TE-to-x MODE ANALYSIS OF CORRUGATED WAVEGUIDE CIRCULAR POLARIZERS

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INTRODUCTION

Compact polarizer components are required in primary feed radiators to produce a circularly polarized elliptical far-field radiation pattern from a reflector [1, 2]. To achieve 40 dB cross polarization in a corrugated rectangular horn system, the ratio between the two orthogonal fundamental modes of the polarizer has to be maintained within ±0.17 dB in amplitude and 90 ± 1 degrees in differential phase shift over the operating frequency range [1, 4].

Due to these specifications, the computer-aided design of corrugated waveguide polarizers is extremely critical. Since equivalent circuit models yield unacceptable deviations of 10 per cent between theory and measurements [3], field theory design methods using the mode-matching technique have been developed [2, 5, 6] to more accurately predict the polarizer performance. For the horizontal electric field excitation (c.f. Fig. 1), the component is analyzed using a set of TE_{0n} waves or, alternatively, a set of TE_{m0} types for inductive corrugations if the circuit is assumed to be rotated by 90 degrees. For the vertical excitation, however, the analysis methods published so far [1, 2, 5, 6] utilize a linear superposition of TE_{1n} and TM_{1n} modes to model the capacitive influence of the corrugations. Due to the fact that in this case the non-existing orthogonal E-field component is approximated to be zero by linear superposition, the technique is extremely sensitive to relative convergence phenomena.

This paper present a unified TE-to-x (TE^{x}_{mn}) mode analysis [7] of the corrugated waveguide circular polarizer. Since the condition of vanishing orthogonal E-field is automatically satisfied, the matrix sizes in the computer software can be reduced to one fourth of those of the superposition principal. This not only contributes to the numerical stability of the algorithm but also makes the processing time up to eight times faster for a typical application. The predicted results are found to be in excellent agreement with measurements.

THEORY

Fig. 2 shows the general double-plane discontinuity in waveguide. The vertical E-field response is analyzed using a set of TE^{x}_{1n} modes with n even

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and $a_1 = a$. Setting $b_1 = b$ and assuming that the structure be rotated by 90 degrees, a set of TE^{x}_{m0} modes with m odd models the discontinuities for the horizontal E-field response. In both cases, the electromagnetic field in regions $i = I,\ II$ (c.f. Fig. 2)

$$\vec{E}^{i} = \nabla \times (A^{i}_{hz}\vec{e}_z)$$
$$\vec{H}^{i} = \frac{j}{w\mu}\nabla \times \nabla \times (A^{i}_{hz}\vec{e}_z)$$

can be derived from a vector potential function

$$A^{i}_{hz} = \sum_{m=1}^{M}\sum_{n=0}^{N} A^{i}_{mn}T^{i}_{mn}(x,\ y)(V^{i}_{mn} - R^{i}_{mn})\exp(\mp jk^{i}_{zmn}z)$$

where V^{i}_{mn}, R^{i}_{mn} are the wave amplitudes travelling in $\pm z$-direction, T^{i}_{mn} is the related cross-section function, and A^{i}_{mn} is a power normalization term [7, 8].

If the superposition principal is used, e.g. [5, 6], four field components (E_x, E_y, H_x, H_y) have to be matched at $z = 0$, one of which equals zero. The present TE^{x}_{mn} mode analysis, however, requires only two components (E_y, H_x) for the matching conditions. Therefore, the resulting matrix size is reduced to $N \times N$ compared with $(2N-1)\times(2N-1)$ for the TE_{1n} and TM_{1n} superposition [5, 6]. Cascading the scattering matrices of all the sections involved [7, 8] finally leads to the overall S-matrix of the polarizer. The differential phase shift $\triangle\phi = \phi\ (TE_{01})\ - \phi\ (TE_{10})$ is calculated from the separately obtained transmission phases of horizontal and vertical E-field excitation.

