Short Papers

A Compact Ring-Style 8-Port Comparator Circuit Using Coupled Lines

G. P. Riblet

Abstract— **A novel ring-type 8-port comparator circuit is described which has a circumference of only 1 wavelength at midband. It consists of a symmetrical arrangement of 4 coupled line sections etched on the top and bottom surfaces of a thin circuit board. All ports are external to the ring.**

I. Introduction

An 8-port comparator is used in a monopulse radar system for determining the azimuth and evaluation of a target. In addition, the circuit may be used as a 4-way power combiner/divider with output port isolation. Generally, the 8-port comparator is constructed with four 180° hybrids. The conventional comparator circuit has only limited symmetry.

Recently, it was realized that this component may be based on a symmetrical 8-port circuit with 90° and 180° phase shifters connected at certain ports [1], [2]. As a result, some novel planar configurations for the comparator become possible. One of these is a compact microstrip-slotline ring circuit with a circumference of only 1 wavelength [1]. However, some ports lie internal to the ring. Another is a much larger 8-port branch line circuit [2]. It has the advantage that all ports lie external to the circuit. In this short paper, a planar-type 8-port hybrid will be described which combines the advantages of both of these circuits. It has a circumference of only 1 wavelength, and has all ports external to the ring. It is based on the use of four coupled line sections.

II. Theory

In this section, the theory of the 90° hybrid coupled symmetrical comparator circuit will be reviewed. A schematic diagram of the circuit is given in Fig. 1. It is based on the use of four 90° hybrids connected together in a symmetrical arrangement to produce an 8-port circuit. Based on the properties of the 90° hybrid, it may be shown that at an appropriate reference plane, its S matrix has the form

$$S = \frac{j}{2}\begin{pmatrix} 0 & 0 & 0 & 0 & 1 & 1 & j & -j \\ 0 & 0 & 0 & 0 & 1 & 1 & -j & j \\ 0 & 0 & 0 & 0 & j & -j & 1 & 1 \\ 0 & 0 & 0 & 0 & -j & j & 1 & 1 \\ 1 & 1 & j & -j & 0 & 0 & 0 & 0 \\ 1 & 1 & -j & j & 0 & 0 & 0 & 0 \\ j & -j & 1 & 1 & 0 & 0 & 0 & 0 \\ -j & j & 1 & 1 & 0 & 0 & 0 & 0 \end{pmatrix}. \quad (1)$$

All ports are matched, there is mutual isolation between the sets of 4 input and 4 output ports, and power divides equally from any input port to the output ports. By including a −90° phase shifter at ports 3 and 7, and a +90° phase shifter at ports 4 and 8 (as indicated in Fig. 1 by the primed ports), the S matrix becomes

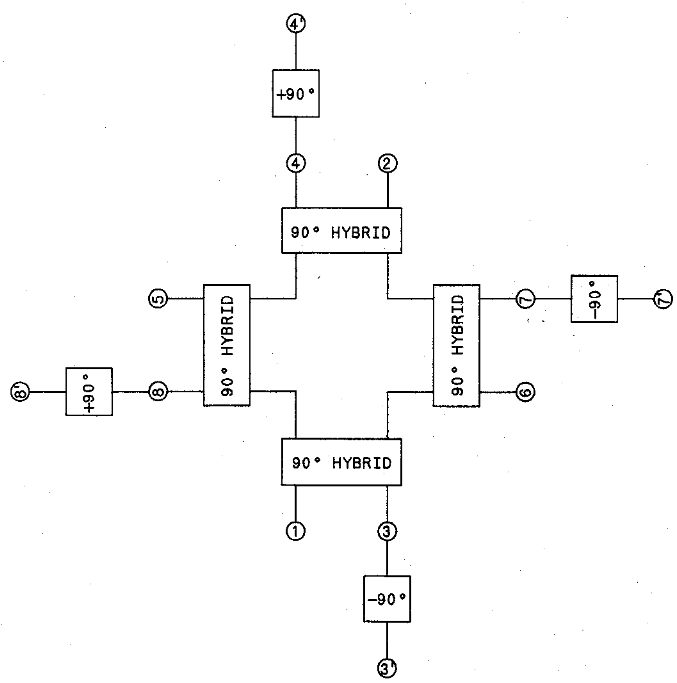


Fig. 1. Schematic diagram of an 8-port comparator based on a symmetrical arrangement of four 90° hybrids.

