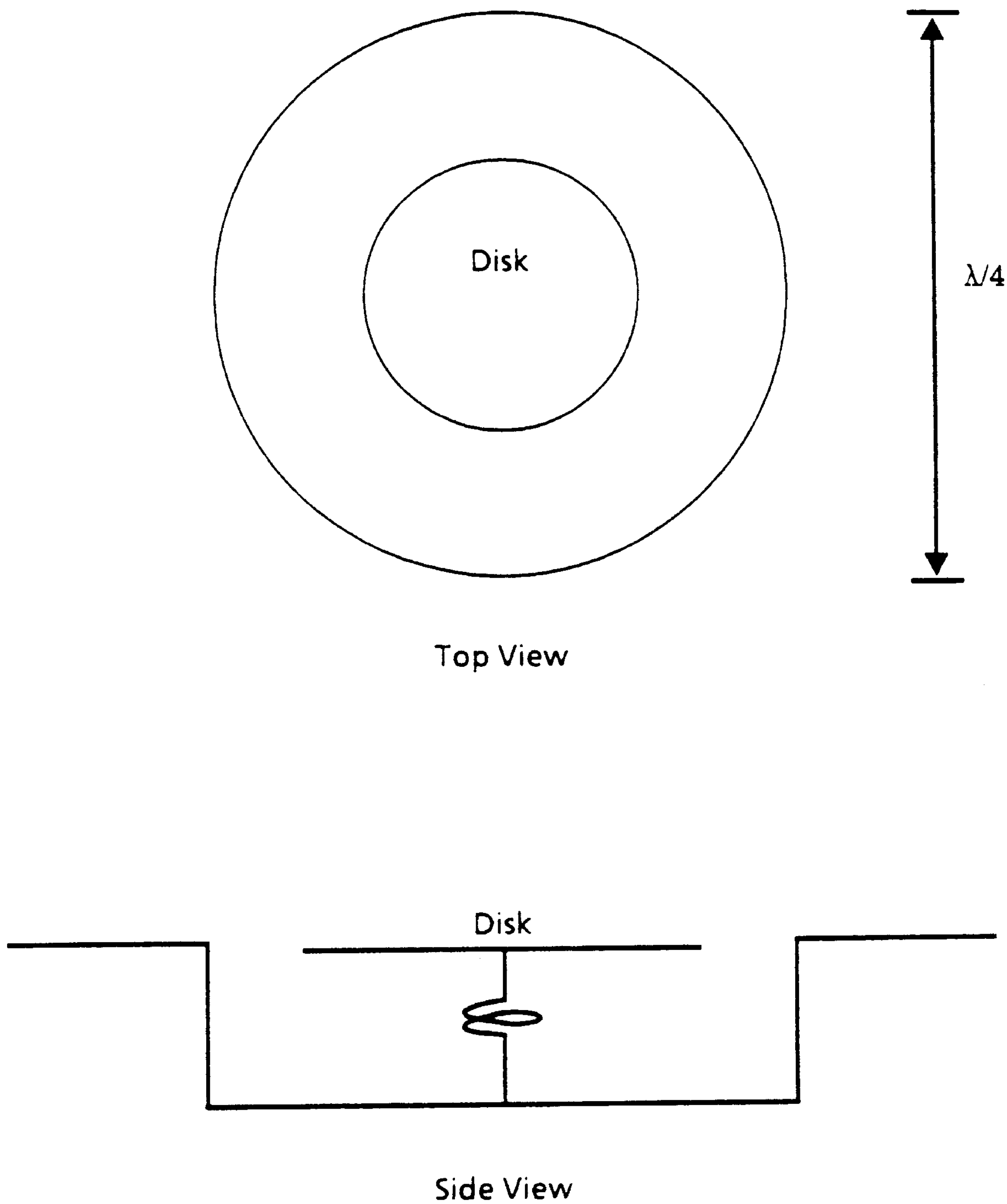
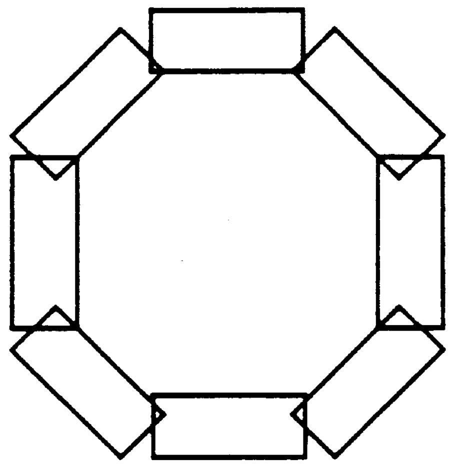
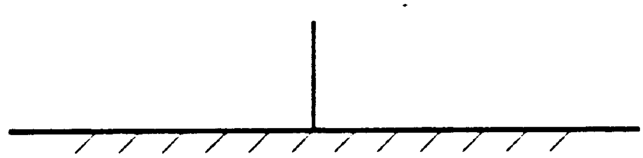


