OPTIMISED DESIGN OF EIGHT-PORT BRANCH-WAVEGUIDE DIRECTIONAL COUPLERS

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Abstract

An optimised design method for eight-port branch-waveguide directional couplers with arbitrary output power distribution is presented. This componet is suitable for beam forming networks (BFN's) applications. In fact the proposed device yields a more compact design of BFN's.

An eight-port coupler prototype in WR75 waveguide has been manufactured. Comparing scattering parameter measurements with the computed frequency performance shows that the design procedure is verified very satisfactorily.

Moreover these couplers can be used as multiport power dividers with four input and four output ports. An example of 4-way power divider suitable for multiport amplifier applications is presented.

Introduction

The growth of satellite communications requires antennae with multiple or contoured beams and then BFN's more and more complicated. Power splitters constitute the key components of BFN's.

Multiple-slot narrow or broad-wall couplers [1], [2] and four-port branch-waveguide couplers [3], [4] have been used in the past as power splitters. Recently,in order to simplify BFN's, six-port branch-waveguide couplers have been considered [5], [6], [7].

In this paper an eight-port branch-waveguide directional coupler with arbitrary output power distribution is presented. This component offers the potential to reduce further complexity, mass and size of BFN's.

Besides BFN's applications these eight-port couplers can be used as multinput power splitters. An example of 4-way power divider is presented. This component is very suitable for multiport amplifier applications.

Design procedure

The first building block of the design method is the device analysis algorithm. The eight-port power divider is shown in Fig. 1a. The four rectangular waveguides are connected to each other by three arrays of branch-guides. The device is symmetrical with respect to the plane A-A. The choice of the number of branches is related to the coupler frequency bandwidth.

The analysis technique is based on the model shown in Fig. 1b by S-matrix representation. The calculations are carried out by dividing the coupler in sections as shown in Fig. 1b. The field-theoretical treatment of each section is accomplished by investigating separately the E-plane T-junctions [8] and the double asymmetrical E-plane T-junctions [9] inside of the section and subsequently connecting them as shown in Fig. 1b. Finally, connecting all sections of the coupler model the S matrix of the eight-port power divider is obtained.

A remarkable thing is that a full-wave analysis of the overall structure is done. In fact, instead of [6], interaction effects of higher order modes are taken into account in all the above mentioned connections.

This analysis method allows to reduce calculation time because the coupler symmetry decreases the number of sections that must be calculated (in the example of Fig. 1b only four of the seven sections must be calculated).

The synthesis of the eight-port coupler shown in Fig.1a, with input power at the port 3 of the device, is here presented. But the design method can be applied feeding any of the four input ports.

The first step of the synthesis technique is the design of three four-port couplers [3] with the nominal couplings related to the desired output power destribution of the eight-port component.

The geometrical dimensions of these three couplers are the first approximation dimensions of the eight-port device of Fig. 1a. Then the electrical performance of the device, calculated by the previous analysis algorithm, are optimised in order to obtain the desired values.

The core of the optimisation algorithm makes use of a multivariable pattern search [10] in which the geometrical dimensions of the eight-port coupler are the variables. However it must be kept in mind that the device symmetry reduces the number of varibles by two.

The objective function, that is to be minimized, takes into account: input reflection, isolations and coupling coefficients; all of them evaluated in several points of the frequency band.

Experimental results and applications

The design technique described above has been successfully employed to design and manufacture a eight-port seven-branch coupler in WR75 waveguide with 10.95-12.75 GHz bandwidth. The nominal coupling values were (dB): C35=15.4, C36=6, C37=2.8, C38=7. The coupler prototype is shown in Fig. 2.

Figs. 4 and 5 show the calculated and experimental frequency response of the coupler. A good agreement is observed The measured results are obtained without the necessity of any experimental triming and that demonstrated the validity of the proposed design method.

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Besides BFN's applications these components can be used as multiport power dividers with four input and four output ports. Fig. 3 shows a device maked with two eight-port couplers connect by waveguide step phase-shifters [11]. It gives uniform output power distribution (see Fig. 6) feeding any of the four input ports. Input reflections and isolations of the device are better of 35 dB.

This device has the same performance of a 4-way hybrid power divider (4x4 Butler matrix) but is more compact and no waveguide crossing are needed. The size of the device is only 160x60 mm and then it is very suitable for multiport power amplifier applications.

Conclusions

In this paper a design procedure for eight-port branch-waveguide couplers has been presented. This component offers the potential to reduce size, mass and complexity of BFN's for multiple or contoured satellite antennas. Theory has been verified by measurements.

The performance of this device is very suitable not only in BFN's applications but even for multiport power dividers.

