ANALYSIS OF QUASI COMPLEX MODES ON LOSSY SUBSTRATE BOXED MICROSTRIP LINES

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ABSTRACT:

In this communication, by using spectral domain approach improved by asymptotic expansions, we show by means of coupling integral values that the notion of quasi complex modes can be introduced for lightly lossy substrates. The quasi complex modes are particular modes with similar behaviour than lossless structure complex modes.

The analysis of discontinuities between planar transmission lines, particulary for microstrip lines, has received a great interest from many years.Accurate modeling of such discontinuities is of fundamental importance for successful monolithic integrated circuit design.In fact increasing circuit complexity needs very efficient numerical techniques in order to solve electromagnetism problems.In this mind when mode matching method in the discontinuity plane is used, it is necessary to determine the set of modes with as accuracy as possible.More ever for boxed losseless structure, it has been shown that complex modes can occur, so that ignoring those modes would lead to non accurate solutions [1] [2].

The properties of complex waves have been investigated in detail, both theoretically and experimentally for shielded circular dielectric rod [3],[4] and for boxed microstrip line[2].

Up to now, most of published works concern the possibility of propagation of complex modes in lossless structure and only a few works focuse on complex and backward-wave modes in lossy waveguides [5].So, when shielded microstrip lines laid on semi-insulating or doped semi-conductor substrates, are considered for MMIC applications, it is necessary to investigate the evolution of complex solutions for lossless structure, under the effect of bulk losses in the substrate.

In this communication, by using spectral domain approach improved by asymptotic expansions, we show by means of coupling integral values that the notion of quasi complex modes can be introduced for lightly lossy substrates. Futhermore, we show as example the distribution of electric and magnetic fields in the cross section plane of the boxed microstrip line. Naturally, for lossy structures all modes have complex propagation constant, so in our mind, the quasi complex modes are particular modes with similar behaviour than lossless structure complex modes.

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NUMERICAL RESULTS

The studied microstrip geometry is shown in figure 1. It has already been shown that complex modes can be supported by this lossless structure, using the Singular Integral Equation (S.I.E.) or the Spectral Domain Approach (S.D.A.) technics. This communication addresses the effect of a lossy substrate on complex modes. With this aim, as example we present fig. 2, 3 and 4 the frequential evolutions of the two propagation constants (γ_1, γ_2) for a pair of modes initialy complex on lossless structure, then we point out the evolutions of these modes, when we consider respectivly a substrate conductivity of $\sigma = 3.10^{-3}$ S/cm, $\sigma = 7.10^{-3}$ S/cm and finally $\sigma = 2.10^{-2}$ S/cm.

For the lossless structure, in the complex frequency range, we obtain:

$\gamma_1 = \beta_1 - j\,\alpha_1 ; \gamma_2 = -\beta 2 - j\,\alpha 2$ with $\beta 1 = \beta_2 > 0 , \alpha_1 = \alpha_2 > 0$

Now let us investigate this pair of complex modes when losses are taking into account. As shown in fig. 3, 4 and 5, in the initialy complex frequency range γ_1 and γ_2 cannot yet be linking, so we are tempted to say that the pair of complex modes becomes two usual modes. Indeed, we obtain a continuous variation of γ_1 and γ_2 with α_1 never equals to α_2. However, when we take into account small values of the conductivity ($\sigma = 3.10^{-3}$ S/cm, $\sigma = 7.10^{-3}$ S/cm), we have to notice that if we consider frequencies smaller than the maximum of the complex frequency range, we obtain for the two modes (fig. 2 and 3):

$\gamma_1 = \beta_1 - j\,\alpha_1 ; \gamma_2 = -\beta_2 - j\,\alpha_2$ with $\beta_1 \neq \beta_2 > 0 , \alpha_1 \neq \alpha_2 > 0$

This means that the mode 2 propagates in the -Z direction and it is attenuated in the opposite direction. This phenomenon is equally describing by the fig.5 which represents the evolution of the propagation constant for the two modes versus the substrate conductivity for a frequency equal to 19 GHz.

