UNCLASSIFIED

Defense Technical Information Center Compilation Part Notice

ADP011661

TITLE: Radiation Control on a Step Discontinuity of a Grounded Chiral Slab

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: International Conference on Electromagnetics of Complex Media [8th], Held in Lisbon, Portugal on 27-29 September 2000. Bianisotropics 2000

To order the complete compilation report, use: ADA398724

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP011588 thru ADP011680

UNCLASSIFIED

Radiation Control on a Step Discontinuity of a Grounded Chiral Slab

A. L. Topa, C. R. Paiva, and A. M. Barbosa

Instituto Superior Técnico, Technical University of Lisbon
Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal
Fax: + 351 - 21 - 8417284; E-mail: antonio.topa@lx.it.pt

Abstract

In this paper, we analyse the radiation on a step discontinuity of a grounded chiral slab, and we show that it can be enhanced due to the effect of chirality. In addition to the surface modes, the continuous spectrum of radiation modes is also taken into account. In fact, it is the coupling between these two types of modes that is responsible for the radiation occurring on the step. We show that chirality may increase such coupling and, therefore, improve radiation. The complete spectral representation includes two subsets of continuous hybrid modes: Incident Transverse Electric (ITE) and Incident Transverse Magnetic (ITM) radiation modes. The scattering matrix of the step is determined by minimizing the boundary residual error in the sense of the least squares. The influence of chirality on the characterization of the step is demonstrated and we show that some control on the radiation pattern is achieved, mainly in the angle and width of the radiation beam.

1. Introduction

Step discontinuities play an important role in optical and millimeter wave components, as constituent blocks of several interacting structures. In dielectric planar waveguides involving chiral media, such discontinuities have been already analyzed, either isolated [1-2], or in periodic structures [3].

This paper extends the previous analysis to consider the radiation effect, and shows that the radiation of the step discontinuity can be enhanced due to the inclusion of chirality. Since the grounded chiral slab is an open structure, in addition to the surface modes, the continuous spectrum of radiation modes must be taken into account. Moreover, appreciable coupling may take place between the surface and the radiation modes of the waveguide, and so the continuous spectrum will be responsible for the radiation from the step. Chirality may affect such coupling and increase radiation from the step.

In order to calculate the radiated field, a rigorous description of the problem must be achieved, by selecting a complete spectral field representation. Two subsets of continuous hybrid modes may be considered: (i) a pair of Incident Transverse Electric (ITE) and Incident Transverse Magnetic (ITM) radiation modes; (ii) a pair of Reflected Transverse Electric (RTE) and Reflected Transverse Magnetic (RTM) radiation modes. These sets of modes were found to be mutually orthogonal and have the advantage of presenting a clear physical interpretation [4]. To apply a discrete mode matching technique, the continuous spectral amplitudes are discretized and the residual error in the boundary conditions is minimized in the sense of the least squares. Finally, the accuracy of the solution is checked by means of a power balance criterion.

The reflection and transmission coefficients of the incident fundamental surface mode, as well as the fully characterization of the radiation effect are presented. The analysis includes the influence of the chirality on the radiation control of the step. Finally, by using the saddle-point technique, the radiation pattern is calculated. The effect of the chiral parameter on both the angle and width of the radiation beam is also considered.

2. Problem Formulation and Solution

The step discontinuity in a grounded chiral slab, shown in Fig. 1, is considered. By introducing normalized fields $\mathscr{D} = \mathbf{D}/\varepsilon_0$, $\mathscr{B} = Z_0\mathbf{B}/\mu_0$ and $\mathscr{H} = Z_0\mathbf{H}$, the constitutive relations in the chiral medium, for time-harmonic fields ($e^{j\omega t}$), may be written as [5]

$$\mathscr{D} = \varepsilon\,\mathbf{E} - j\chi\,\mathscr{H} \tag{1a}$$

$$\mathscr{B} = j\chi\,\mathbf{E} + \mu\,\mathscr{H} \tag{1b}$$

where χ is the chirality parameter, ε is the permittivity and μ is the permeability.

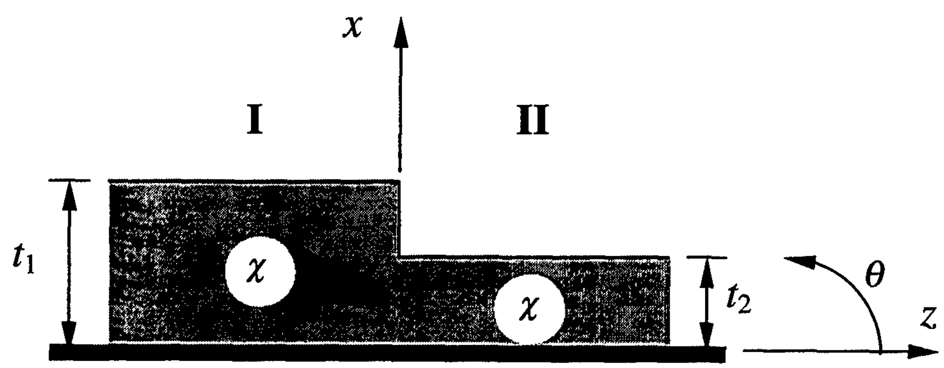

Fig. 1 Step discontinuity a grounded planar chiral slab.

