A New Class of Dual-Mode Directional Couplers for Compact Dual-Polarization Beam-Forming Networks

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***Abstract*—A new class of directional couplers for the realization of compact dual-polarization beam-forming networks is presented in this letter. This component functions as two independent directional couplers for the TE_{01} mode and the TE_{10} mode of a rectangular waveguide. The two modes are not coupled. Different values of the coupling for the two modes can be obtained. This coupler can be used twice for two orthogonal polarizations. Therefore a considerable reduction of size and complexity of the overall network can be obtained. Experimental data for a 3-dB dual mode coupler are also presented here.**

***Index Terms*— Couplers, mode matching, waveguide components.**

I. Introduction

THE REDUCTION of size and weight is one of the main goals in the design of a beam-forming network for satellite applications. The antenna feeds commonly employ two orthogonal polarizations for purposes of frequency reuse or cross-polarization reduction. Usually, two different beam-forming networks are employed for the copolarization and the cross polarization, respectively. A directional coupler is one of the main components of a beam-forming network. A new class of directional couplers realized with two rectangular waveguides coupled by a double set of aligned rectangular holes in the common wall is presented in this letter. The use of sidewall holes is a common way of realizing directional couplers in both the E and the H planes [1]–[4]. At the same time this new component realizes an H-plane coupler for the TE_{01} mode and an E-plane coupler for the TE_{10} mode. The symmetry of the structure avoids any coupling between the two modes. Different values of the coupling for the two modes can be obtained. Therefore, two independent couplers are realized at the same time using the same structure. This component can be used to design compact dual-mode beam-forming networks.

II. Theory

The proposed structure is shown in Fig. 1. Two rectangular waveguides are coupled by two rows of rectangular holes symmetrically aligned on the common wall. The lengths of the holes are longer then the widths. The holes can be also considered as slots oriented in the propagation direction. A vertical longitudinal symmetry plane splits the slots into two parallel rows. By considering the symmetry one can explain simply how the coupler works. In Fig. 2(a) and (b) one half of a coupling section of the device is shown. When we excite the structure with the TE_{01} mode the symmetry plane can be considered as an electric plane [Fig. 2(a)] and half the structure works as an H-plane coupler with slots in the narrow wall [4]. In this case a variation of the distance (c/2) of the slots from the central plane has a weak effect on the coupling because the field of the TE_{01} mode is constant in the horizontal direction. The value of the coupling mainly depends on the slot width

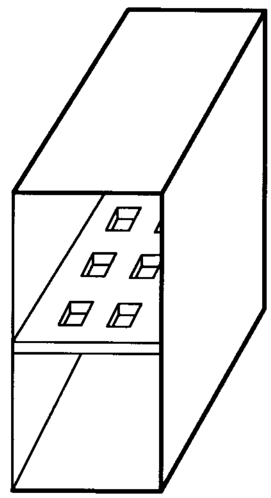

Fig. 1. Structure of a dual-mode coupler.

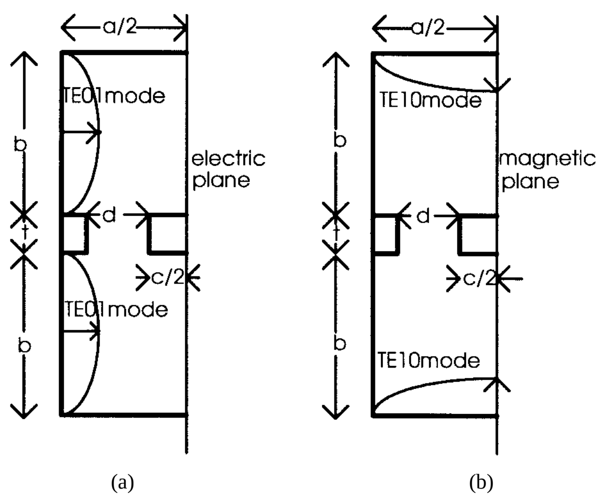

Fig. 2. Half of a coupling section of the coupler.

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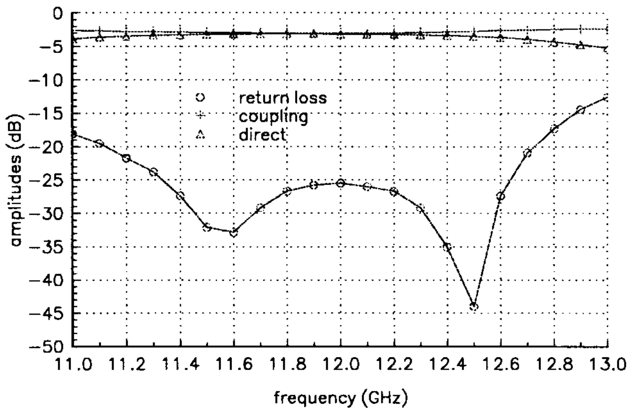

Fig. 3. Measured scattering parameters of the H-plane coupler (TE_{01} mode).