This apparent continuous energy gain on passive structure, can again be explained by strong coupling in energy sense [1] between the two considered modes (γ_1, γ_2) in the frequency and conductivity ranges when $\gamma_2 = -\beta_2 - j\,\alpha_2$ (β_2 and $\alpha_2 > 0$).This phenomenon is pointed out as example fig. 6; this curves show the evolution of the real part of the integrals (1) versus the substrate conductivity for a frequency equal to 19 GHz, while the fig. 7 represents the imaginary part of these integrals.

$$\int_S (e_1 x h_2^*) dS = p \quad ; \int_S (e_2 x h_1^*) dS = p' \text{ with } p' \rightarrow -p^* \quad (1)$$

As example, we present fig. 8, 9, 10 and 11 the evolution of the distribution of magnetic fields in the cross section plane of the boxed microstrip line for the two normal modes versus frequency, when we take into account a substrate conductivity of 7.10^{-3} S/cm.

CONCLUSION:

In this communication we have studied the evolution of the complex modes solutions initialy obtained for a lossless microstrip line, due to bulk losses introduced in the substrate.

Naturally, all the propagation constants of the different modes become complex. In fact for the conductivity values considered ($\sigma \lesssim 2.10^{-2}$ S/cm), the two initial complex modes are strongly coupled in the energy sense, and stay much more coupled around the initial complex frequency range, than outside; so that these two modes cannot exist alone inside this range ($\gamma_2 = -\beta_2 - j\,\alpha_2$, β_2 and $\alpha_2 > 0$).

As the frequency behaviour of these two modes are quite similar to the initial complex modes of lossless structure, we have called this pair of modes quasi complex modes.

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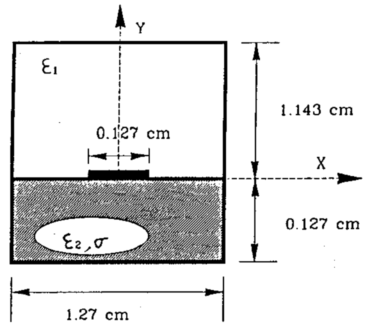

Figure 1: Cross section of the shielded microstrip line, $\epsilon_1=\epsilon_0$, $\epsilon_2=\epsilon_0(\epsilon_r-i\sigma/\epsilon_0\omega)$; $\epsilon_r=8.875$

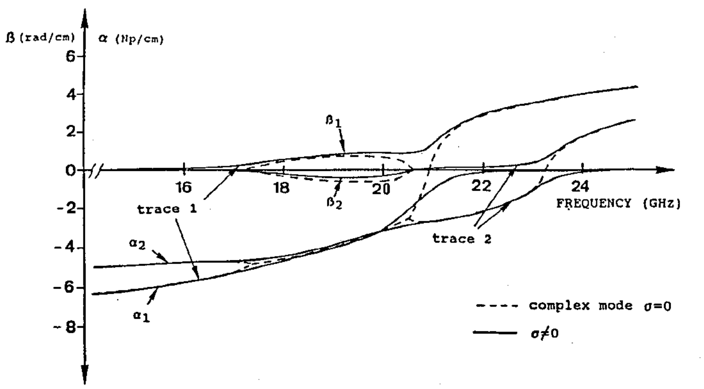

Figure 2: Propagation constant $\gamma = \beta + i.\alpha$ of the two modes versus the frequency for $\sigma = 3.10^{-3}$ S/cm.

