International Journal of Research in Signal Processing, Computing & Communication System Design
Volume 2, Issue 1&2, 2016
ISSN: 2395-3187

Design and Analysis of Mono Pulse Comparator for Tracking Applications at KU-Band

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Abstract – This paper presents design of mono pulse comparator. The main aim of this comparator is for tracking applications, in this comparator total 8 ports in that 4 ports are input and another four ports are out put ports, in that output ports one is sum port and two ports difference ports, one termination port, in that two difference ports one is azimuth difference and elevation difference, ratio of difference (azimuth or elevation), sum will give the bore sight error. And this comparator will give accurate elevation and azimuth angle. it is designed and simulated by using RT/DUROID 5880 substrate at the operating frequency 17GHz improve the performances. After a theoretical study on the use of open stubs, we present the simulation results of this mono pulse comparator by using CST Microwave Studio. Good agreement is found simulation. in this we follow to steps one is to design hybrid coupler and second one is adding extra 900 bend line to the hybrid coupler by integrating combination of this type four hybrid coupler we get four out put channels in that one sum port, two difference ports, one termination port.

Keywords:

I. Introduction

The couplers are from of the most passive components used in modern communication systems. These hybrid couplers are the key elements in the design of microwave devices such as power amplifiers, mixers and antenna systems due to their simplicity, wide bandwidth power distribution, and high isolation between ports. This work is unscrewed into two parts. The first part devoted to the theoretical study of directional coupler with a detailed development of the 3 dB coupler. In the second part, we will discuss the conception, optimization and the achievement of a new coupler (3dB, 90°) with extra 90^0 bend line later integrating together and seen the results. Like four hybrid couplers were integrated structure which is build by using software CST Microwave Studio.

II. Theorical Study of Couplers

Couplers called "Branch-Line" as shown in fig. 1, directional couplers are generally used for distribution to 3dB of energy, with a phase difference of 90° between the way "direct" and the way "coupled. This kind of coupler is commonly designed in micro strip technology, and is one of the couplers called "phase quadrature, the power between the port 1 will be divided between the port 2 (direct path), and port 3 (channel coupled) with a phase difference of 90° between the outputs. No energy is transmitted to port 4 (isolated port). The directional coupler is characterized by three parameters:

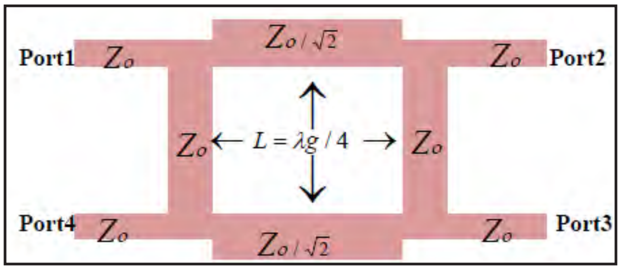


Fig. 1. Hybrid coupler

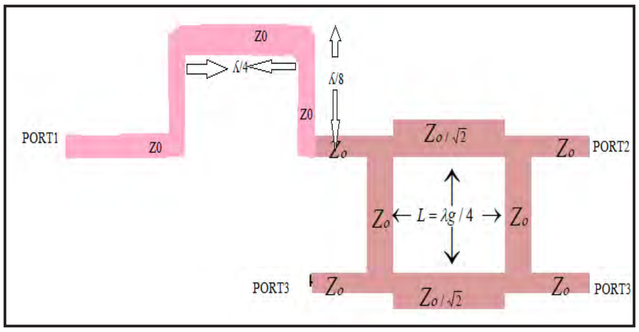


Fig. 2. Extra 900 bend line hybrid coupler

The hybrid coupler is a four-port microwave device which takes an input on one port and provides an even power split on two output ports with a 90 degree phase shift between them. The fourth port on the device is isolated from the first. The device exhibits reciprocal behavior because any port can act as an input, and the device will operate in the same manner (albeit with different output ports). The coupler is made of four sections of quarter wavelength transmission line. Two sections have a characteristic impedance of Z0, and the other two have an impedance of Z0/ √ 2. Each port is fed with a transmission line of impedance Z0. A coupler can be categorized by five main parameters: bandwidth, insertion loss, coupling ratio, phase shift between ports, and isolation. Bandwidth is defined as the frequency range where the device provides a phase shift within ±10 degrees of the desired phase shift. Insertion loss is the additional loss within the device above the loss due to splitting. This can be caused by reflections of signals, dielectric losses, and conductor losses. Coupling ratio is defined as the ratio of the lower of the two output powers to the input power. Isolation refers to the ratio between the input power and the leakage power at the isolated port .It will be necessary to have an idea of the typical specifications that commercially available hybrid couplers possess in order to gauge the performance of the constructed coupler. Hybrid couplers tend to have bandwidths of about 13:1 at a maximum. Over this bandwidth, couplers will typically exhibit about 3 dB of insertion loss, a coupling ratio of 3 dB and isolation of 20 Db.