RESULTS

Fig. 3a shows the comparison with differential phase measurements presented by Dewey [1]. The agreement is extremely close, hence verifying the phase accuracy of the TE-to-x method. Moreover, the calculated input return loss values for TE_{10} and TE_{01} mode excitation (Fig. 3b) are within the measured margins specified in [1]: Return loss (TE_{10}) better than 36.5 and 40 dB for 12 - 12.5 GHz and 14 - 14.5 GHz, respectively; return loss (TE_{01}) better than 34 and 40 dB in the same frequency ranges. Almost identical results are obtained by the superposition technique, c.f. [2, 6].

Fig. 4a shows the differential phase shift of a TE-TM mode polarizer design with linearly tapered corrugation. Although calculations with eight TE^{x}_{mn} modes are in good agreement with the performance given in [6], the structure was recalculated with 35 modes due to a convergence analysis. It is believed that the deviations of more than four degrees are related to relative convergence phenomena in the differential phase shift of the full-mode linear superposition technique used in [6]. The VSWR behavior (Fig. 4b) is obviously not affected since the results of an eight and a 35 mode analysis are within the plotting accuracy and agree closely with the data presented in [6].

CONCLUSION

A powerful TE-to-x mode method for the analysis of corrugated waveguide circular polarizers is presented. Since it reduces storage and CPU time requirements of the algorithm but, at the same time, improves the convergence behavior compared to the commonly used linear superposition technique, the new formulation offers an attractive solution for the analysis and design of corrugated waveguide structures.

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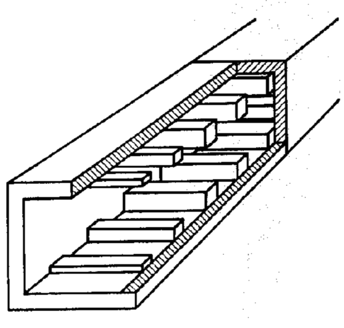

Fig. 1 Corrugated waveguide circular polarizer

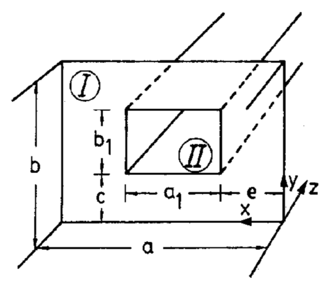

Fig. 2 Double-step discontinuity in rectangular waveguide

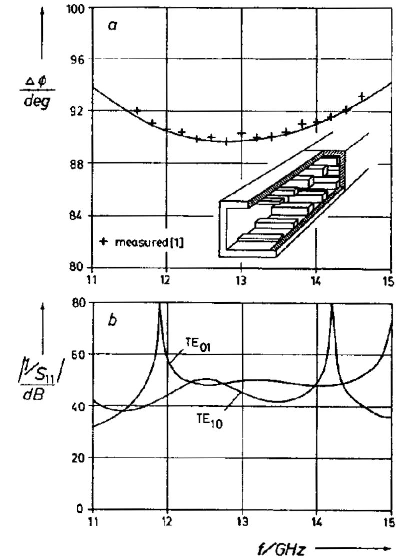

Fig. 3 Performance of corrugated waveguide polarizer according to Dewey [1]: a) differential phase shift (— this theory, + + measured [1]); b) calculated input return loss for fundamental modes

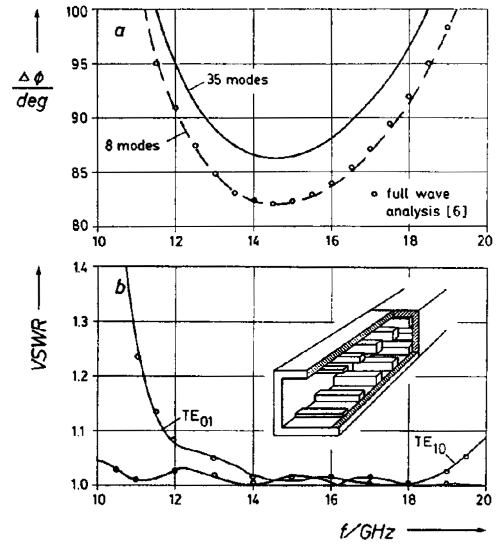

Fig. 4 Polarizer with linearly tapered corrugation according to [6]; — this theory (35 modes); - - - this theory (8 modes); o o linear superposition [6]; a) differential phase shift; b) VSWR.