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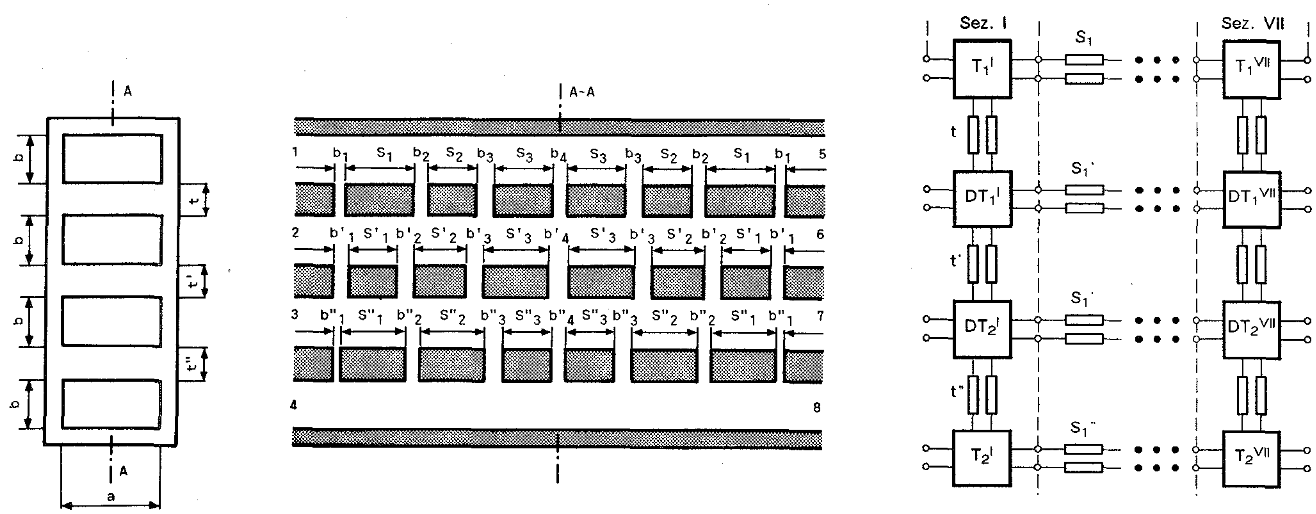

a) b)

Fig. 1 – (a) Eight-port branch-waveguide coupler.
(b) Model of the coupler for S matrix computation: T = E-plane T-junction; DT = double E-plane T-junction;
multimode line of a rectangular waveguide with length L.

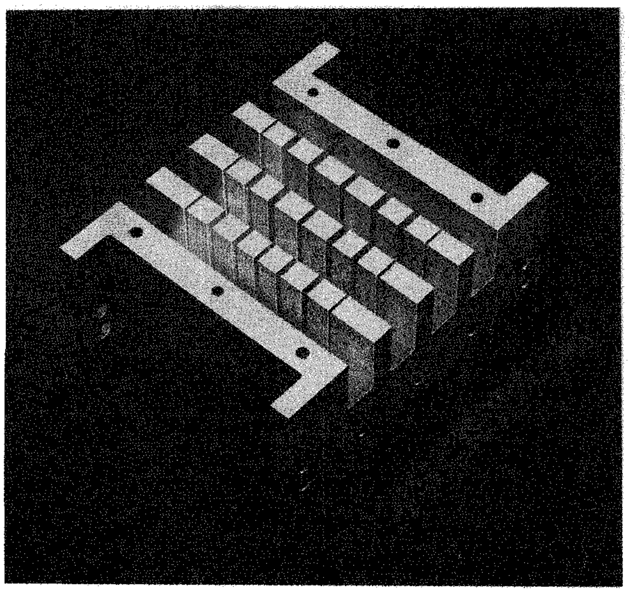

Fig. 2 - Eight-port branch-waveguide prototype.

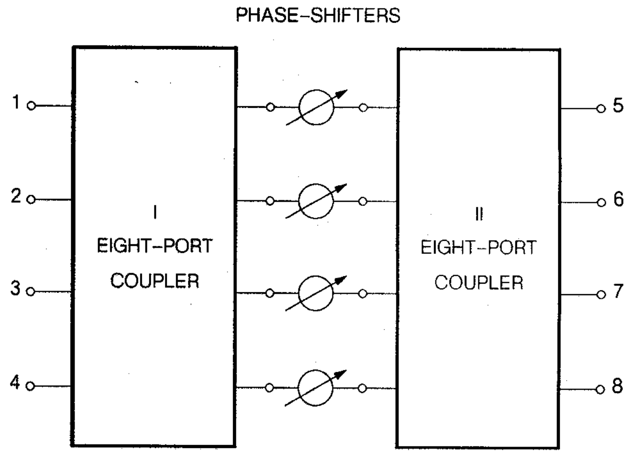

Fig. 3 - 4-way power divider.

