MICROWAVE EXPERIMENT ON ELECTROMAGNETIC SCATTERING BY THE LUNEBERG LENS

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Abstract:
As a model of the Luneberg lens, a six layered lens was fabricated, in which the optimum dielectric variation is also obtained. A model experiment was performed at 9.2 GHz by using this lens. The electromagnetic focusing effect is theoretically and experimentally observed.

1. Introduction

The Luneberg lens has widely been used as the microwave antennas, radar reflector and transformer from spherical wave into plane wave, etc. The electromagnetic scattering by the Luneberg lens has theoretically been studied by using homogeneous multilayered approximate method[1].

In general the Luneberg lens can be approximated by using a number of different homogeneous dielectric layered media, however, it is very difficult to fabricate the Luneberg lens having many homogeneous dielectric materials. For the applying the radar testing obstacle, the six layered spherical lens was fabricated by Tokipec Company and the optimum dielectric variation is also obtained.

For the purpose of studying the focusing effect by the Luneberg lens, the electromagnetic plane wave scattering by the six layered structure is analyzed by using homogeneous multilayered approximate method and numerical results on the near field distributions in space are presented. In order to check the theory, a microwave model experiment is performed by using Tokipec Company six different homogeneous layered lens. The experimental values are a good agreement with theoretical ones.

2. Formulation of the problem

The geometry of the problem is shown in Fig. 1(a) and the dielectric constant $\varepsilon_s(r)$ of the sphere is defined by

$$\varepsilon_s(r) = 2 - \left(\frac{r}{a}\right)^2 \tag{1}$$

whose profile is a parabolically continuos function of r, it can be approximated by using six different homogeneous dielectric layered media ($\varepsilon_1, \varepsilon_2, \cdots, \varepsilon_6$) illustrated in Fig. 1(b).

The plane wave along the z axis as shown in Fig. 1(a) is assumed to be given by

$$\mathbf{E}^i = E_0 e^{-jkz}\mathbf{i}_x = E_0 \sum_{n=1}^{\infty} (-j)^n \frac{2n+1}{n(n+1)} \left\{\mathbf{M}^i_{o1n} + j\mathbf{N}^i_{e1n}\right\} \tag{2a}$$

The scattered and transmitted waves are represented as

$$\mathbf{E}^s = E_0 \sum_{n=1}^{\infty} (-j)^n \frac{2n+1}{n(n+1)} \left\{a^s_n \mathbf{M}^s_{o1n} + jb^s_n \mathbf{N}^s_{e1n}\right\} \tag{2b}$$

$$\mathbf{E}^t = E_0 \sum_{n=1}^{\infty} (-j)^n \frac{2n+1}{n(n+1)} \left\{a^t_n \mathbf{M}^t_{o1n} + jb^t_n \mathbf{N}^t_{e1n}\right\} \tag{2c}$$

where $\mathbf{M}_{o1n}$, $\mathbf{N}_{e1n}$ are the vector mode functions[2] and defined by

$$\mathbf{M}_{o1n} = z_n(kr)\frac{P^1_n(\cos\theta)}{\sin\theta}\cos\varphi\mathbf{i}_\theta - z_n(kr)\frac{\partial P^1_n(\cos\theta)}{\partial\theta}\sin\varphi\mathbf{i}_\varphi \tag{3a}$$

$$\mathbf{N}_{e1n} = n(n+1)\frac{z_n(kr)}{kr}P^1_n(\cos\theta)\cos\varphi\mathbf{i}_r + \frac{\left[krz_n(kr)\right]'}{kr}\frac{\partial P^1_n(\cos\theta)}{\partial\theta}\cos\varphi\mathbf{i}_\theta + \frac{\left[krz_n(kr)\right]'}{kr}\frac{P^1_n(\cos\theta)}{\sin\theta}\sin\varphi\mathbf{i}_\varphi \tag{3b}$$

a^s_n, b^s_n, a^t_n, b^t_n are the unknown coefficients determined from the boundary conditions on $r=a_1, a_2, \ldots, a_6$ using hormonious approximate multilayared method.

3. Experiment

In the most of papers the theoretical works are mainly treated[1]. A model experiment was performed at f=9.2 GHz. Tokipec company lens is used as the model of Luneberg lens, which has six layered structure (ka=14.5) as shown in Fig. 1(b). Large horn antenna for transmitter and monopole antenna (1/4 λ length) for the receiver are used.

At first the incident plane wave along the z axis (i.e., kz=14.5～72.5) as illustrated in Fig. 2(a) is measured at x=y=0, from which the constant amplitude is found. The electric field along the y axis (i.e., ky=-29～+29) is also measured at x=z=0. As illustrated in Fig. 2(b), almost constant amplitude is also obtained.

In order to find the focusing effect by the Luneberg lens, the amplitude of the near field distribution along the z and y axis is shown in Fig. 3(a) (b). It is found that the peak value of the field occurs at the surface of the sphere, which is called the focal point. Fig.3 shows the comparison between theoretical and experimental value, which is good agreement with ones.

4. Conclusions

Electromagnetic scattering by the Luneberg lens is considered and their near field distributions in space is numerically obtained by using H. M. A. M.. In order to check the theory, a microwave experiment was also performed. As a model of the Luneberg lens, the six layered media was fabricated.

