Analysis of Linearly Tapered Slot Antennas on a Dielectric Substrate

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Abstract

A two level approach has been developed for the analysis of the Linearly Tapered Slot Antenna (LTSA) on a finite dielectric substrate. An approximate closed form Green's function is obtained for the infinite dielectric structure. Galerkin type Method of Moments and RWG basis functions are used in order to solve Electric Field Integral Equations derived for the LTSA conductor and infinite dielectric parts. The feed section of the antenna is modeled as a voltage source with a small gap. In order to model the truncation effects of the dielectric region, equivalent volume polarization current density in the dielectric part is obtained. Obtaining the current distribution on the conducting plates and the polarization current density in the dielectric region separately reduces the number of unknowns, and improves the solution speed.

1 Introduction

The Linearly Tapered Slot Antenna (LTSA) as shown in Figure 1 is very important for the millimeter wave and and microwave antenna applications [1]. Method of Moment (MoM) analysis of the antenna was first presented by Johansson and Janaswamy [2-3]. In their method, linearly tapered slot geometry is approximated by two skewed rectangular plates, and the patterns of antennas with actual geometry has shown differences. Koksal and Kauffman considered the actual geometry of the antenna and analyzed LTSAs on a finite dielectric substrate by using MoM [4].

In this work LTSAs on a finite dielectric substrate is analyzed by the MoM using a two level approach. First, an approximate Green's function for an infinite dielectric slab is obtained. The Green's function expressed in closed forms in terms of complex images is used in the MoM solution of the electric field integral equation to obtain the resulting current distribution on the structure. In order to take into account the effect of the truncated dielectric slab, dielectric region is modeled by the polarization currents.

2 Method

In order to analyze the conducting part of the LTSA by using the MoM, the conductor current is expanded using RWG basis functions and the same functions are also used for testing of the electric field integral equation.

After the current on the conducting parts of the antenna is found, The dielectric region is replaced with the equivalent volume polarization current density and the the whole problem is considered in free-space. To compute the polarization current, the closed-form Green's function for an infinite dielectric substrate is utilized. The Green's function is obtained in the first level in terms of complex images for the source of a horizontal electric dipole. Then, using RWG function for both basis and testing functions, the surface current density for the infinite dielectric slab is obtained. After obtaining the surface current density, the dielectric slab geometry is divided into cubical sections as shown in the Figure 2

The components of the scattered electric field in the middle of each cubical sections can be written in terms of the surface current density and the associated closed-form Green's function, derived for the vector and scalar potentials as follows [6]:

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$$E_x^s = -j\omega G_{xx}^A * J_x + \frac{1}{j\omega}\frac{\partial}{\partial x}\left(G^q * \nabla.\boldsymbol{J}\right) \tag{1}$$

$$E_y^s = -j\omega G_{yx}^A * J_x - j\omega G_{yz}^A * J_z + \frac{1}{j\omega}\frac{\partial}{\partial x}\left(G^q * \nabla.\boldsymbol{J}\right) \tag{2}$$

$$E_z^s = -j\omega G_{zz}^A * J_x + \frac{1}{j\omega}\frac{\partial}{\partial x}\left(G^q * \nabla.\boldsymbol{J}\right) \tag{3}$$

The scalar potential Green's function can be obtained in closed form as [7]:

$$G \cong \sum_{m=1}^{M} a_m \frac{e^{-jkr_m}}{r_m}, \tag{4}$$

where complex distance r_m is given by

$$r_m = \sqrt{(x-x')^2 + (z-z')^2 - \alpha_m^2}. \tag{5}$$

α_m is obtained from the GPOF approximation. The equivalent volume polarization current is obtained [8] as follows:

$$\boldsymbol{J_p} = j\omega(\epsilon - \epsilon_0)\boldsymbol{E}. \tag{6}$$

By using the procedure outlined in this paper, the radiation characteristic of a tapered antenna on a dielectric substrate has been analyzed. Method gives correct results quickly as discussed next.

3 Numerical Results

In order to investigate the effect of the dielectric permittivity, the same antenna geometry with three different permittivities of the dielectric substrate is considered. The results with the antenna parameters of the LTSA are given in Figure 3 and in Figure 4 respectively. It is seen that as the permittivity of the LTSA increases, the E and H-Plane pattern sidelobe levels decrease. The 3 dB beamwidth in the E-Plane increases, whereas the H-plane pattern beamwidth remains essentially the same. This should be expected since a higher percentage of the radiated power is trapped in the dielectric region of the antennas causing directivity to increase as the permittivity increases [8].

4 Conclusion

LTSAs on a finite dielectric substrate are analyzed by using a two level approach: Conductor currents are calculated using MoM method with a closed-form Green's function and the finite dielectric effects are approximated by the polarization current. Numerical results are compared with the existing data favorably. The two-level approach used in this work is a fast and accurate method, and can be used for these type of antennas.

