Radiation Characteristics of Microstrip Antenna on the Cylindrical Bianisotropic Substrates Loaded bianisotropic superstrate

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Abstract - **Radiation characteristics of axial elementary current source on the cylindrical bianisotropic substrateloaded with bianisotropic superstrate layer are presented. The effects of bianisotropic superstrate cover on the radiation problems of a microstrip antenna are studied. This investigation is performed by using the Green function formulation in the spectral domain. Numerical results for the radiation pattern of the bianisotropic superstrate-loaded microstrip antenna is analyzed**

I. INTRODUCTION

Micorstrip antennas on cylindrical substrates have found many applications in aircraft and missiles due to the features of conformability, light weight, small volume, and geometrical compatibility to the vehicle they are mounted on. Printed strip diploes, rectangular and wraparound patches in cylindrical structures have been considered by many researchers.[1]~[3] For many applications, a dielectric superstrate layer is usually added on the top of the antenna element to provide protections against environmental hazard, such as rain, hail, and snow.[4]~[6] Electromagnetic application of complex have received considerable attention in recent years. Wave propagation in bianisotropic media has been discussed in various articles.[7]~[10] Radiation characteristics of element current source on cylindrical bianisotropic substrates were discussed in the paper by Yang[10]. So, the aim of our work is to investigate the radiation characteristics of elementary current source on bianisotropic superstrate-loaded cylindrical bianisotropic substrates. In frequency domain, the most general composites can be characterized via bianisotropic constitutive relations of the type

$$D = \bar{\varepsilon}E + \bar{\xi}H \tag{1}$$

$$B = \bar{\mu}H - \bar{\eta}E \tag{2}$$

the tensors $\bar{\varepsilon}$, $\bar{\xi}$, $\bar{\mu}$, $\bar{\eta}$ are represented by a 3×3 matrix. Our consideration is limitted to the lossless case where the eight tensors in a cylindrical coordinate system are defined as

$$\bar{\varepsilon}_i = \varepsilon_0 \begin{bmatrix} \varepsilon_{ix} & 0 & 0 \\ 0 & \varepsilon_{iy} & 0 \\ 0 & 0 & \varepsilon_{iz} \end{bmatrix}, \quad \bar{\mu}_i = \mu_0 \begin{bmatrix} \mu_{ix} & 0 & 0 \\ 0 & \mu_{iy} & 0 \\ 0 & 0 & \mu_{iz} \end{bmatrix} \tag{3}$$

$$\bar{\xi}_i = c_0^{-1} \begin{bmatrix} 0 & \zeta_i & 0 \\ \zeta_i & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad \bar{\eta}_i = c_0^{-1} \begin{bmatrix} 0 & \zeta_i & 0 \\ \zeta_i & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \tag{4}$$

$i = 1, 2$

where c_0 is the speed of light in free space and the first, the second, and the third columns in the tensors are corresponding to ρ, ϕ, and z, respectively.

The necessary and sufficient conditions for lossless bianisotropic material are that $\bar{\xi}^* = -\bar{\eta}^t$[11]. Under such circumstances, it is seen that ζ in Eq 4. is purely imaginary. The matrix forms in Eqs. 3 and 4 result in an analytic representation for the Green's function which is otherwise not possible. The time dependence $e^{j\omega t}$ is suppressed throughout this paper.

II. ANALYSIS

The geometry of elementary dipole on a

cylindrical bianisotropic substrate with a bianisotropic superstrate cover is shown in Fig.1. The radius of the conducting cylinder is a. The thickness of the coaxial cylindrical bianisotropic substrate and superstrate is d=b-a(region 1) and h=c-b(region 2), respectively. The air is in region 3 with free space permittivity ε_0 and permeability μ_0. The relative permittivity and permeability of bianisotropic superstrate is $\overline{\varepsilon_2}$ and $\overline{\mu_2}$.

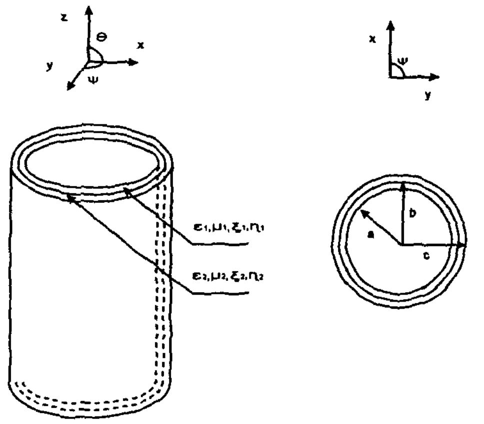

Fig. 1. Elementary dipole on a cylindrical bianisotropic substrate with a bianisotropic superstrate cover.