References:

[1] Mikulski, J. J. and Murphy, E. L., "The computation of electromagnetic scattering from concentric spherical structures," IEEE Trans. Antennas & Propag., AP-11, pp.169-177, 1963

[2] Stratton, J. A., Electromagnetic Theory, McGraw-Hill, New York, pp.416-419, 1941.

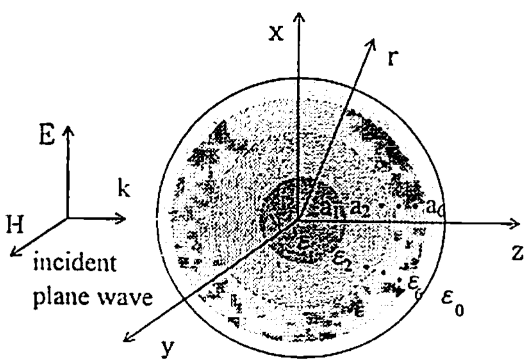

Fig. 1(a) Geometry of the six layred lens and plane wave.

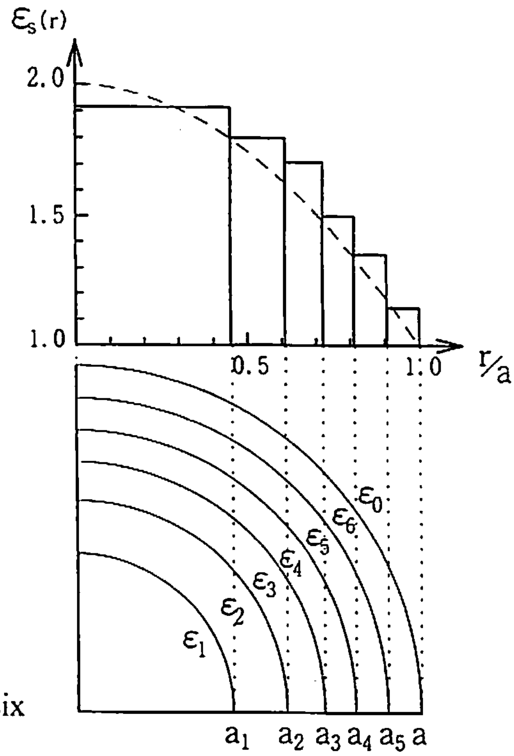

Fig. 1(b) Structure of the six layred media.

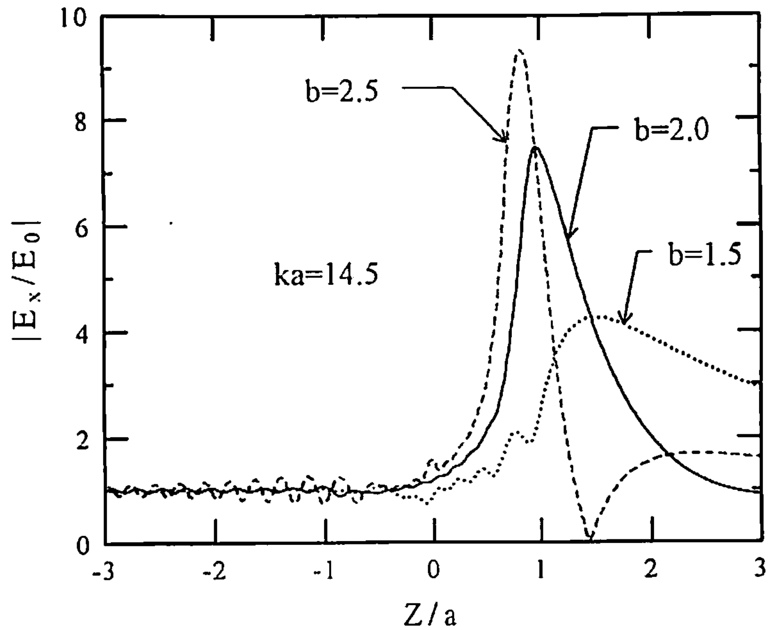

Fig.2 Amplitude of the total electric field along the z/a axis for the various parameters of b and ka=14.5

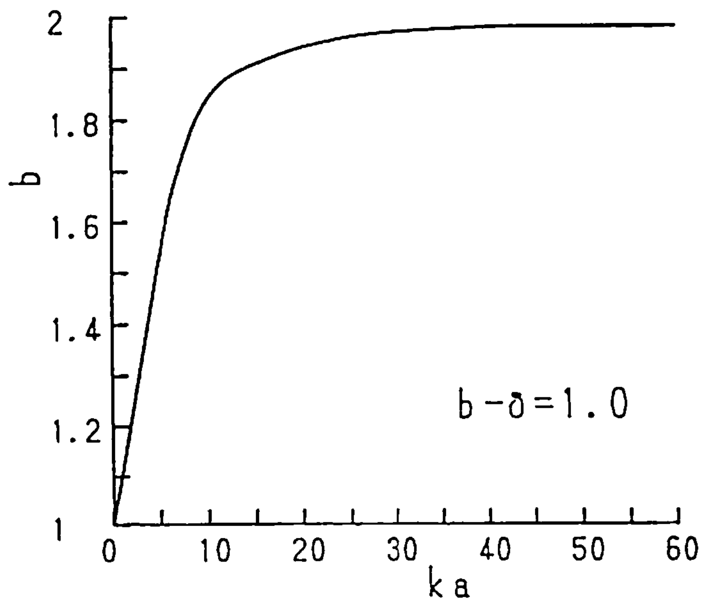

Fig.3 Variation in the dielectric constant b versus radius ka