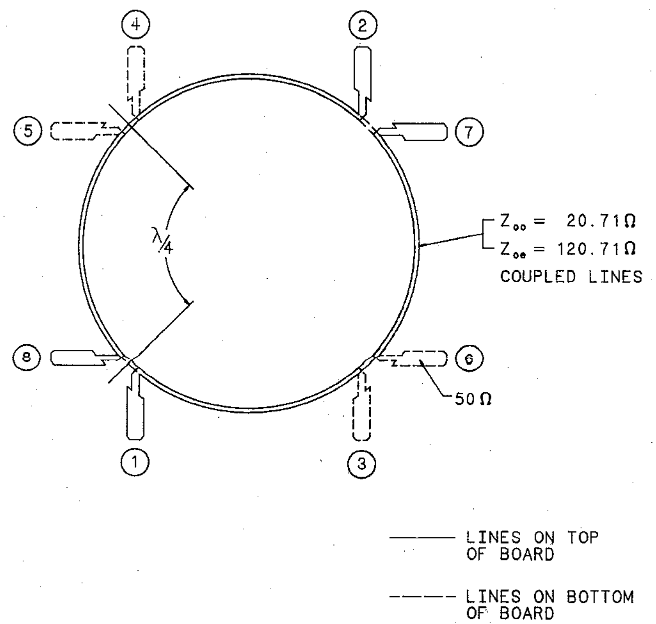


Fig. 2. Schematic diagram of an 8-port hybrid ring circuit based of four coupled line 90° hybrids.

Manuscript received August 20, 1992; revised November 2, 1992.
The author is with Microwave Development Laboratories, Inc., 11 Michigan Drive, Natick, MA 01760.
IEEE Log Number 9209357.

0018-9480/93$03.00 © 1993 IEEE

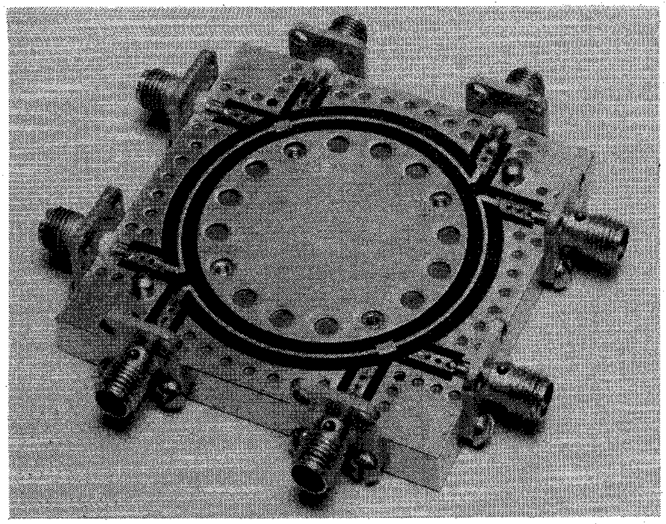


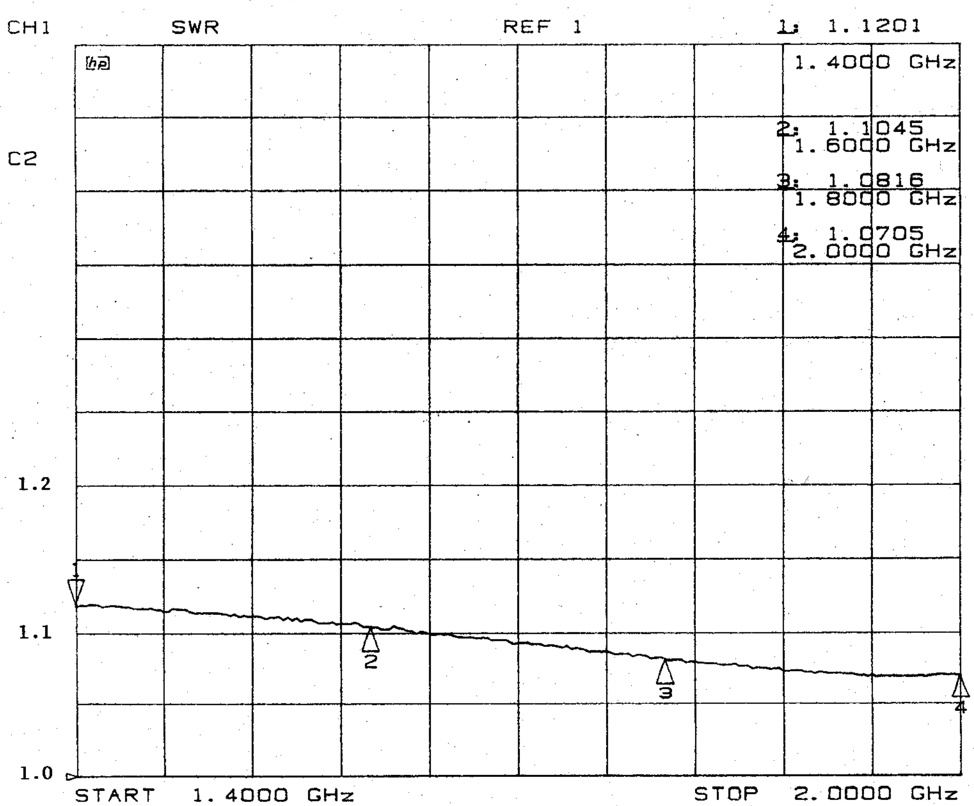
Fig. 3. Picture of the experimental 8-port hybrid ring circuit.

