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SYNTHESIS OF CYCLICALLY SYMMETRIC FIVE-PORTS

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DK-2800 Lyngby, Denmark**Abstract**

A class of matched, symmetric five-ports have been synthesized by solving the circular cylindrical wave equation. Among the solutions are chosen those for which the match condition is fulfilled over the broadest bandwidth. Bandwidths up to $\pm 20\%$ have been found.

Introduction

It has been shown by Hanson and Riblet [1] that a lossless, reciprocal, matched, cyclically symmetric five-port is close to the ideal solution for a six port microwave network analyser due to the position of the so-called q-points.

Unfortunately the match condition is difficult to fulfil over a broad bandwidth. The high degree of symmetry, however, means that it is possible to express general solutions to Maxwell's equations for a class of five-ports by means of known mathematical functions; in the present case series of Bessel and Neumann functions.

The purpose of the present work has been to find the most broad banded five-port among a multi-dimensional number of possible five ports. The simple form of the five ports means that they can easily be integrated with detector diodes and amplifiers etc and thus form a large part of the network analyser.

Method for solution of the wave equation

The geometry chosen is a (flat) circular cylindrical cavity whose plane boundaries are ideally conducting. The curved boundaries are at radii r_i and r_o (Fig. 1). They may be independently chosen as either ideally conducting or isolating. The five ports are evenly distributed along a circle with radius r_{int} where $r_o > r_{int} > r_i$. Each port is connected across the cavity and may in practice consist of a coax connector. The size of the connectors is assumed to be small compared with the wavelength (as the diameter of the cavity is comparable to the wavelength).

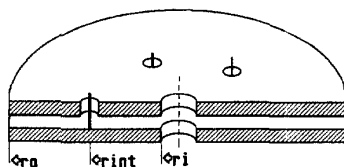


Fig. 1. Sketch of five-port cavity

Only circular magnetic modes are considered and dependence along the axis is neglected.

A third (imaginary) circular boundary at r_{int} is introduced by considering the five currents from the ports as the sum of a Fourier series of linear current densities at the interface. For each of the sections: $r_i < r < r_{int}$ and $r_{int} < r < r_o$, and for each Fourier component the solution to the wave equation can be expressed as a linear combination of a Bessel and a Neumann function (of the same order as the Fourier term). The problem is thus reduced to the determination of coefficients to the Bessel and Neumann functions which satisfy the boundary conditions. The Fourier series and thus the order of the Bessel and Neumann functions must be truncated to a finite number in accordance with the diameter or width of the connector pin. The wave equation can be solved as described for each of the three independent excitation conditions possible. Finally the current and voltage at each connector and thereby the scattering matrix can be determined.

As described above the solution to the wave equation is fairly straight forward. It is a much greater task to find the optimal geometry i.e. the values of r_i , r_{int} , r_o and the height (along the axis) that fit the external characteristic impedance and the desired center frequency and which also yield the broadest bandwidth.

A computer programme has been constructed which for each geometry computes S_{11} as a function of frequency and chooses the geometry for which the numerical value of S_{11} is less than a given value over the largest possible relative bandwidth. Since the characteristic impedance scales with the cavity height and the center frequency scales with a common factor for the three radii the problem is reduced to contain only two independent parameters e.g. r_i/r_{int} and r_o/r_{int} .

When the computer programme has found a number of solutions close to the optimum, polar plots of S_{11} for those solutions can be presented.

Results

Solutions to the problem have been found with bandwidths up to about $\pm 20\%$ (for $|S_{11}| < 0.1$) depending on the combination of boundary conditions and on the truncation of the order of Bessel and Neumann functions (and thereby on the size of connector pin).

References

- [1] E. R. B. Hanson and G. P. Riblet: "An ideal six-port network consisting of a matched reciprocal lossless five-port and a perfect directional coupler", IEEE Trans. Microwave Theory Tech., MTT-31, pp. 283-288, Mar. 1983.