Figure 1. Annular Slot or Flush Disk Capacitor Antenna



"Wagon train" of slots computer model
(top view)



Monopole computer model, $\lambda/200$ long.
(side view)

Figure 2 Computer Models

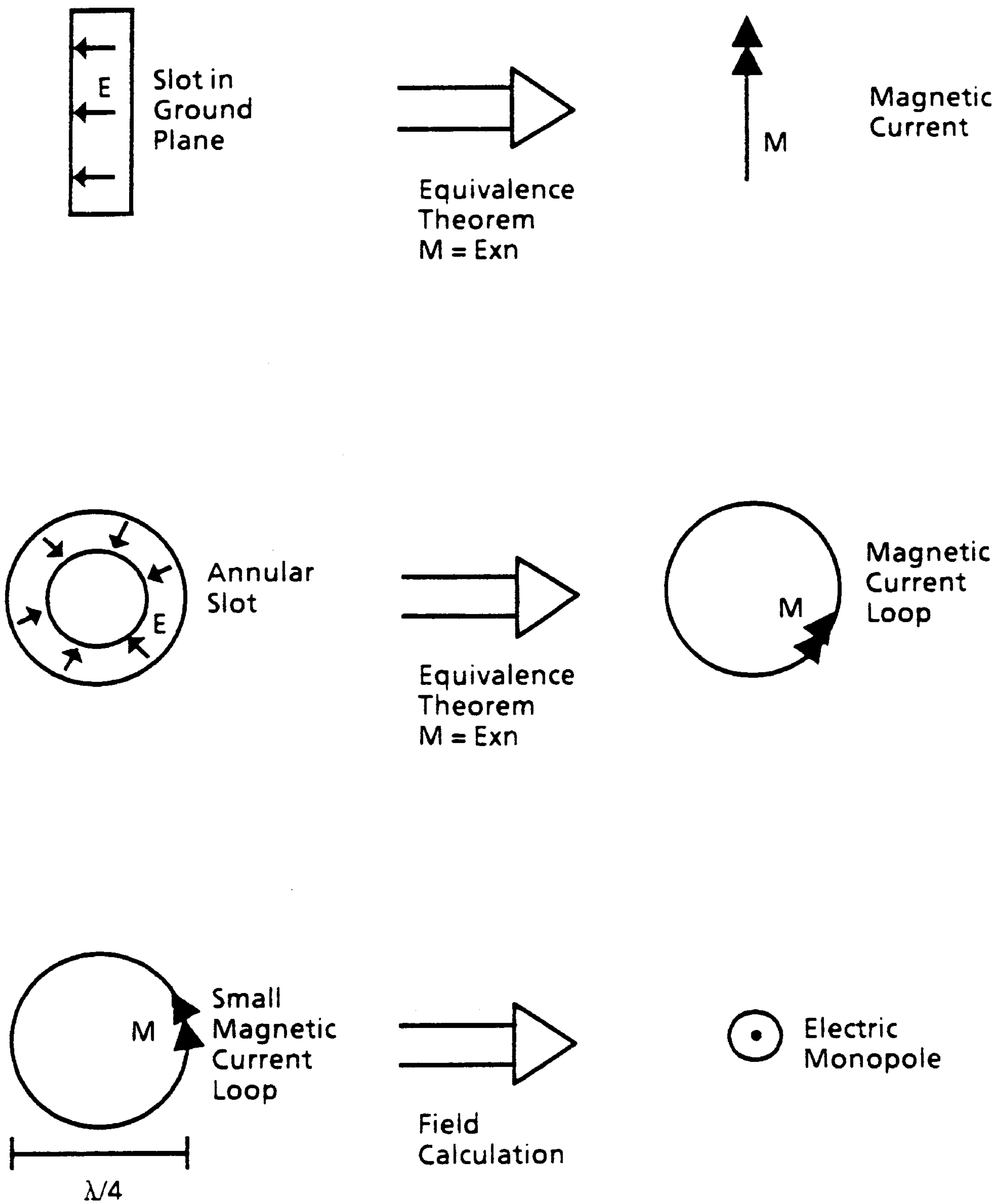
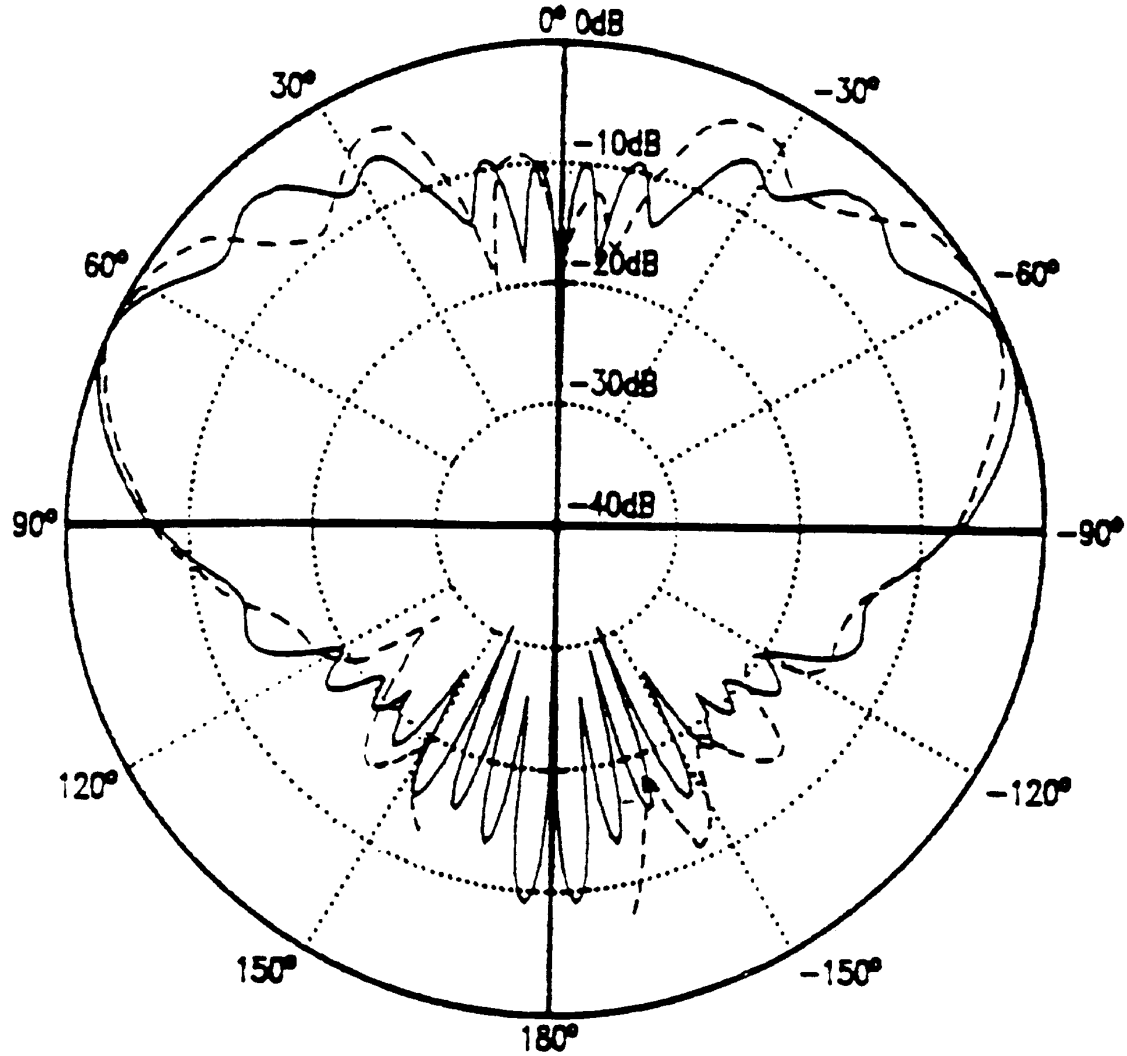