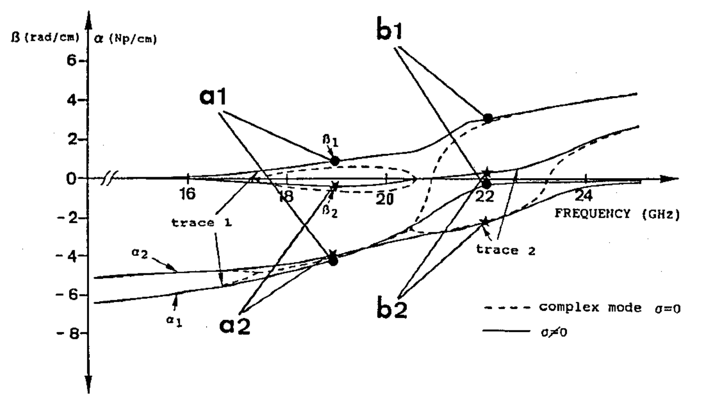

Figure 3: Propagation constant $\gamma = \beta + i.\alpha$ of the two modes versus the frequency for $\sigma = 7.10^{-3}$ S/cm.

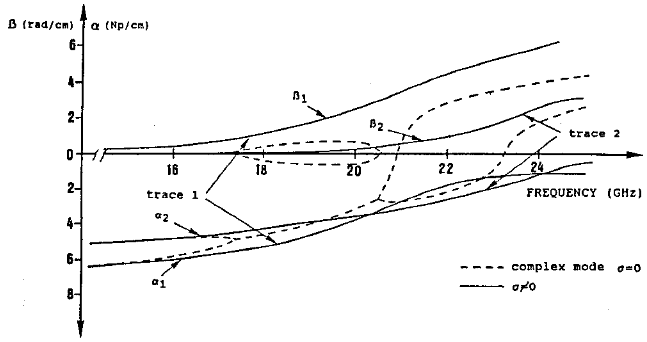

Figure 4: Propagation constant $\gamma = \beta + i.\alpha$ of the two modes versus the frequency for $\sigma = 2.10^{-3}$ S/cm.

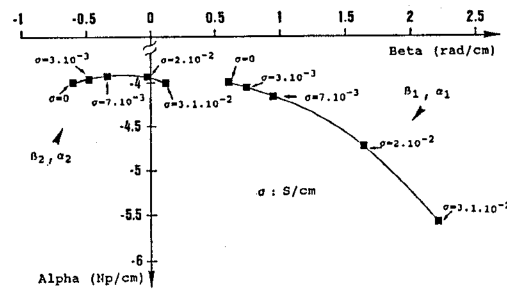

Figure 5: Propagation constant $\gamma = \beta + i.\alpha$ of the two modes versus the conductivity for a frequency, F = 19 GHz.

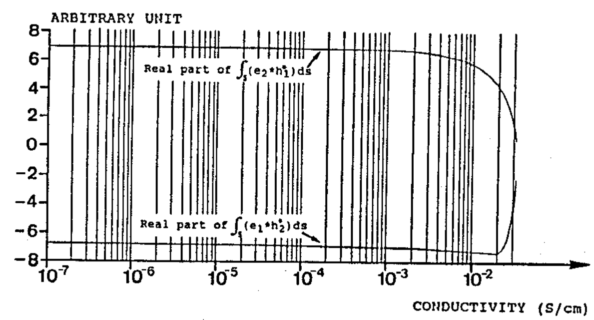

Figure 6: Evolution of the real part of the integrals $\int_S (e_i * h_j^*) ds$ versus the conductivity for a frequency, F = 19 GHz.

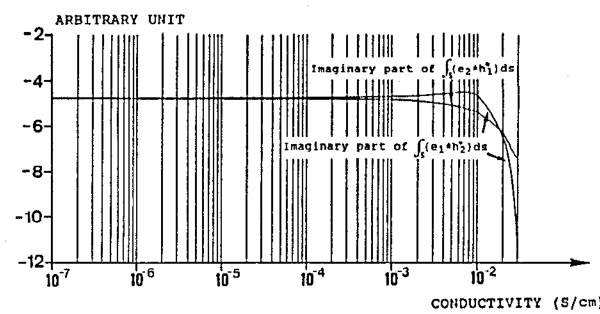

Figure 7: Evolution of the imaginary part of the integrals $\int_S (e_i * h_j^*) ds$ versus the conductivity for a frequency, F = 19 GHz.