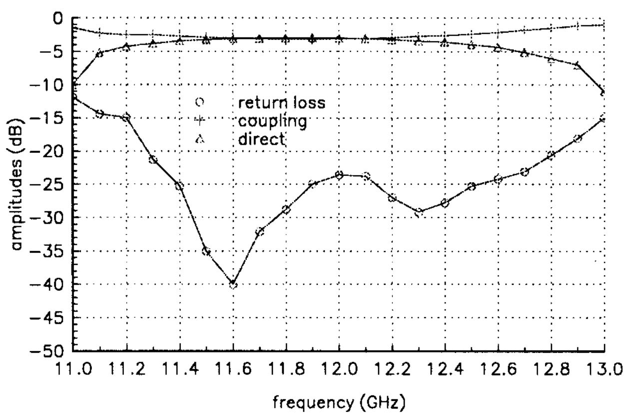

Fig. 4. Measured scattering parameters of the E-plane coupler (TE_{10} mode).

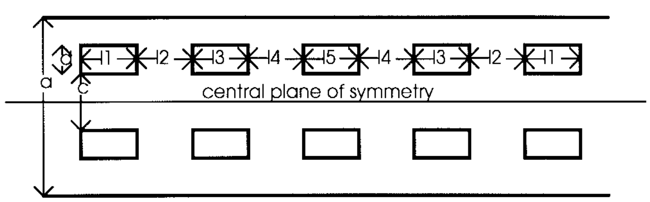

Fig. 5. Scheme of the holes on the common wall: $111 = 9.556, 12 = 1.731, 13 = 10.528, 14 = 1.833, 15 = 10.780, a = 13.8, b = 15.5, t = 2.0, c = 3.370, d = 1.538$.

(d) and on the length of the slots. A variation of the waveguide height (b) modifies the propagation constant of the TE_{01} mode, therefore a change of the electrical length and longitudinal distance of the slots is obtained. The waveguide height is the key parameter for controlling the position of the operating band of the coupler with fixed length and longitudinal distance of the slots. Note that the propagation constant of the TE_{01} mode does not depend on the waveguide width (a). On the contrary when we excite the coupler with the TE_{10} mode the symmetry plane can be considered as a magnetic plane [Fig. 2(b)]. In this situation the overall device functions as an E-plane coupler with two coupling slots on the common wall for each coupling section. In this case the parameter (c) has a strong influence on the coupling value, because the amplitude of the field of the fundamental mode varies horizontally.

By moving the slots symmetrically with respect to the central plane the value of the coupling is modified. Therefore, the distance (c) is the most important parameter for the control of the ratio of the coupling values for the two fundamental modes of the coupler. In this case the propagation constant of the TE_{10} mode depends on the waveguide width (a) and does not depend on the waveguide height (b). The waveguide width has a strong influence on the position of the operating band. Note that the symmetry of the overall structure with respect to the central plane ensures that the TE_{01} and the TE_{10} modes are not coupled. These basic ideas can help one to understand that the proposed structure has enough free parameters to obtain two independent couplers with the same structure. A mode-matching code for the full-wave analysis of the device has been developed. The analysis program has been used together with an optimization code to obtain a software for the design of the coupler [5], [6]. The starting point for optimization has been obtained by using an equivalent circuit for the even and the odd mode of both the couplers in the E plane and the H plane, respectively [2], [7]. The circuit consists of a cascade of shunt parallel inductances separated by the lengths of waveguides.

III. Experimental Results

A coupler with five coupling sections (ten holes) has been realized by Alenia Spazio. The coupler has been designed in the 11.5–12.5-GHz band, with a coupling of 3 dB for both the TE_{01} mode and the TE_{10} mode. In Fig. 5 the dimensions of the coupler are shown in millimeters. In Fig. 3 the measured scattering parameters of the H-plane coupler (TE_{01} mode) are shown. In Fig. 4 the measured scattering parameters of the E-plane coupler (TE_{10} mode) are shown. The experimental data demonstrate that the two modes are not coupled by the structure.

IV. Conclusions

A new class of dual mode directional couplers has been proposed. The possibility of realizing two independent couplers with the same structure for the TE_{10} and the TE_{01} modes of a rectangular waveguide has been demonstrated. The theory has been verified by experimental results. The structure is proposed for the realization of very compact dual-polarization beam-forming networks.

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