According to the boundary conditions at the discontinuity plane, the transverse field components must be continuous. In this case, since all the modes are six-component hybrid modes, it is very convenient to introduce the two following transverse state vectors:

$$\phi = [E_y,\; j\mathscr{H}_y]^{\mathrm{T}} \tag{2.a}$$

$$\psi = [\mathscr{H}_x,\; -jE_x]^{\mathrm{T}}, \tag{2.b}$$

where ϕ is the transverse field supporting vector. In addition, we may introduce the boundary residual vector as

$$\varepsilon = \begin{bmatrix} \phi^I - \phi^{II} \\ \alpha\,(\psi^I - \psi^{II}) \end{bmatrix}, \tag{3}$$

where α represents a dimensionless weighting factor between the two boundary residual components. This residual can be minimized according to the least squares method. However, in order to apply this discrete mode matching technique, the spectral amplitudes of the radiation mode must be discretized within a complete set of orthogonal basis functions. Legendre polynomials and Gauss-Laguerre functions have been used in this procedure.

The complete spectral field representation includes two types of radiation modes. In the present analysis, Incident Transverse Electric (ITE) and Incident Transverse Magnetic (ITM) radiation modes were considered [4]. The radiation pattern of the chiral step was calculated by the use of the steepest descent method.

3. Numerical Results and Discussion

For numerical simplicity we have considered monomodal slabs on each side of the step discontinuity (waveguides I and II), which means that we will only have the fundamental surface mode propagating on the structure. Fig. 2 shows the variation of the reflection and transmission coefficients Γ_0 and T_0 of the fundamental incident surface mode, as a function of the chirality parameter χ. The suddenly decrease of the value of $|T_0|$ for χ near 1.8, is due to the fact that the fundamental mode propagating in waveguide II is approaching cutoff.

The variation of the reflected and radiated power P_r and P_{rad} with chirality parameter χ, is depicted in Fig. 3. The radiated power is much higher than the reflected power, which shows that, due to the discontinuity, there is a strong coupling between the incident surface mode and the continuous spectrum of radiation modes. Moreover, one should note the monotonous increase in the value of radiated power, whenever the chirality is increased. This value may reach 80% of the total incident power, which proves that, on any circumstance, one may disregard the contribution of the radiation modes to the total fields. Only when the surface mode in waveguide II approaches cutoff, the reflected power becomes significant.

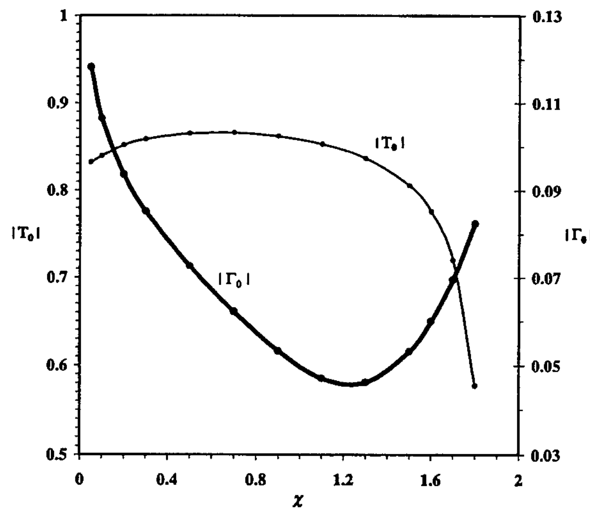

Fig. 2 Reflection and transmission coefficients for the incident surface mode as a function of the chirality parameter χ.

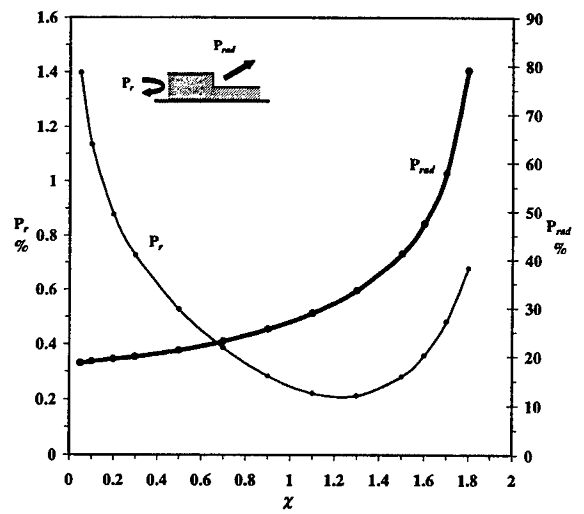

Fig. 3 Reflected and radiated power in a chiral step discontinuity as a function of the chirality parameter χ.

