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Finite Element Analysis of Curved Cone Corrugated Ground Plane Conical Antenna

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Abstract: Curved cone corrugated ground plane conical antenna has been designed and analyzed using Finite Element Method. In this paper, we introduce a novel Curved cone corrugated ground plane conical antenna for ultra-wideband (UWB) applications. The antenna is composed of curved cone with narrow corrugation on finite ground plane and fed by a 50Ω coaxial cable. The designed antenna operates over impedance bandwidth (200 MHz-11.17 GHz) for return loss S_{11} < -10dB. Parametric studies have been carried out to arrive at the optimum antenna dimensions to have a wide bandwidth (VSWR<2).

Keywords: Finite Element Method, Conical Antenna, Wideband Antenna, Corrugation.

1. INTRODUCTION

The need of ultra wideband antennas is increasing for both military and commercial applications. The UWB radio technology promises high resolution radar applications, sensor networks with a large number of sensors as well as high data rate communication over short range for personal area networks. With a need for antennas with the characteristics of broadband and small electrical size, conical antenna structures have been focused by researchers. Moreover conical antennas are extensively used for wireless applications due to their broadband characteristics and relative simplicity.

Bandwidth enhancement has been achieved by suitably introducing narrow corrugation on the ground plane with curved cone. The conical antenna is ideally mounted on a semi-infinite ground plane. Practical finite ground planes can limit the performance of antenna. Periodic surfaces such as rotationally symmetric corrugated structures have been capable of improving the field characteristics of the conical antenna. Finite ground planes for monopole antennas can be viewed as having two main functional properties. Firstly they act as a plane of symmetry which in the ideal case allows the device to produce a radiation pattern that is identical to the equivalent dipole over one hemisphere. Secondly, the presence of the ground plane provides shielding in the other hemisphere. In certain applications it is highly desirable to mitigate the effects of finite (and imperfect) ground planes. The main effects of a finite ground plane are the introduction of standing waves between the antenna feed point and the edge and also the presence of diffraction due to the discontinuity. The objective of the work presented here is to investigate whether applying surface wave modification techniques such as corrugated grounds and curved cone can achieve this objective.

2.USE OF COMSOL MULTIPHYSICS

Antenna geometry is simulated using COMSOL Multiphysics. The 2D In plane TM wave application mode of RF module is used for simulation of conical antenna. Harmonic propagation is used for analysis of the field characteristics. Transverse electromagnetic fields (TEM) wave propagating in a coaxial cable. Assuming time-harmonic fields with complex amplitudes containing the phase information, the electric and magnetic field strengths, E and H are represented by:

$$E = e_r \frac{C}{r} e^{J(wt-kz)} \quad (1)$$

$$H = e_\phi \frac{C}{rZ} e^{j(wt-kz)} \quad (2)$$

Where, C is an arbitrary constant, z is the direction of propagation and r, ϕ, and z are cylindrical coordinates centered on axis of the coaxial cable. w is the angular frequency, the wave impedance in the dielectric of the cable is denoted by Z, and

The electric field has a finite axial component in air whereas the magnetic field is purely azimuthal. Thus axisymmetric transverse magnetic (TM) formulation is used to construct the antenna, and the wave equation is given as:

$$\Delta \times (\frac{1}{\varepsilon} \Delta \times H_\phi) - \mu w^2 H_\phi = 0 \quad (3)$$

The boundary condition for the metallic surfaces is „

$$n \times E = 0 \quad (4)$$

For the coaxial cable to make the boundary transparent to the wave, a matched coaxial port boundary condition is used. The geometry is bounded some distance from the antenna to limit the radiation in a finite region using a scattering boundary condition, allowing outgoing spherical waves to pass without being reflected. A symmetry boundary condition for boundaries at „r = 0" is applied because the model is axis-symmetric. Scattering boundary conditions are represented by the equation

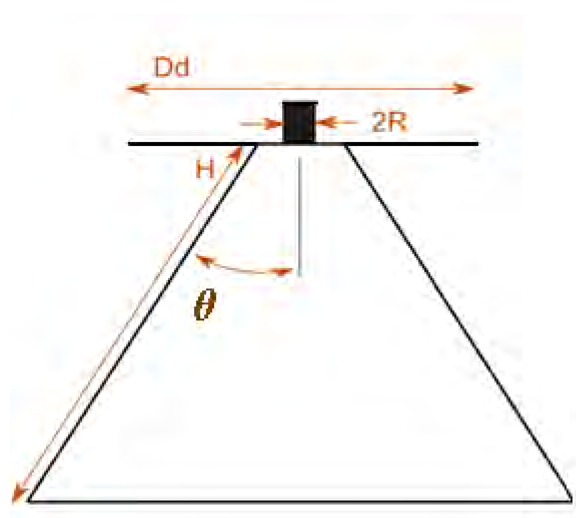
$$n \times (\nabla \times H_\phi) - jkH\phi = 0. \quad (5)$$

The boundary at the antenna feed is used as a port because the excitation source of input power P = 1W is attached to it. For port the boundary condition is

$$S = \int \frac{(E - E1) \times E1}{E1 \times E1} \quad (6)$$

3. ANTENNA GEOMETRY

The reference conical antenna is shown in Fig.1. D_d is the diameter of the disk; θ is half of the cone angle; H is slant height.



The Fig. 1 Reference Conical Antenna

The outer conductor of coaxial cable connects the cone and the inner conductor connects the disk. Reference conical antenna geometry consists of a 0.2 m tall metallic cone with a half of conical flare angle of 45° on a finite ground plane. The finite ground plane radius is 0.282 m. 50Ω coaxial cable is used for feeding purpose. Coaxial feed has a central conductor of 1.5 mm radius and an outer conductor of 4.916 mm radius. Central conductor is separated from outer conductor by a Teflon dielectric of relative permittivity of 2.07. In the proposed conical antenna there is no feed gap between the cone and disk.