III. Hybrid Coupler As A Phase Shifter

When the hybrid coupler is implemented as a phase shifter, the output ports are terminated with reactive (capacitive or inductive) loads. These reactance's cause a reflection, which, when combined, will cause an output on the fourth port that is phase shifted by a certain degree from the input. The reactance's are also typically either switched or analog variable to allow for a switched phase difference to be 5 obtained from the device . The implementation used for this design will be two switched reactance's. Phase shifters are categorized by several parameters: phase response over bandwidth, insertion loss, and its desired switched phase shift Specifications of typical phase shifters tend to have about 2-3 dB of insertion loss, 90 or 180 degrees of switched phase shift (i.e. switching between 0 and 90/180 degrees of shift), and a 10% bandwidth. This bandwidth is the frequency range over which the device exhibits a phase shift that is ±10 degrees from the desired phase shift.

IV. Analysis Of Hybrid Coupler

The basic layout for a micro strip hybrid coupler is shown in figure The hybrid coupler can be analyzed using an even-odd mode technique. This technique can be used because the coupler is a linear device. Linearity allows for the use of superposition to split an input source into a sum of even (in phase) and odd (out of phase) sources. This split allows the symmetry of the coupler to be preserved which simplifies analysis. Once the source is split, each mode can be analyzed separately and the sum of the results gives the total response of the coupler.

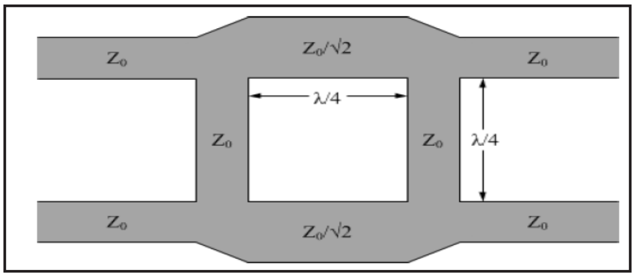
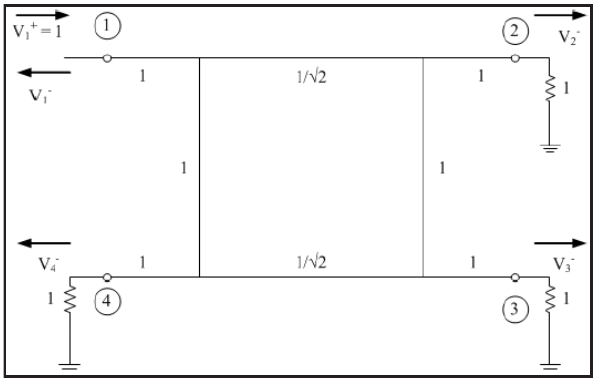
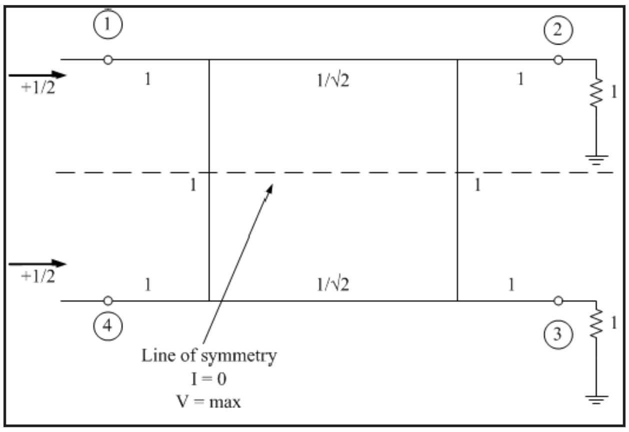


