AN INVESTIGATION OF SHARP DISCONTINUITIES
IN RECTANGULAR WAVEGUIDES BY RAY THEORY

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Sharp lossless discontinuities in the walls of a rectangular waveguide operating in the dominant mode are commonly introduced for the sake of matching the waveguide to a given termination or for the transmission and distribution of microwave power. The presence of such discontinuities, however, gives rise to reflected waves and storage of reactive energy in the vicinity of the discontinuity because of the excitation of higher order evanescent waveguide modes. A reliable method for predicting the scattering coefficients at the plane of the discontinuity is naturally of great interest in the design or application of waveguide discontinuities.

The purpose of this investigation is to apply the geometrical theory of diffraction, by J.B. Keller, in order to predict the scattering coefficients for rectangular waveguide junctions due to sharp wall discontinuities. An essential feature of this method is that it requires the construction of a ray diagram which shows the paths of the excited geometrical-optics and edge rays passing through the observation point. The accuracy of the method is improved with a new diffraction coefficient in order to deal with the near field and shadow boundary regions of the edge discontinuity. The conversion of ray to mode fields is formally obtained by the Poisson sum formula and the stationary phase method of integration. The technique is illustrated for an incident TE_{10} mode in a rectangular waveguide with four types of wall discontinuities:

(i) The E and H-plane steps of arbitrary height,
(ii) The E and H-plane right-angled corners,
(iii) The E and H-plane tee junctions, and
(iv) The E and H-plane flares in a sectoral waveguide.

These solutions are compared with available theoretical and numerical results [1-3] and an excellent agreement is obtained. In particular, it is shown that the solution for the E and H-plane corners is not restricted to right angles and that the edge diffraction terms present a significant improvement over previous solutions based on quasioptical theory [4].

The theory is also applied to study the coupling between tandem junctions in a rectangular waveguide with cross-sectional discontinuities. It is shown that the edge-edge interaction terms become increasingly important for close junctions and may be expressed in terms of an asymptotic series involving the separation between the junctions in radians. It is also shown that the solution for the particular case of a stepped quarter-wave transformer is in excellent agreement with experiment [5] and is of direct interest in practical design applications. Finally, it is concluded that the method can be used with confidence to provide the solutions to any desired degree of accuracy and gives a physical insight into the mechanisms of mode conversion and reconversion in a rectangular waveguide with sharp discontinuities.

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References

[1] R. E. Collin, "Field Theory of Guided Waves", McGraw-Hill, 1960, Chapter 8.

[2] K. G. Goyal, "Analysis of the Field Structure in Corners and Tees in Rectangular Waveguides", M.Sc. Thesis, Dept. of Electrical Engineering, University of Toronto, 1966.

[3] M. A. K. Hamid, "Near Field Transmission Between Horn Antennas", Research Report No. 43, Antenna laboratory, Dept. of Electrical Engineering, University of Toronto, April 1966, Chapter 2.

[4] K. C. Kao, "Approximate Solutions of the H-plane Right-angled Corner in Overmoded Rectangular Waveguide, Operating in the H_{10} Mode", Proc. IEE, Vol. 111, No. 4, pp. 624-628, April 1964.

[5] S. B. Cohn, "Optimum Design of Stepped Transmission-Line Transformers", IRE Transactions on Microwave Theory and Techniques, April 1955.