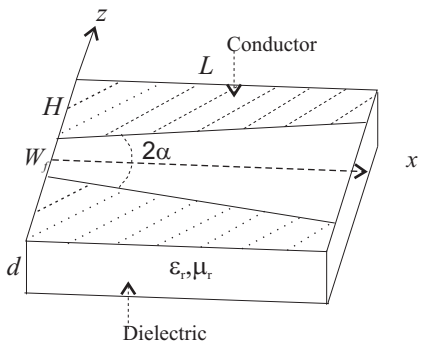

Figure 1: LTSA Geometry

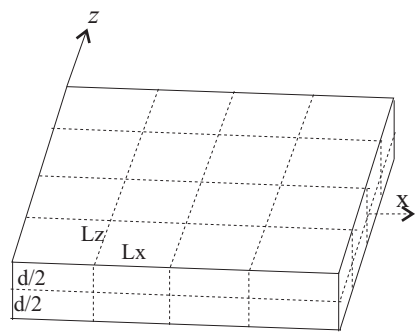

Figure 2: Dielectric Segmentation

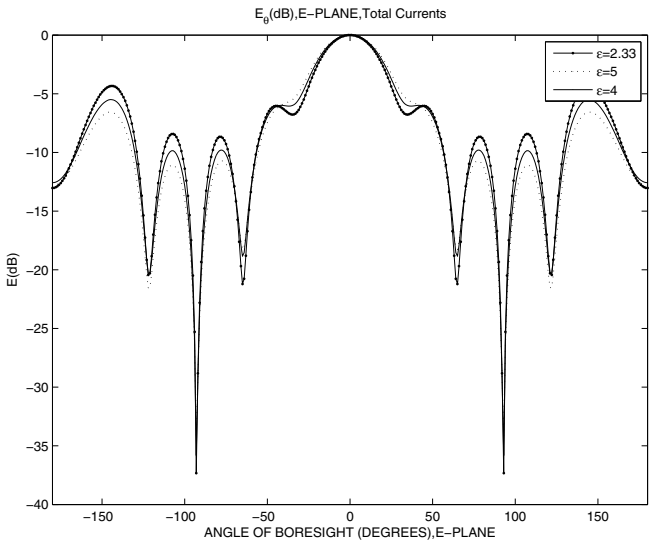

Figure 3: Variation of the E-Plane pattern for a LTSA with $\epsilon_r = 2.33$ (L=2λ, H=$0.4\lambda_0$, d=$0.03\lambda_0$ α=5 degrees) [8].

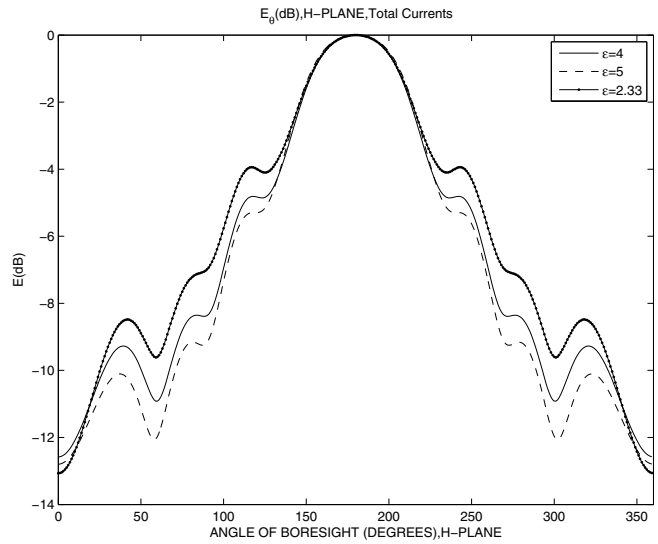

Figure 4: Variation of the H-Plane pattern for a LTSA with $\epsilon_r = 2.33$ (L=2λ, H=$0.4\lambda_0$, d=$0.03\lambda_0$ α=5 degrees).

5 References

1. G.M. Rebeiz, "Millimeter-Wave and Terahertz Integrated Circuit Antennas," *Proceedings of the IEEE*, vol. 80 No.11, pp 1748-1770, Nov. 1992.

2. J. F. Johansson, "A Moment Method Analysis of the Linearly Tapered Slot Antenna," *IEEE AP-S Symposium*, vol.1, pp 383-386, June 1989.

3. R. Janaswamy, "An Accurate Moment Method Model for the Tapered Slot Antenna,"*IEEE Trans. AP-S*, vol. AP-37, pp 1523-1528, Dec 1989.

4. A. Köksal and J. F. Kauffman, "Moment method analysis of linearly tapered slot antennas," *Int J Microwave and Millimeter-Wave CAE 4*, pp 76-87, 1994.

5. S. Balk, “Analysis of Triangular Antennas,” *M. Sc. Thesis*, Department of Electrical and Electronics Engineering, Hacettepe University, Ankara, Türkiye, 2008.

6. F. Çalışkan, “Electromagnetic Analysis of Planar Layered Structures,” *Ph. D. Thesis*, School of Electrical and Computer Engineering, Georgia Institute of Technology, May 2004

7. M. I. Aksun, “A robust Approach for the Derivation of Closed-Form Green’s Functions,” *IEEE Trans. on Microwave Theory Tech.*, vol. 44, pp. 651-658, May 1996.

8. A. Köksal, “Moment Method Analysis of Linearly Tapered Slot Antennas,”*Ph. D. Thesis*, Department of Electrical and Computer Enginnering, North Carolina State University, November 1992.