$$S = \frac{j}{2}\begin{pmatrix} 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & -1 & -1 \\ 0 & 0 & 0 & 0 & 1 & -1 & -1 & +1 \\ 0 & 0 & 0 & 0 & 1 & -1 & +1 & -1 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & +1 & -1 & -1 & 0 & 0 & 0 & 0 \\ 1 & -1 & -1 & +1 & 0 & 0 & 0 & 0 \\ 1 & -1 & +1 & -1 & 0 & 0 & 0 & 0 \end{pmatrix}. \quad (2)$$

This is the S matrix of the standard sum and difference comparator. Port 1 is the sum port, while ports 2, 3, and 4 are difference ports. The process is analogous to building a 4-port 180° hybrid by introducing a 90° phase shift at 1 output port of a symmetrical 90° hybrid. However, the basic symmetrical circuit without the phase shifters with an S matrix given by (1) is of interest in its own right. It has recently been termed an 8-port hybrid [3].

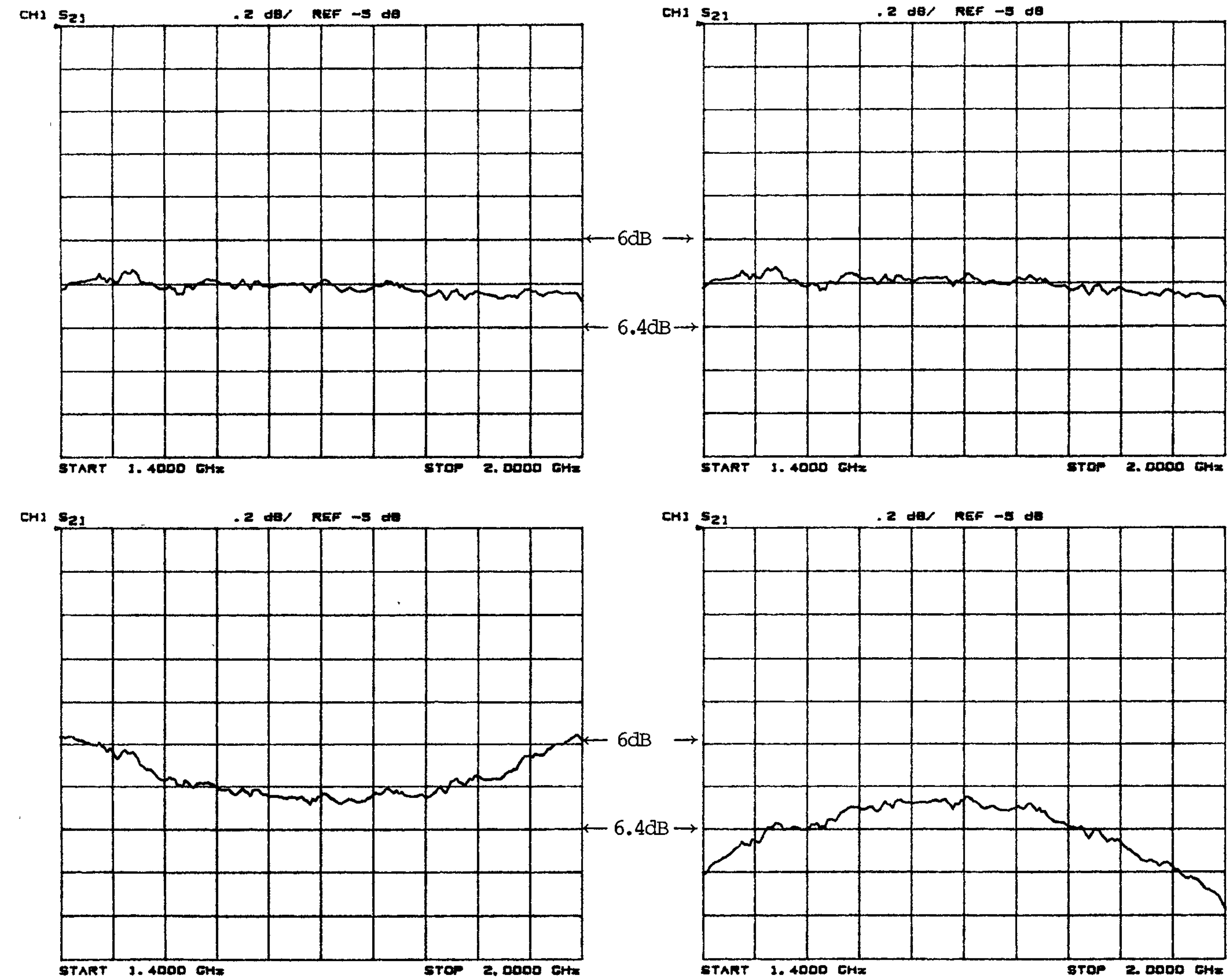
Versions of this 8-port hybrid have been proposed based on interconnected branch guide 90° hybrids [2] and transmission lines [3]. In this short paper, an even more compact version based on coupled transmission lines will be discussed. In effect, the 90° hybrids given schematically in Fig. 1 are quarter-wavelength-long coupled line hybrids. The circuit becomes a ring circuit with a circumference of only 1 wavelength. This particular circuit is given schematically in Fig. 2. As a result, at a given frequency, the 8-port hybrid has the same size as a 2-branch 90° hybrid. The coupled transmission lines are etched on the top and bottom surfaces of a thin circuit board. In the schematic diagram, solid lines correspond to transmission lines on the top surface, while dashed lines correspond to transmission lines on the bottom surface. The proper operation of the device depends on the backward wave nature of the coupling. As a result, power incident at port 1 will divide equally between ports 5, 6, 7, and 8. The frequency dependence of the scattering matrix is given at an approximate reference plane by