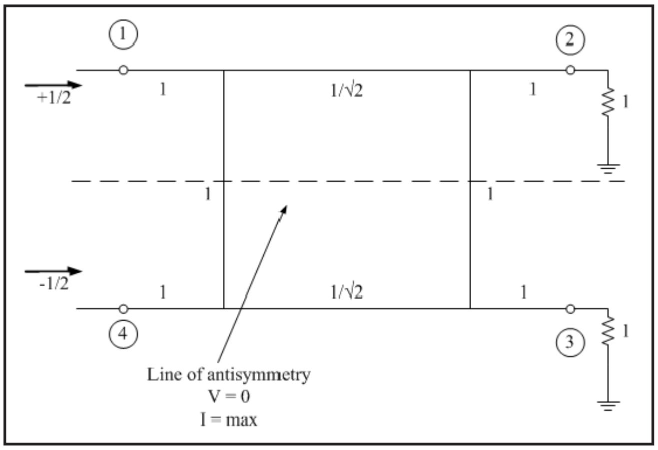
Fig. 3 : Schematic view of hybrid coupler

The first step in this analysis is to redraw the coupler as a normalized (with normalization constant Z0, the characteristic impedance of the output ports) circuit schematic as shown in figure.



To find the S parameters of the coupler, the circuit needs to be excited at one port while all other ports are terminated with a matched load. Once the reflected waves are found, the S parameters of the coupler can be determined by Port 1 is chosen arbitrarily as the first input port. As seen in figure V_1 is incident on port 1, and we have reflected waves at each port (V1,V2,V3,V4) This excitation can be split into its even and odd modes as shown in figure.





V. Design of Mono Pulse Comparator

In order to construct a hybrid coupler phase shifter, the hybrid coupler at its center must be built first. This will cover the design goals and design process for the hybrid coupler. The goal for this mono pulse comparator design will be to have approximately 10% bandwidth over which it exhibits greater than 1 dB of return loss, a coupling ratio of 3 dB (0:5 dB) and isolation of 15 dB with a center frequency of 17GHzThe hybrid coupler for this design will be matched to ports with 50 ohm impedance. Because of this, the quarter-wavelength sections of the device have 50 and 35.4 ohm impedances. The coupler will be built out of micro strip on a substrate of RT Duroid 5880

Parameter	Value
50ohm	182mils
35.4	299.4mils
Quarter wavelength	3.13mm

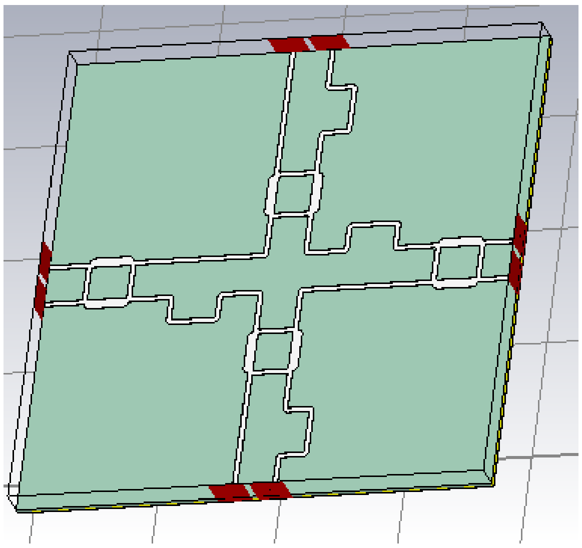


Fig. 4. Schematic view of mono pulse comparator

VI. Mathematical Equations And Simulation

An initial simulation of this circuit was created in RF Sim to verify design widths and lengths. The phase velocity through the micro strip lines can be found using

$$\upsilon_{ph} = \frac{1}{\sqrt{\mu \in}} = 1.96 * 10^8 \, m/s$$

The phase velocity of the microstrip can then be set in RF Sim along with the quarter wavelength section lengths to get the simulation circuit

Length = $3\lambda/4 + Z_0$(width of particular impedance) = 9.31mm

$\lambda/4 = 2.97$, $\lambda = 11.89$, Z_0=158ohm

(width=0.4mm), $\frac{Z_o}{\sqrt{2}}$ = 111.72 ohm(width=1.1mm)

