Parallel-Plate Waveguides Formed by Arbitrary Impedance Sheets

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Abstract—In this work, we introduce and study parallel-plate-waveguide structures that are formed by two penetrable metasurfaces having arbitrary sheet impedances. We investigate the guided modes which can propagate in such structures and derive the corresponding dispersion relations. Different scenarios including series- and parallel-resonant impedance sheets are considered. The obtained theoretical formulas are applied to predict the dispersion properties for different separations between the two symmetric or asymmetric metasurfaces.

I. INTRODUCTION

Waveguides have many applications in microwave and optical technologies. Following the development of artificial impedance surfaces [1], [2], novel waveguide structures that exploit impedance surfaces have been investigated for guiding and controlling waves [3]–[7]. Such waveguides, which were initially considered for the purpose of radiating electromagnetic energy, are supporting surface waves. Surface waves along a single sheet [3] or along a sheet placed over a ground [4] have been studied and exploited for controlling the propagation path of guided utilizing stop-bands or for leaky-wave radiation [6]. However, most of the studies, from the early days till today, have been focused on guided waves in one sheet and little is known about what happens if we bring another thin sheet close to the first one. Can we modify and control the waveguide properties if we use two parallel sheets?

In this presentation, we will discuss our results regarding these two sheets which are parallel to each other and separated by a distance. We study guided modes supported by such structures assuming that the sheets have arbitrary isotropic impedances. We also reveal the electric currents density at the sheets for different polarizations and distances between those two sheets.

II. PROPERTIES OF THE STRUCTURE UNDER STUDY

The proposed and studied parallel-plate waveguide is shown in Fig. 1. It consists of two parallel sheets which are separated by the distance \(d\) and have only electric response. One sheet is supposed to be positioned at \(y = d/2\) and consequently the other one is placed at \(y = -d/2\). The space between the two sheets is filled by air (vacuum). We assume that the electromagnetic wave is propagating along the \(z\)-axis. The impedances of the sheets are denoted as \(Z_1\) and \(Z_2\), respectively. Figure 2 illustrates the realization of the impedance of each sheet as a series or parallel connection of effective sheet inductance \((L)\) and capacitance \((C)\). This means that the equivalent impedance of each sheet has a resonance at \(\omega_{res}=1/\sqrt{LC}\). Since we have two sheets, there can be three different scenarios as shown in Fig. 2. Regarding the first and second scenarios, the impedances of both two sheets are realized by a series or parallel connection, respectively. For the third scenario, one sheet is realized by a series connection and the other one by a parallel connection. For each scenario, two different cases can be considered: Asymmetric and symmetric.

III. RESULTS AND DISCUSSION

There is a possibility to decompose the fields into two polarizations: The transverse magnetic polarization (TM modes) and the transverse electric polarization (TE modes). The
As the distance between the sheets decreases, the cut-off frequency of the second TE mode increases. When $d = \lambda_6\text{GHz}$, two TM modes can propagate because both sheets are inductive. It is worth to mention that the two TM modes have cut-off frequencies below $6\text{GHz}$ since two sheets are capacitive, when the distance between the two sheets is comparable with $\lambda_{\text{GHz}}$. As we bring the two sheets close to each other, the first TM mode and the second TE mode are compressed to the resonance frequency. Such dual-polarized resonant mode supporting waves with a wide range of propagation constants can have applications in super-resolution imaging devices.

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References

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