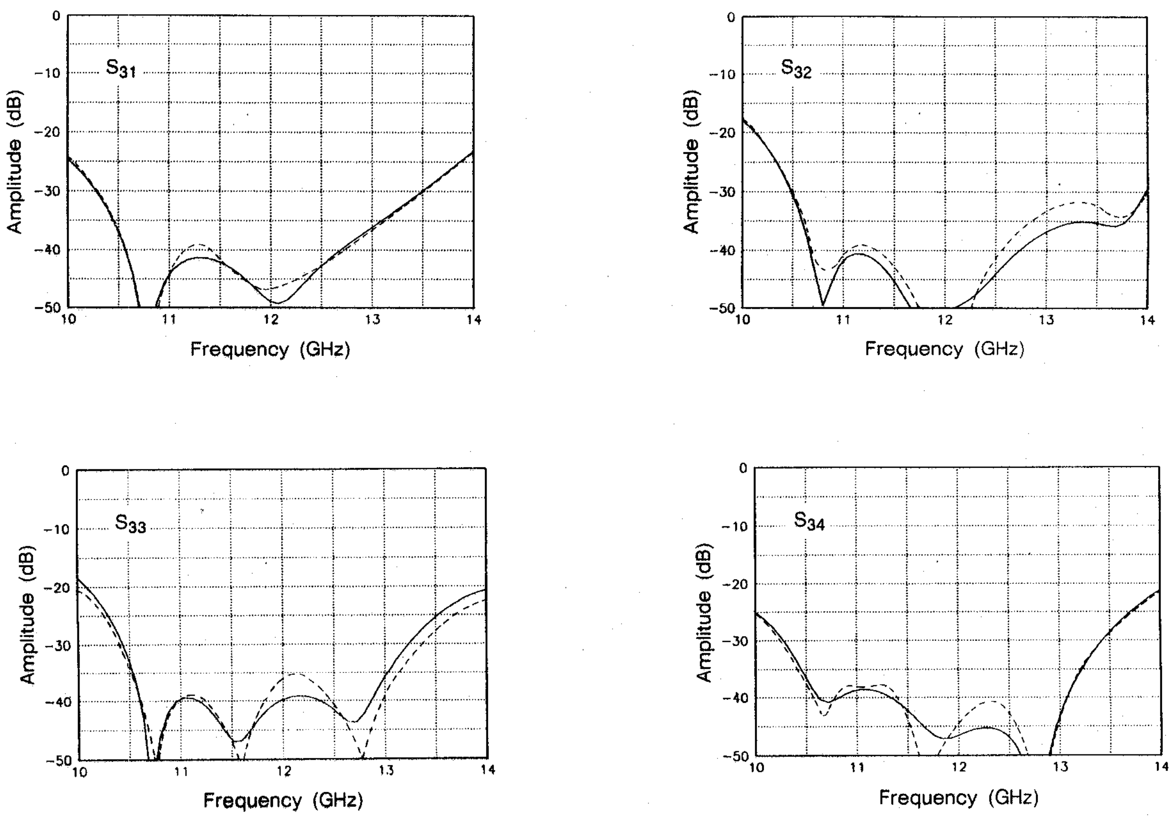

Fig. 4 - Refletion and isolation parameters of the eight-port coupler.
Theory: ——— ; experimental: - - - - -

