MULTI-WAY UNEQUAL POWER DIVIDER CIRCUITS USING SECTOR-SHAPED PLANAR COMPONENTS

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ABSTRACT

In this paper the design of a sector shaped unequal power divider is presented. The design and the method of analysis are extensions of those previously presented for the sector shaped multi-way equal power divider. The initial experimental results for a 4-way power divider show that the power distribution among the output ports can be controlled by suitably locating shorting pins along the radial edges of the sector. Designs with bandwidths greater than 40% (for S_{11} better than -14 dB) have been realized experimentally for a four-way divider with power output at two ports being 4 dB lower than that at the other two ports. The experimental results are in agreement with the theoretically computed values.

1. INTRODUCTION

Design of the multi-way power divider circuits with equal power outputs has received considerable attention [1-4] in recent years. However, for certain applications it is desirable to have signals with unequal amplitudes coming out of the various output ports. One such application is the design of feed networks for linear antenna arrays. In order to reduce the sidelobe levels in these arrays, the central elements are excited with higher inputs than the elements at the two ends of the array. The initial results reported in this paper hold the promise of leading to a compact planar design suitable for such applications.

The proposed design is a modification of the sector-shaped planar equal power divider configuration discussed earlier [4]. Numerous experiments with a 4-way power divider circuit have shown that the power distribution at the output ports can be controlled by appropriately locating shorting pins along the radial edges of the sector. These experimental results are discussed in Section 2. The two-dimensional planar analysis suitable for analyzing these configurations is described in Section 3. The theoretical results are in agreement with the measured data.

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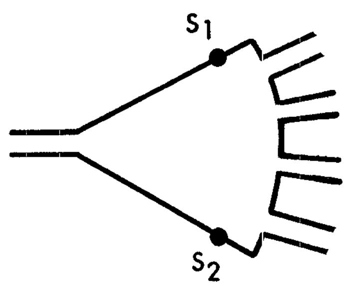

Figure 1. Configuration of a planar 4-way unequal power divider.

2. PROPOSED CONFIGURATION

2.1 Configuration

The proposed configuration for planar power dividers with unequal outputs is shown in Figure 1. It uses a sector-shaped geometry with the input port located at the apex of the center whereas the various output ports are located along the circumferential edge. The shorting pins S_1 and S_2 are 1 mm diameter metallic fuzz buttons connecting the top conductor to the ground plane. Multiple shorting pins (more than one) may also be used at the radial edges. In absence of these shorting pins, the configuration is identical to that used for equal output power divider circuits [4]. As discussed in [4] and shown in Figure 2, the equal power divider circuits operate in two different frequency bands centered around

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the resonance frequencies of the (1,0) and the (2,0) modes. Both of these modes are azimuthally symmetric hence yielding uniform voltage distribution along the open circuited circumferential edge. This azimuthal symmetry leads to equal power outputs.

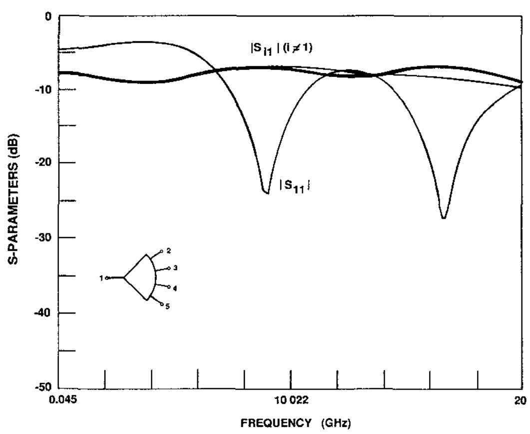

Figure 2. Measured performance of a planar 4-way equal power divider.

By locating shorting pins along the radial edges, modes with azimuthal field variation are excited. This is in addition to the (1,0) and (2,0) modes mentioned earlier. These asymmetric modes reduce the voltage on portions of the circumferential edge near the radial edges, causing the output power from the ports located near the radial edges to be reduced.

2.2 Experimental Results

Extensive experiments have been carried out on 4-way power divider circuits fabricated on a 31 mil Duriod (ε_r = 2.2) substrate. The sector angle of the circuit is 90° and the radius is 1.5 cm. All the input-output lines have Z_o=50 Ω. Measurements have been carried out over the frequency range 2.0 - 20.0 GHz using the HP 8510 Automatic Network Analyzer. The gating feature on the HP 8510 has been used to remove the effect of connectors.