$$S = \begin{pmatrix} 0 & 0 & 0 & 0 & C & C & jA & -jB \\ 0 & 0 & 0 & 0 & C & C & -jB & jA \\ 0 & 0 & 0 & 0 & jA & -jB & C & C \\ 0 & 0 & 0 & 0 & -jB & jA & C & C \\ C & C & jA & -jB & 0 & 0 & 0 & 0 \\ C & C & -jB & jA & 0 & 0 & 0 & 0 \\ jA & -jB & C & C & 0 & 0 & 0 & 0 \\ -jB & jA & C & C & 0 & 0 & 0 & 0 \end{pmatrix} \quad (3)$$



(a)

Fig. 4. (a) and (b) Experimental VSWR and output port coupling for the circuit pictured in Fig. 3 over the frequency range of 1.4–2 GHz.



(b)

Fig. 4. *(Continued)*

where $A = 1/(1+\sin^2\theta)B = \sin^2\theta/(1+\sin^2\theta)$, and $C = \sin\theta/(1+\sin^2\theta)$, and where θ is the electrical length of coupled transmission line sections.

III. Experiment

An experimental model in the form of an 8-port ring circuit has been constructed to operate in the frequency range of 1–2 GHz. The center conductors were etched on both sides of a 0.005″-thick $\varepsilon = 2.22$ board in order to obtain coupled transmission lines of the appropriate impedance levels. Plated through holes were used to connect the four output lines on the bottom of the surface board to the top of the board. As a result, all input and output transmission lines are on the same side of the board. A picture of the unit is given in Fig. 3.

In Fig. 4, some experimental measurements on the unit over the frequency range 1.4–2 GHz are given. In Fig. 4(a), the VSWR is plotted versus frequency, and is less than 1.12 over this band. In Fig. 4(b), the measured coupling to the four output ports is presented. The unbalance is less than 0.2 dB over most of the band 1.4–2 GHz. Consequently, the bandwidth is greater than that of the symmetrical comparator circuits which have been described previously [1], [2]. The experimental model does not include the 90° phase shifters given in the schematic diagram of Fig. 1. Schiffman 90° phase shifters employ coupled lines. Because the circuit board is double sided, these could readily by included in an experimental design.

IV. Conclusions

In this short paper, a compact ring-type 8-port hybrid circuit has been described. It has a circumference of only 1 wavelength at midband. As a result, for a given operating frequency, it has the same size as a 2-branch 90° hybrid. Likewise, all ports are external to the circuit. An experimental model was built and evaluated. The operating bandwidth was determined to be about 25%. This is somewhat greater than for previously described circuits.

References

[1] G.P. Riblet, "Compact planar microstrip-slotline symmetrical ring eight-port comparator circuits," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-38, pp. 1421–1426, Oct. 1990.

[2] T. Kawai, K. Iio, I. Ohta, and T. Kaneko, "A branch-line-type eight-port comparator circuit," in *1991 IEEE MTT-S Int. Microwave Symp. Dig.*, June 1991, pp. 869–872.

[3] I. Ohta, T. Kawai, S. Shimahashi, and K. Iio, "A transmission-line-type eight-port hybrid," in *1992 IEEE MTT-S Int. Microwave Symp. Dig.*, June 1992, pp. 119–122.

[4] B.M. Schiffman, "A new class of broad-band microwave 90-degree phase shifters," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-6, pp. 232–237, Apr. 1958.