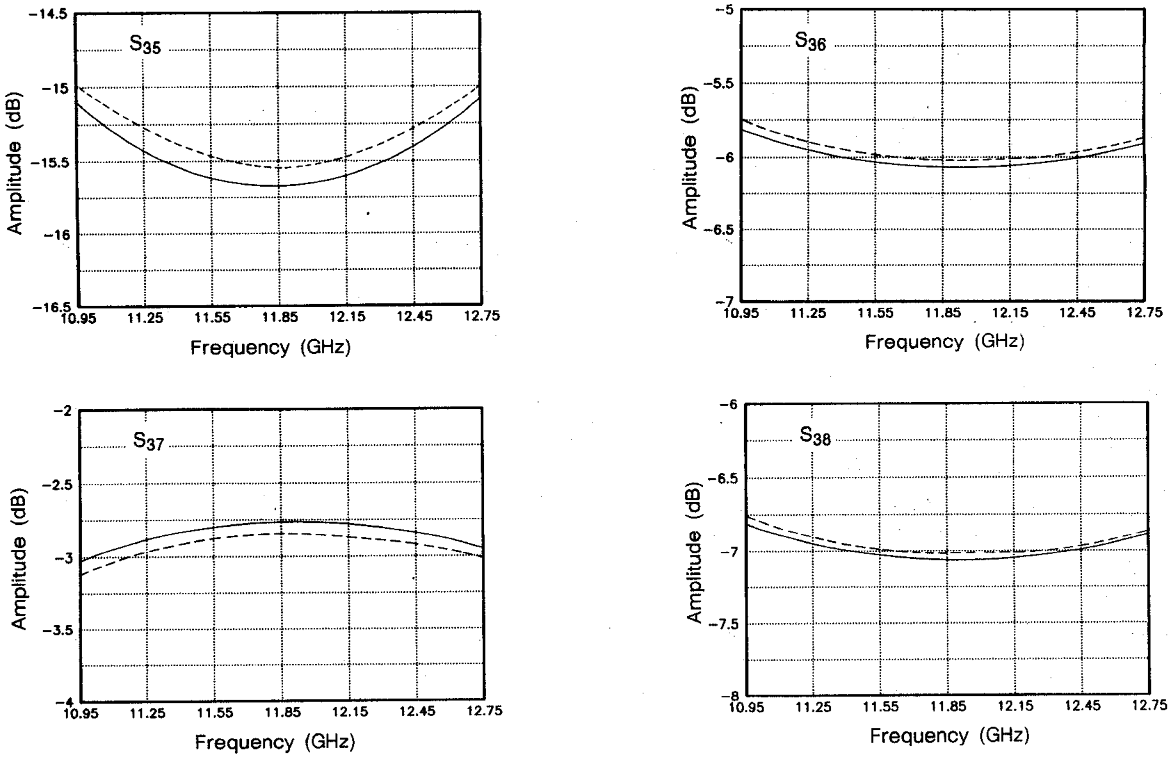

Fig. 5 - Transmission parameters of the eight-port coupler.
Theory: ——— ; experimental: - - - - -

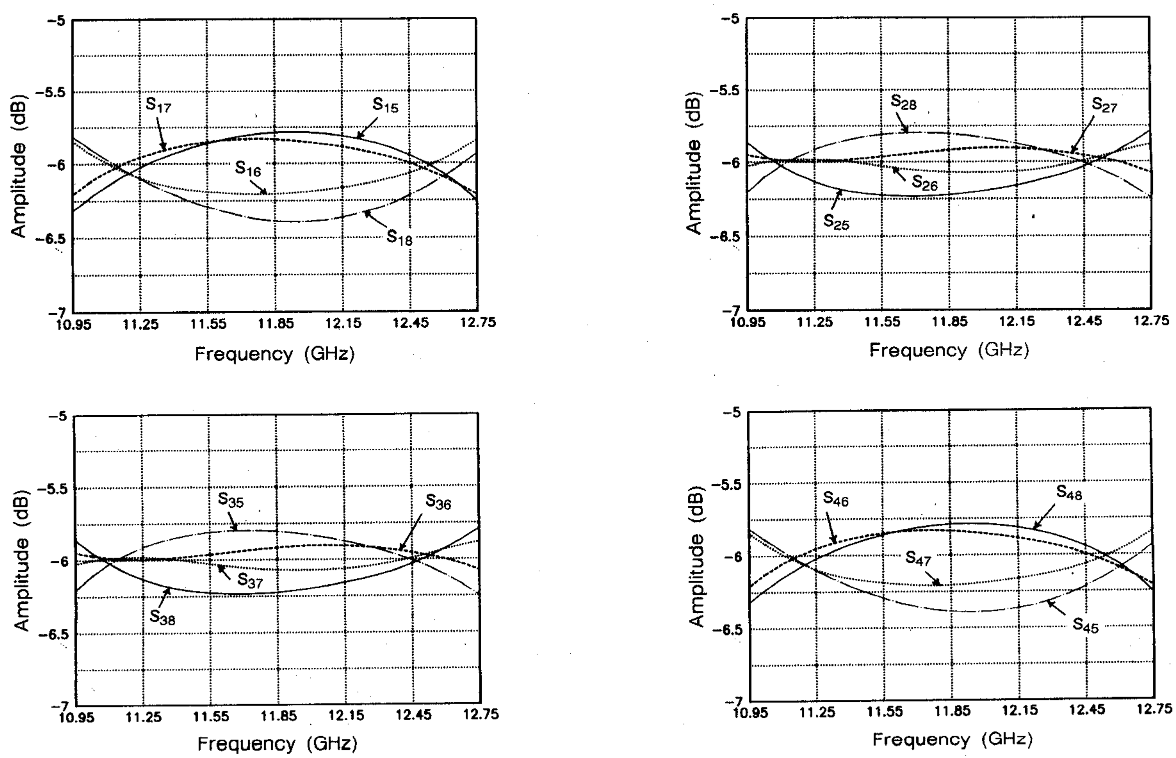

Fig. 6 - Transmission parameters of the 4-way power divider.