Measurements for three different locations of two shorting pins (one on each of the radial edges) are shown in Figures 3, 4 and 5. In these 3 cases the pins were located at distances of 0.22 cm, 0.33 cm, and 0.44 cm from the circumferential edge. Interesting results are observed in all of the three cases, and unequal power division is obtained in both the lower frequency band (around the (1,0) mode) and the higher frequency band (around the (2,0) mode). Perhaps the most interesting case is the one shown in Figure 4 (shorting pins 0.33 cm from the circumference). Return loss of less than -14 dB is obtained over the frequency range 5.8 to 9.0 GHz (a bandwidth of 43.24%). For $S_{11} < -10$ dB the bandwidth is about 77%. Over this bandwidth, the output at the outer ports (#2 and 5) is-9.5 dB (±0.5 dB) whereas the power output at the inner ports (#3 and 4) is 5.5 dB (±0.25 dB). Thus, fairly wideband power dividers may be designed using this approach.

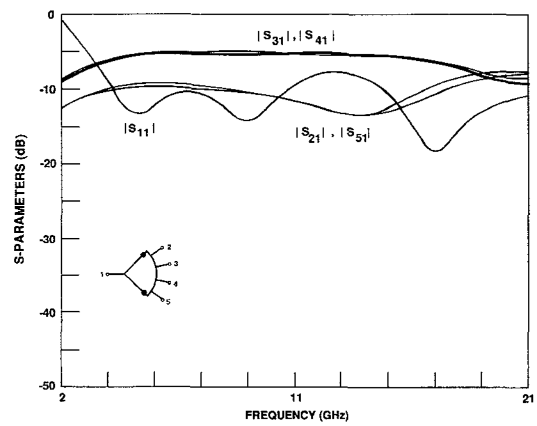

Figure 3. Measured characteristics of a 4-way unequal power divider when the shorting pins are located 0.22 cm from the circumferential

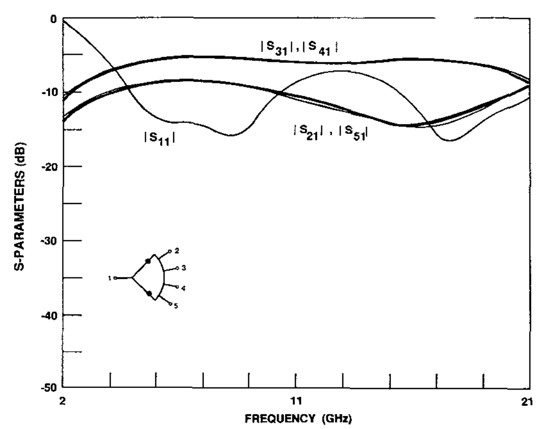

Figure 4. Measured characteristics of a 4-way unequal power divider when the shorting pins are located 0.33 cm from the circumferential edge.

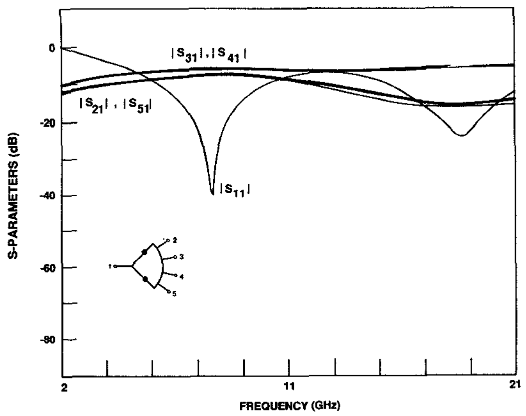

Figure 5. Measured characteristics of a 4-way unequal power divider when the shorting pins are located 0.44 cm from the circumferential edge.

A modification of the design described above is obtained by using two shorting pins on each of the radial edges. A number of experiments were carried out for several different locations of these pins. Results for one of these (with pins located at distance 0.22 cm and 0.11 cm from the circumferential edge) are shown in Figure 6. The most interesting feature of this configuration is the response for S_{11} , whose value is -12.0 dB ($\pm$1 dB) from 3.8 GHz to 10.5 GHz (a bandwidth of 46.85%). Power output at the inner (#3 and 4) and the outer ports are -6 dB ($\pm$0.5) and -12.5 dB ($\pm$0.5) respectively over this range.