Figure 3. Summary of Electromagnetic Derivation of Monopole Model from Annular Slot

CALCULATED AND MEASURED FIELDS
MONOPOLE MODEL



Solid is Calculated at Georgia Tech Using GTD
Dashed is Measured at Georgia Tech

Figure 4.

CALCULATED FIELD
"WAGON TRAIN OF SLOTS" MODEL

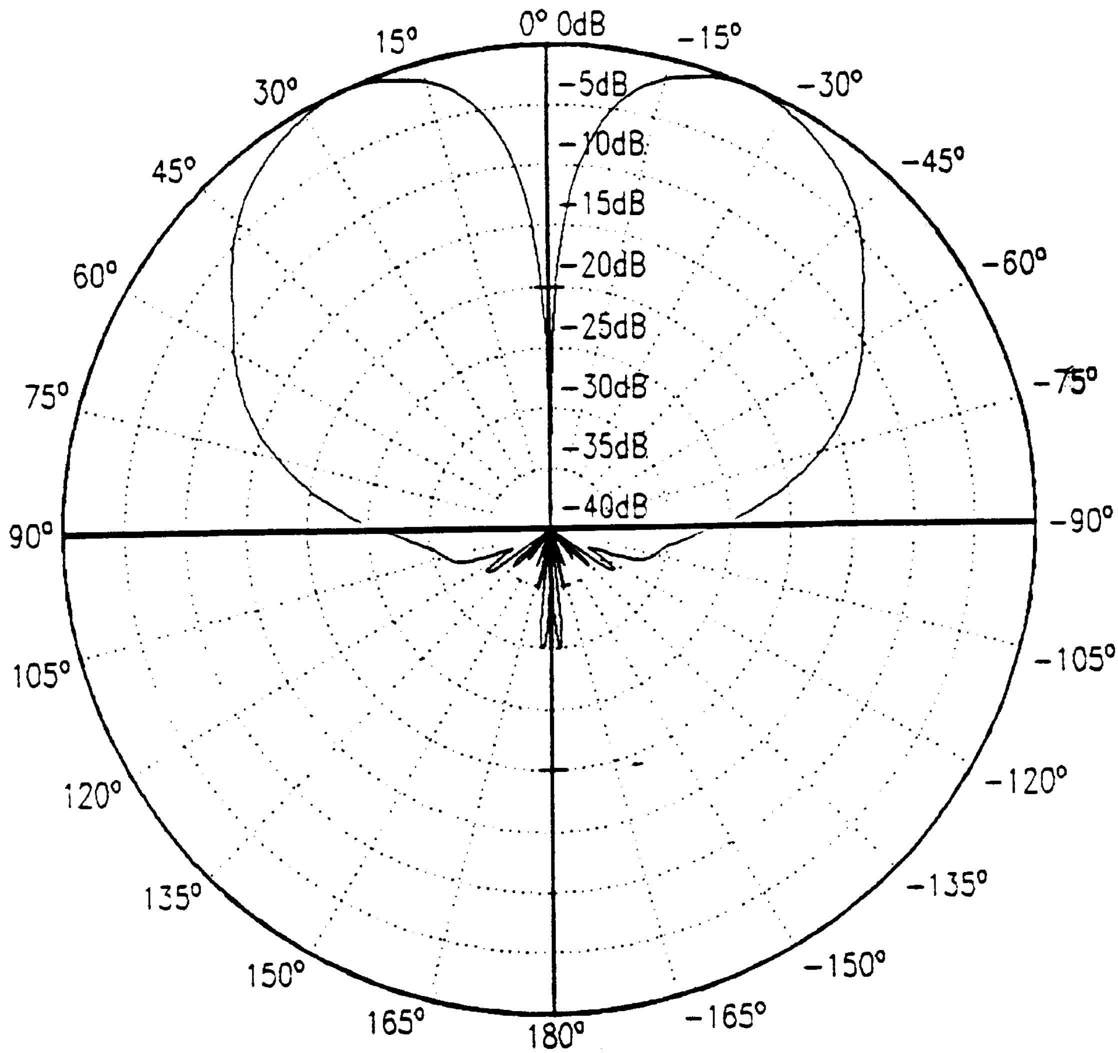


Figure 5. **Computed Pattern - Wagon Train of Slots (Full Ring Radius)**

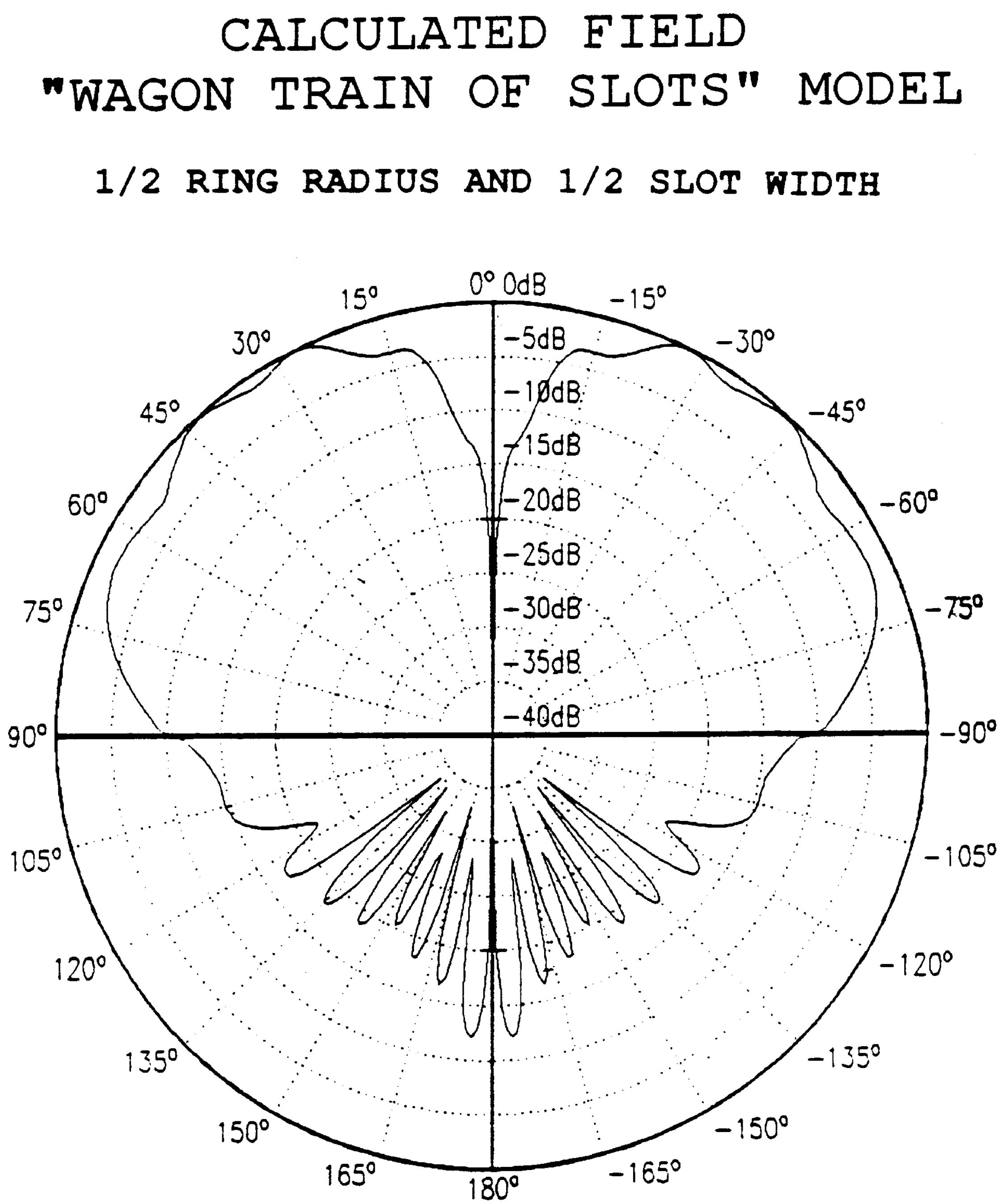


Figure 6. Computed Pattern - Wagon Train of Slots (Half Ring Radius)