The forward radiation pattern of the chiral step is depicted, in Fig. 4, for different values of the chirality parameter χ. A strong increase in the radiation intensity can be clearly seen, as far as chirality is raised. Meanwhile, the beam angle observes a slightly decrease. Backward radiation pattern does not differ significantly in shape of the forward pattern, although being considerably small. Forward-backward ration is about 20 dB, which shows that, in the present case, radiation is mainly in the propagation direction.

Finally, Fig. 5 shows the variation of the beam angle θ_{max} and the 3dB beam width $\Delta\theta_{3dB}$, as a function of χ. For small values of the chirality parameter, θ_{max} and $\Delta\theta_{3dB}$ suffer a linear increase with χ. As far as the fundamental mode in waveguide II approaches cutoff, those values suddenly decay.

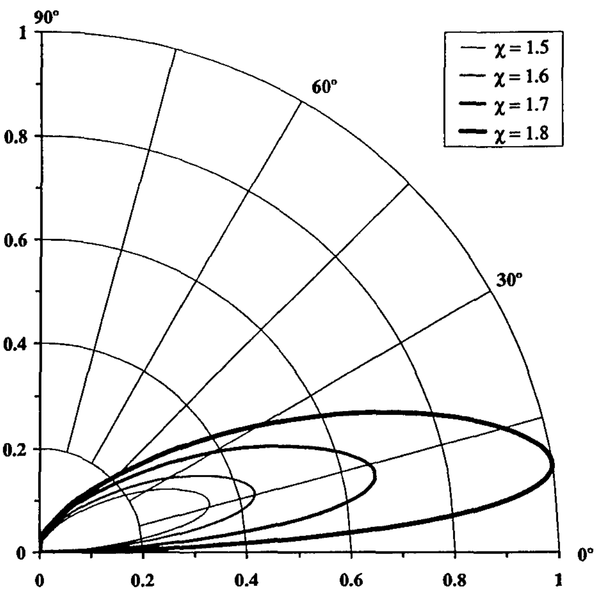

Fig. 4 Forward radiation pattern for different values of the chirality parameter χ.

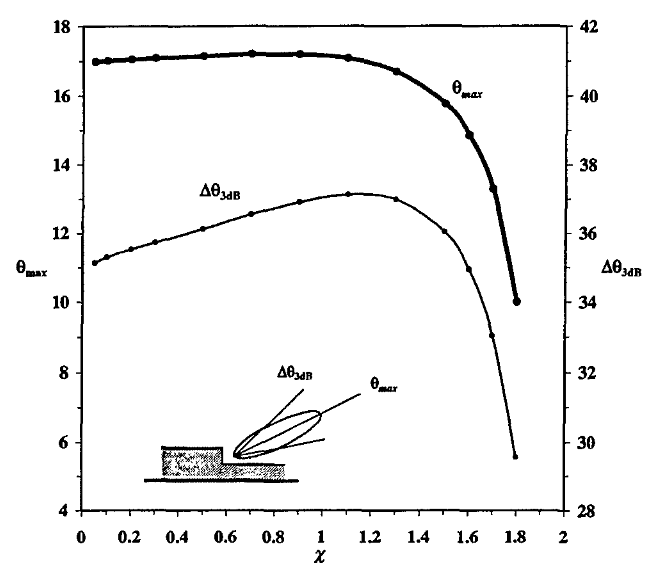

Fig. 5 Beam angle and 3 dB beam width as a function of the chirality parameter χ.

4. Conclusion

We have shown that the power radiated from a step discontinuity in a planar dielectric slab can be significantly increased with the inclusion of chirality in the dielectric substrate. On the other hand, this may cause a slightly decrease in the beam radiation angle as well as a reduction of its width. Therefore, we have proven that chirality represents an extra degree of freedom for the radiation control of a step discontinuity in a planar dielectric waveguide.

References

[1] A. L. Topa, C. R. Paiva, and A. M. Barbosa, "Rigorous analysis of a step discontinuity in a planar dielectric chiral slab," in *Proc. CHIRAL'95* - 4th International Conference on Chiral, Bi-isotropic and Bi-anisotropic Media, State College, PA, pp. 131-134, October 1995.

[2] A. L. Topa, C. R. Paiva, and A. M. Barbosa, "Step discontinuity in a planar dielectric slab," in *Proc. PIERS'96* - Progress in Electromagnetic Research Symposium, Innsbruck, Austria, p. 495, July 1996.

[3] X. Wu and D. L. Jaggard, "Discontinuities in planar chirowaveguides," *IEEE Trans. Microwave Theory Tech.*, vol. 45, pp. 641-647, May 1997.

[4] A. L. Topa, C. R. Paiva, and A. M. Barbosa, "Radiation modes of an asymmetric chiral slab waveguide: A general approach to a new canonical problem," in *Proc. PIERS' 97* - Progress in Electromagnetic Research Symposium, Kowloon, Hong Kong, p. 684, Jan. 1997.

[5] C. R. Paiva and A. M. Barbosa, "A linear-operator formalism for the analysis of inhomogeneous biisotropic planar waveguides," *IEEE Trans. Microwave Theory Tech*, vol. 40, pp- 672-678, Apr. 1993.