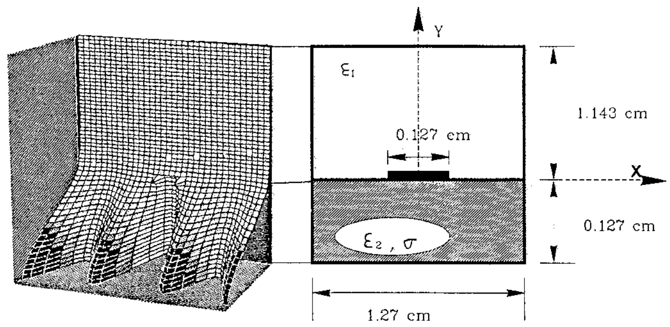

Figure 8: Distribution of the magnetic fields in the cross section plane of the boxed microstrip line for the point a1 (figure 3, $\sigma=7.10^{-3}$ S/cm).

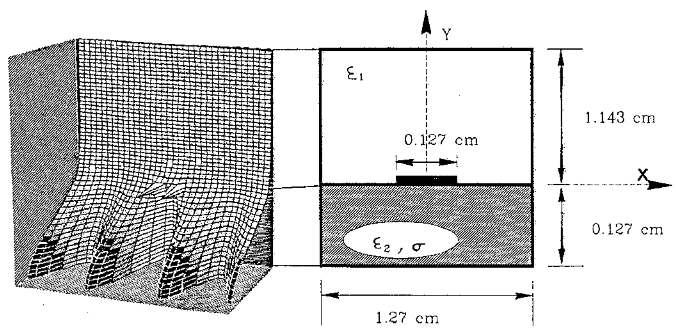

Figure 9: Distribution of the magnetic fields in the cross section plane of the boxed microstrip line for the point a2 (figure 3, $\sigma=7.10^{-3}$ S/cm).

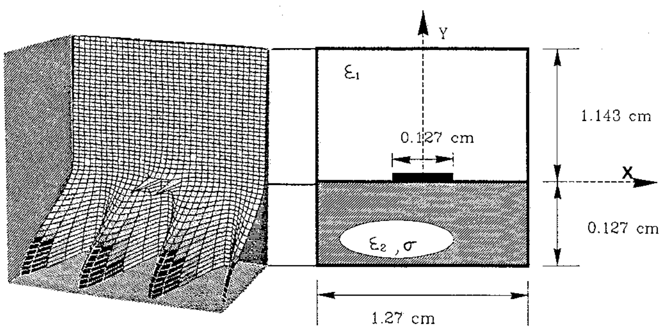

Figure 10: Distribution of the magnetic fields in the cross section plane of the boxed microstrip line for the point b1 (figure 3, $\sigma=7.10^{-3}$ S/cm).

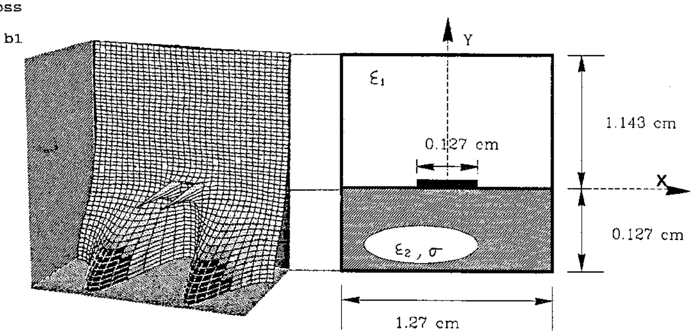

Figure 11: Distribution of the magnetic fields in the cross section plane of the boxed microstrip line for the point b2 (figure 3, $\sigma=7.10^{-3}$ S/cm).