In this geometry the z components of the electric and magnetic fields in each region can be given by [8][12]

$$E_z(\rho,\phi,z)=\frac{1}{4\pi^2}\sum_{n=-\infty}^{\infty}\int_{-\infty}^{\infty}e^{jk_z z}dk_z e^{jn\phi}$$

$$\cdot\begin{cases} A_n^e[H_n^{(1)}(k_{1\rho a}\rho)H_n^{(2)}(k_{1\rho a}a) \\ \quad -H_n^{(2)}(k_{1\rho a}\rho)H_n^{(1)}(k_{1\rho a}a)], & a<\rho<b \\ B_n^e H_n^{(2)}(k_{2\rho}\rho)+C_n^e J_n(k_{2\rho}\rho), & b<\rho<c \\ D_n^e H_n^{(2)}(k_{3\rho}\rho), & c<\rho \end{cases} \tag{5}$$

$$H_z(\rho,\phi,z)=\frac{1}{2\pi}\sum_{n=-\infty}^{\infty}\int_{-\infty}^{\infty}e^{jk_z z}dk_z e^{jn\phi}$$

$$\cdot\begin{cases} A_n^h[H_n^{(1)}(k_{1\rho b}\rho)\frac{\partial}{\partial\rho}H_n^{(2)}(k_{1\rho b}a) \\ \quad -H_n^{(2)}(k_{1\rho b}\rho)\frac{\partial}{\partial\rho}H_n^{(1)}(k_{1\rho b}a)], & a<\rho<b \\ B_n^h H_n^{(2)}(k_{2\rho}\rho)+C_n^h J_n(k_{2\rho}\rho), & b<\rho<c \\ D_n^h H_n^{(2)}(k_{3\rho}\rho), & c<\rho \end{cases} \tag{6}$$

where

$$\alpha_i=\mu_{iz}+\frac{\zeta_i^2}{\varepsilon_{iz}}-\frac{k_z^2}{k_0^2\varepsilon_{iz}} \tag{7}$$

$$\beta_i=\varepsilon_{iz}+\frac{\zeta_i^2}{\mu_{iz}}-\frac{k_z^2}{k_0^2\mu_{iz}} \tag{8}$$

$$k_{ip}=k_0\sqrt{\varepsilon_{iz}\alpha_i} \tag{9}$$

$$k_{iq}=k_0\sqrt{\mu_{iz}\beta_i} \tag{10}$$

$$k_i^2-k_{ip}^2=k_z^2,\quad i=2,3 \tag{11}$$

There are 8 unknown coefficients to be determined. From the expression of E_z and H_z the components E_ϕ and H_ϕ can also be expressed as

$$E_\phi=\frac{(\zeta_i k_0+k_z)n}{k_0^2\varepsilon_i\alpha\rho}E_z-\frac{1}{j\omega\varepsilon_0\beta}\frac{\partial H_z}{\partial\rho} \tag{12}$$

$$H_\phi=\frac{(\zeta_i k_0+k_z)n}{k_0^2\mu_1\beta\rho}H_z+\frac{1}{j\omega\mu_0\alpha}\frac{\partial E_z}{\partial\rho} \tag{13}$$

in the region 1,2 and

$$E_\phi=\frac{k_z n}{k_{i\rho}^2\rho}E_z+\frac{j\omega\mu_0}{k_{i\rho}^2}\frac{\partial H_z}{\partial\rho} \tag{14}$$

$$H_\phi=\frac{k_z n}{k_{i\rho}^2\rho}H_z-\frac{j\omega\varepsilon_i}{k_{i\rho}^2}\frac{\partial E_z}{\partial\rho} \tag{15}$$

in the region 3.

The coefficient solutions for axial elementary current source at $\phi=\phi_s$ and $z=0$ are found from the boundary conditions. All the tangential components of E and H at $\rho=b$ and $\rho=c$ are continuous except

$$H_\phi(\rho=b^+)-H_\phi(\rho=b^-)=\frac{1}{b}e^{-jn\phi_s} \tag{16}$$

The resultant solution has been checked to agree in the limiting cases where no cover is present[10]. The far-zone radiated fields which are conventionally expressed in spherical coordinate systems are found from the saddle-point method[12].