Thin Cylinder Scattering Geometries

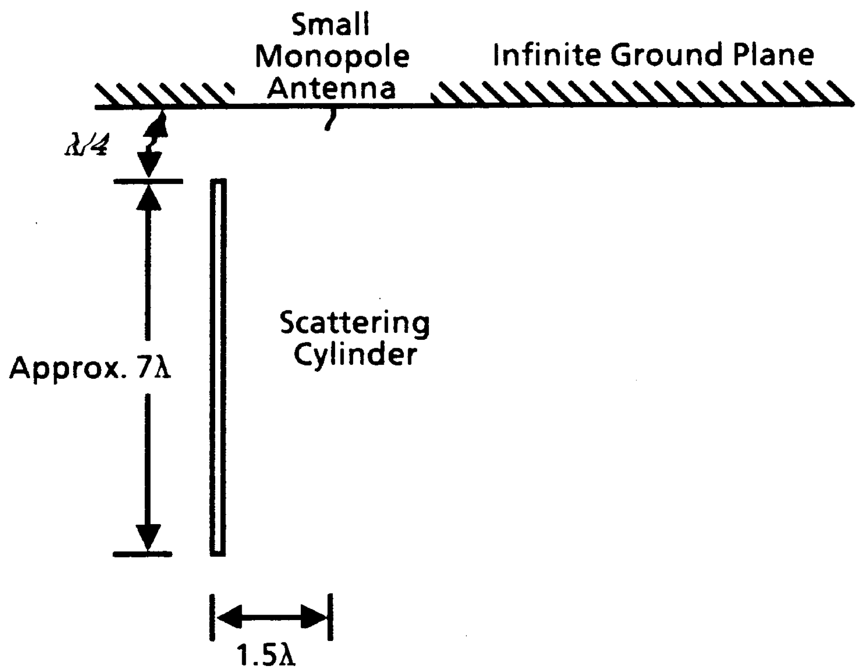


Figure 7

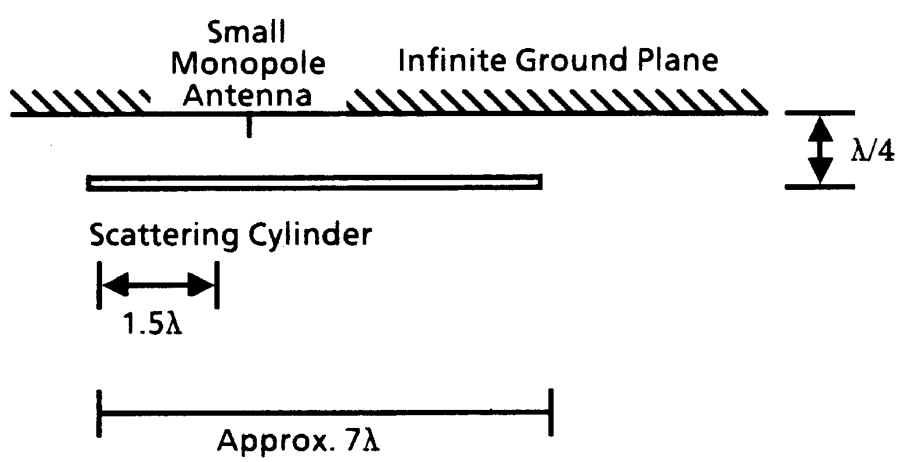