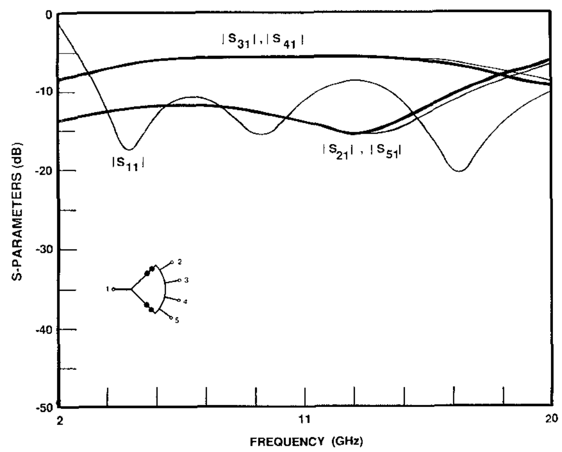

Figure 6. Measured characteristics of a 4-way unequal power divider when shorting pins are located at 0.22 cm and 0.11 cm from the circumferential edge.

Experiments with a larger number of shorting pins (3 pins and 5 pins on each of the radial edges) were also conducted but did not yield any better results.

3. TWO-DIMENSIONAL PLANAR ANALYSIS

The proposed power-divider configuration can be analyzed theoretically by using the two dimensional planar circuit approach. This is an extension of the approach used to analyze power divider circuits with equal outputs discussed in [4].

The theoretical analysis is convenient when the sector angle α is a sub-multiple of 180° because the Green's function method can be applied [4,5]. For any other sector angle, the contour integral approach [5] may be used for evaluating the Z-matrix of the sectorial segment. When $\alpha = 180°/n$, the expressions for the elements of the Z-matrix are obtained from the corresponding Green's functions. These expressions involve infinite series with double summations and have been documented in [4].

When the shorting pins are incorporated the analysis procedure is modified as follows:

1. Extra ports are located at the position of the shorting pins. The effective width of these ports is taken equal to the diameter of the shorting pins used.
2. The Z-matrix is computed with these additional ports taken to be open circuited. For example, in the case of a 4-way power divider with 2 shorting pins (one at each radial edge) we consider a 10-port component and evaluate a 10 x 10 Z-matrix. The additional three ports are due to the fact that the input port has been divided into four subports.
3. The 10 x 10 Z-matrix is converted to the corresponding 10 x 10 Y-matrix, which in turn is reduced to the 5 x 5 Y-matrix when the two extra ports on the radial edge are shorted and the four subports at the feed are combined into a single port. Shorting of the two radial ports corresponds to the removal of the rows and columns corresponding to these two ports from the Y-matrix.
4. The resulting 5 x 5 matrix yields the characterization of the circuit with shorted ports and may be converted to the Z or S-matrix.

Inductive impedances of the shorting pins may be taken into account by following a procedure similar to that discussed in [3].

This theoretical procedure has been implemented. A comparison between the theoretical and experimental results is shown in Figure 7 for a four-way unequal power divider. The lack of agreement above 15 GHz is due to the limited number of terms (n = m = 40) used in the evaluation of the elements of impedance matrix. This observation is consistent with the computation reported earlier [4] for the 90° sector four-way equal power divider. If desired a better accuracy can be obtained by increasing the number of terms in the series. This of course will increase the computational time.

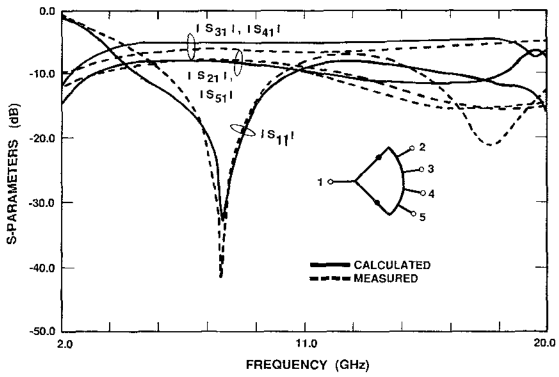

Figure 7. Measured and calculated characteristics of a 4-way 90° sector unequal power divider (Radius = 1.5 cm, h = 1/32 in., ε_r = 2.2, and shorting pins located on the radial edge 0.44 cm from the curved edge).

4. CONCLUDING REMARKS

A novel configuration for designing unequal power-divider circuits has been presented. The configuration utilizes a sectorially shaped planar component with one or more shorting pins along each of the radial edges. Initial experiment results are very encouraging (> 40% BW for S_{11} better than 14 dB). A theoretical analysis based on the two-dimensional planar approach is proposed and the computed results are in agreement with the measured data.

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