Height = $\lambda/4 + \sqrt{2}\, Z_0$ =4.56mm

$$\frac{W}{d} = \frac{8e^{A}}{e^{2A} \,\square 2}$$

Length of hybrid $\quad L = \frac{90 * \pi * 180}{\sqrt{\in_r} * k}$

$$k = \frac{2Àf}{c}$$

a) $W/H < 2$

$$Z_0 = \frac{60}{\sqrt{\in_{eff}}} \ln\left(\frac{8H}{W} + \frac{w}{4H}\right)\Omega$$

$$\in_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + 12\frac{H}{W}}} + 0.04\left(1 - \frac{W}{H}\right)^2\right]$$

a) for W/H<2

$$Z_0 = \frac{120}{\sqrt{\varepsilon_{eff}\left[\frac{W}{H} + 1.393 + \frac{2}{3}\ln\left(\frac{W}{H} + 1.444\right)\right]}}\Omega$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + 12\frac{H}{W}}}$$

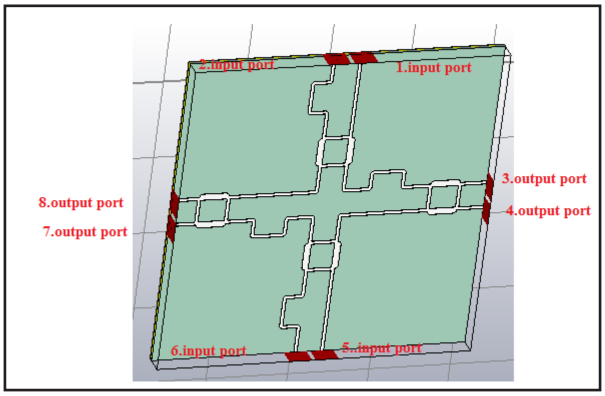


Fig. 5. Designed mono pulse comparator

There are totally 8 ports in that four ports are input and rest four ports are out put ports. In that ports one is sum port , two difference outputs and one is isolation port.

Output Ports :