Figure 8

SCATTERED FIELDS: MOM vs. UTD

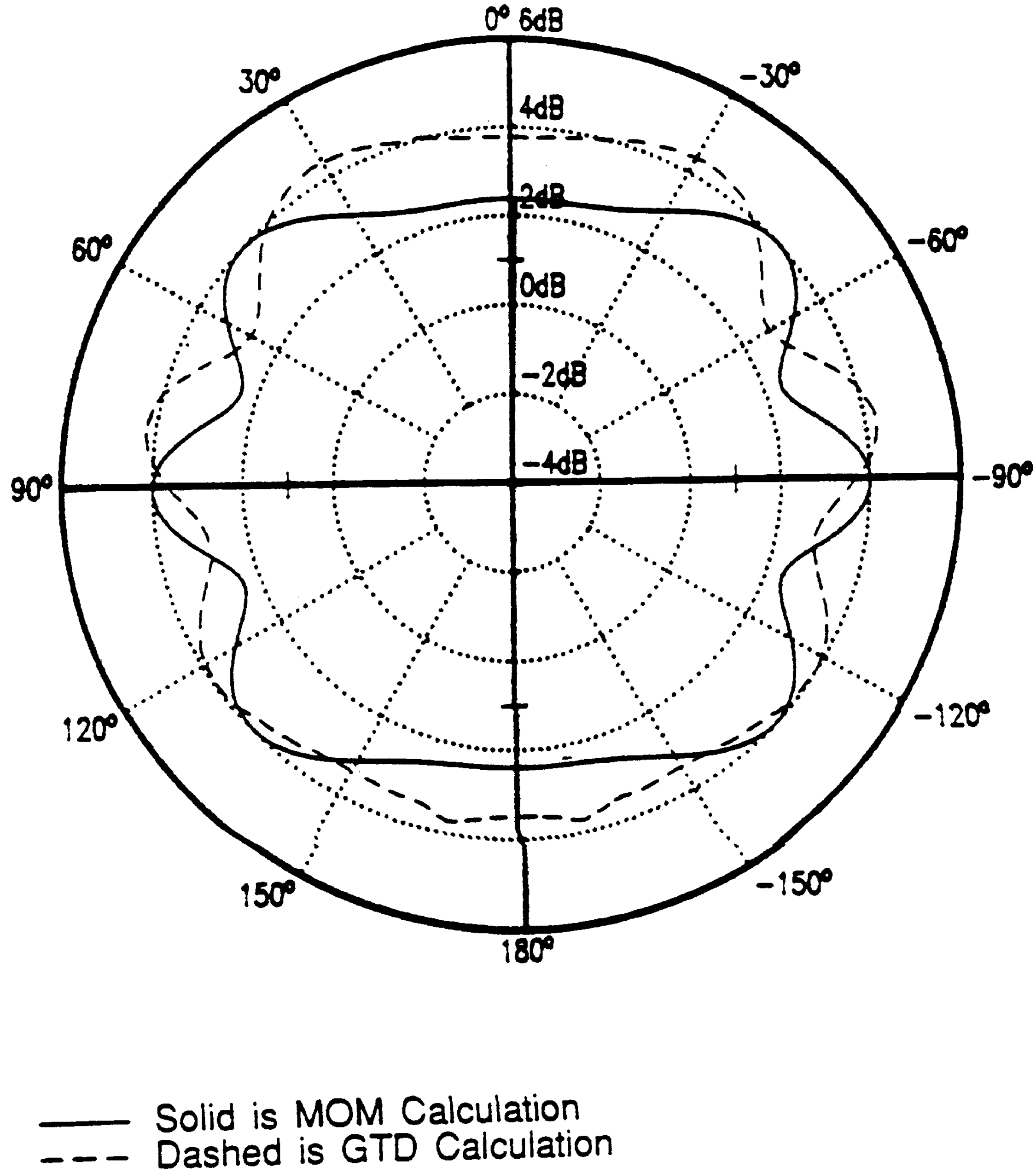


Figure 9.