$$E_\theta = \frac{-j}{\sin\theta}\frac{1}{2\pi^2}\frac{e^{-jk_0 r}}{r}\sum_{n=-\infty}^{\infty} D_n^e(k_z, k_\rho)e^{jn(\phi+\pi/2)} \quad (17)$$

$$E_\phi = \frac{\eta_0 j}{\sin\theta}\frac{1}{2\pi^2}\frac{e^{-jk_0 r}}{r}\sum_{n=-\infty}^{\infty} D_n^h(k_z, k_\rho)e^{jn(\phi+\pi/2)} \quad (18)$$

$$H_\phi = \frac{E_\theta}{\eta_0} \quad (19)$$

$$H_\theta = -\frac{E_\phi}{\eta_0} \quad (20)$$

where

$$k_z = k_0\cos\theta \quad (21)$$

$$k_\rho = k_0\sin\theta \quad (22)$$

III. SIMULATION RESULT

The radiation pattern of an infinitesimal current in a bianisotropic cylindrical structure are presented in this section. Normalized radiation patterns (power density versus θ) for an axial Hertzian dipole at $\phi=0$ and $z=0$ without cover $(c \to b)$ are shown in Fig.2. It is seen that the increase of substrate bianisotropy decreases radiation in the broadside and there is more power in dark region ($90^\circ \leq \phi \leq 270^\circ$). Also, It show the same result with the case of an Yang[8] that the increase of substrate bianisotropy decreases radiation into the horizon. Normalized radiation patterns along ϕ angle (power density versus ϕ) are shown in Fig.3. It is a similar result to infinite line current shown in [7].

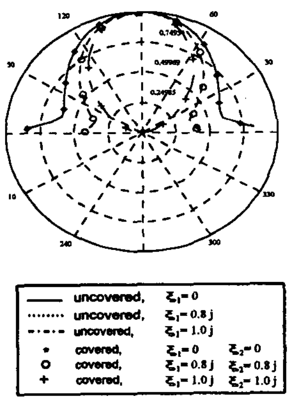

Fig. 2. Radiation pattern for an infinitesimal current at a=5cm, b=5.1cm, $\phi=0$ and $z=0$. f = 3GHz, $\varepsilon_1=\varepsilon_2=2$ $\mu_1=\mu_2=1$

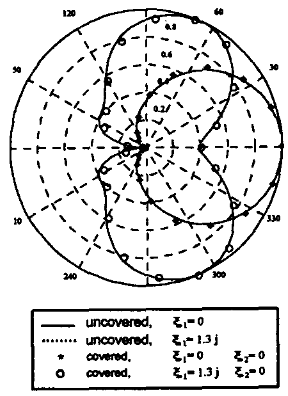

Fig. 3. Radiation pattern for an infinitesimal current at $\phi=0$ and $z=0$. f = 3GHz, a = 5cm, b = 5.1cm, $\varepsilon_1=\varepsilon_2=2$, $\mu_1=\mu_2=1$ and $\phi=\frac{\pi}{2}$ cut

The bianisotropy cover effect is shown in Fig.4-5. In the Fig. 4., We found that the increase of superstrate thickness, the decreases the radiation in the dark region. Also, In the case of Fig.5., the increase of superstrate bianisotropic properties, the radiation in the dark region is decrease.

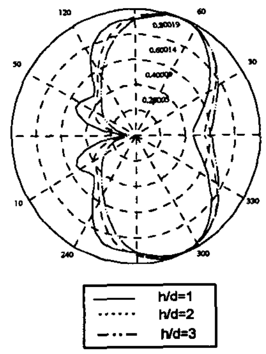

Fig. 4. Radiation pattern for the different thickness of superstrate. f = 3GHz, a = 5cm, b = 5.1cm $\varepsilon_1=\varepsilon_2=2$, $\mu_1=\mu_2=1$, ζ_1 = 1.6 j ζ_2 = 1.3 j ,

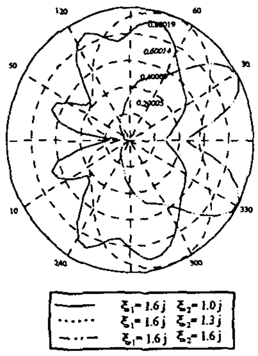

Fig. 5. *Radiation pattern for the different* thicknesss of superstrate. $f = 3GHz$, $a = 5$cm, $b = 5.1$cm , $\varepsilon_1 = \varepsilon_2 = 2$, $\mu_1 = \mu_2 = 1$, $t/d = 2$

Ⅳ. CONCLUSION

In this paper, The effects of bianisotropic superstrate on the radiation patterns of dipole on cylindrical bianisotropic substrates were studied. Special constitutive relations are used to describe the bianisotropic properties of a material, such as that the Green's function can be formulated. Radiation characteristics of axial Hertzian dipole on superstrate loaded cylindrical bianisotropic substrates were analyzed. It was found that when the bianisotropy of superstrate was greater than that of substrates, there were significant variations such as generation of lobes which have maximum radiated power in various directions. The variations of thickness also were analyzed.

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