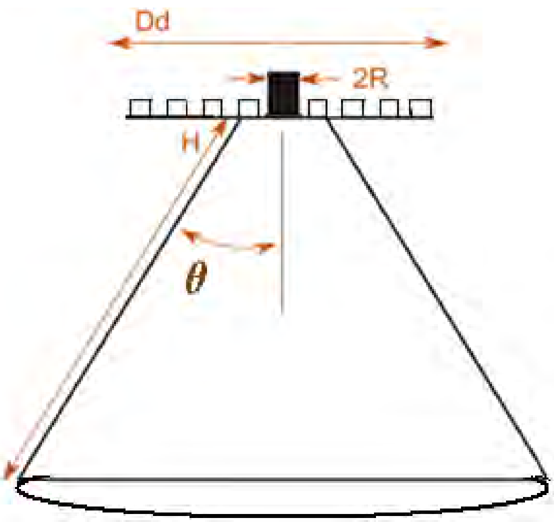


Fig.2 Curved Cone Corrugated Ground Plane Conical Antenna.

Practical finite ground planes can introduces unwanted effects in the radiation patterns such as back lobes. Periodic surfaces such as rotationally symmetric corrugated structures have been proven capable of improving the field characteristics of the antenna. Curved cone corrugated ground plane conical antenna is shown in Fig.2. The corrugations present a capacitive reactance to the passing wave. When a corrugated surface is inductive, it will support surface waves. The depth of corrugations must be between $\lambda/4$ and $\lambda/2$. Less than $\lambda/4$ or greater than $\lambda/2$, it is inductive. Between $3\lambda/2$ and λ it will be capacitive again, but this second pass band is seldom used.

The corrugated surface supports surface waves (TM) when the slot depth is less than $\lambda/4$ (inductive). Inductive corrugate surface supports the surface wave, so the depth of corrugation is chosen to be less than $\lambda/4$.The ground plane is further corrugated with the depth of 0.005m and width of 0.01m.

4. RESULTS AND DISCUSSION

The parametric analysis of antenna characteristic has been done to demonstrate improved broadband properties using the curved cone corrugated ground plane conical antenna. The simulation of the proposed conical antenna has been done using cylindrical-coordinate Finite Element Method. Improvement in performance in terms of bandwidth and matching can be observed from the plots presented below.

4.1 VSWR

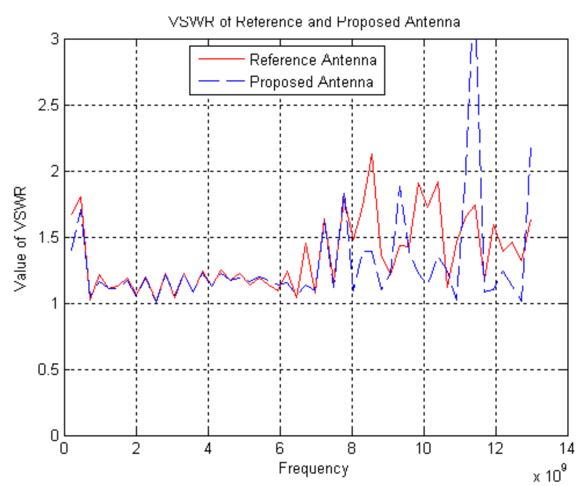


Fig.3 VSWR of Reference and Proposed Antenna.

Fig. 3 compare the VSWR as a function of frequency for the reference antenna with feed radius of 1.5mm and flare angle of 45^{o} with the proposed curved cone corrugated ground plane conical antenna. The VSWR curve can be observed to remain below 2 for the band of frequencies in the range 200 MHz- 8.559 GHz. The curved cone corrugated geometry shows a wider span with VSWR less than 2 for frequencies in the range 200 MHz-11.17 GHz. The bandwidth is improved up to 2.611 GHz.

4.2 Return Loss

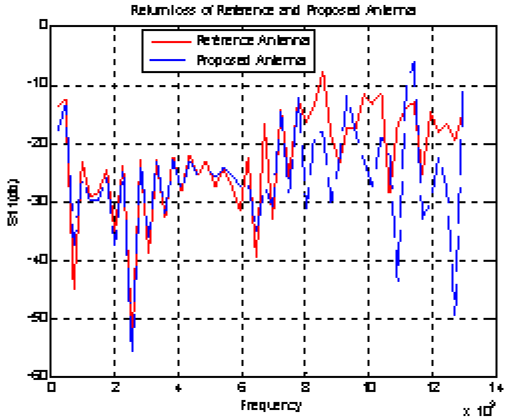


Fig.4 Return Loss of Reference and Proposed Antenna.

Return loss approaches its minima at -54.43 dB for the reference geometry and the return loss peak shoots to -56.64 dB for the proposed geometry. It can be concluded from Fig. 4 that the return loss is improved for the curved cone with narrow corrugations.

The proposed antenna design is therefore suitable for wider band applications maintaining small size of the antenna.

5. CONCLUSION

An efficient curved cone conical antenna with a partially corrugated ground plane has been designed, simulated and analyzed using Finite Element Method. It is observed that curved cone with narrow grooves in the ground plane effectively provide wider bandwidth for the reduced size of the conical antenna. The return loss bandwidth of the proposed antenna is from 200 MHz to 11.17 GHz thus covering an ultra wide band required for wireless communications.

6. REFERENCES

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