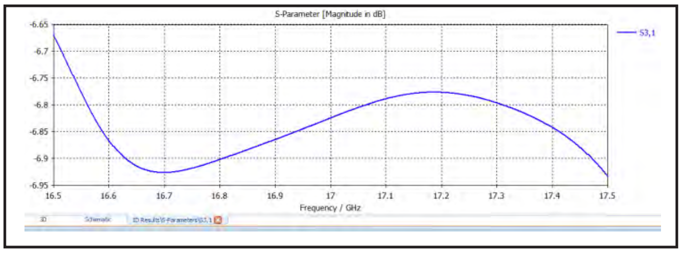


Fig. 6. Output of S31 port

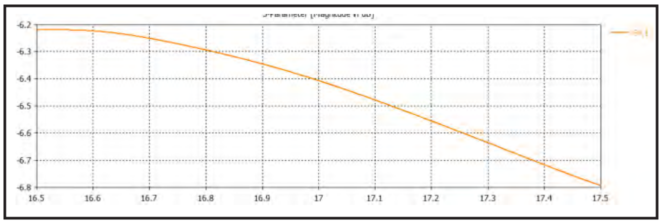


Fig. 7. Output of S41 port

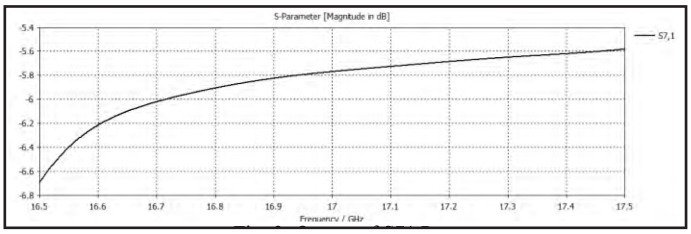


Fig. 8: Output of S71 Port

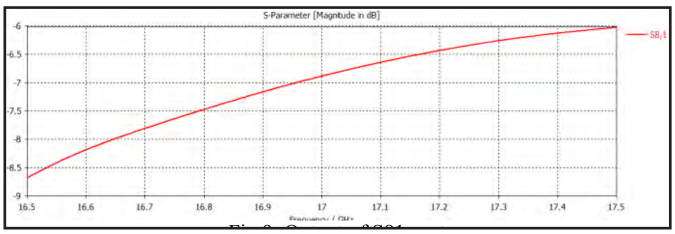


Fig 9: Output of S81 port

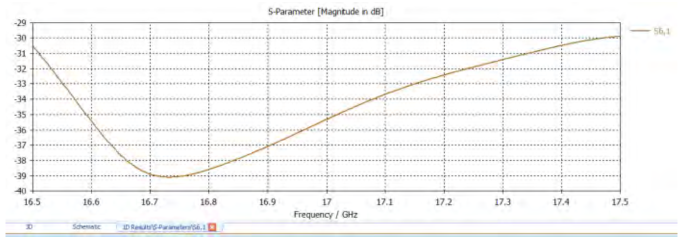


Fig. 10. Output of S61 port

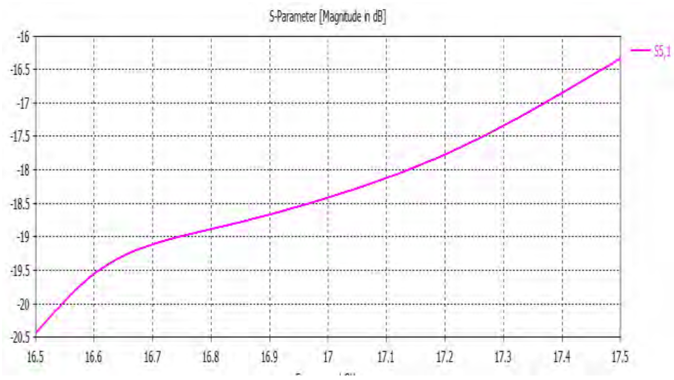


Fig. 11. Output of S51 port

Return Loss of Input Ports:

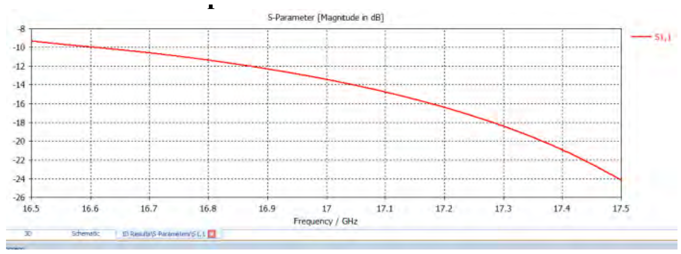


Fig. 12. Output of S11 port

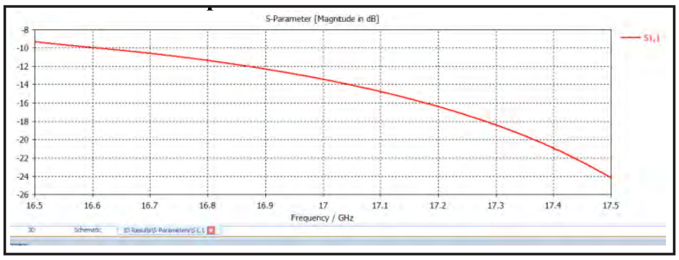


Fig. 13: Output of S22 port

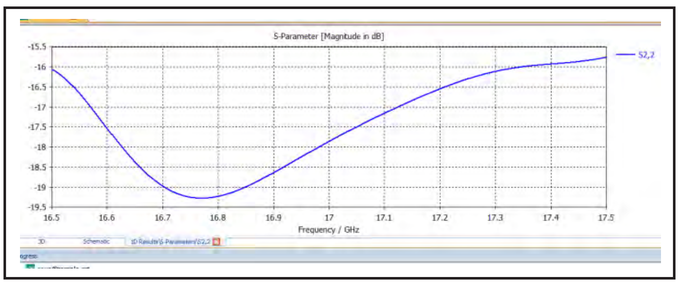


Fig. 14: Output of S33 port

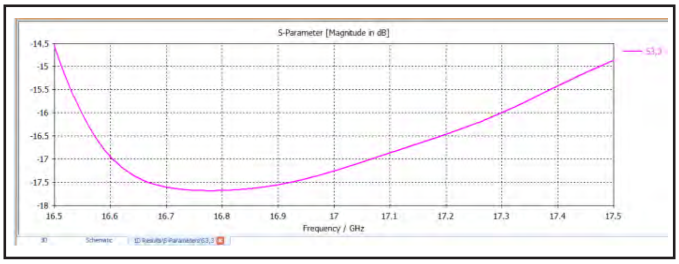


Fig. 15. Output of S44 port

This comparator is used to get one sum channel and 2 difference channels every output gives above -6dB because it come out from two ports. for single coupler it is -3dB as per that the return loss also good for some channel all ports are in same phase that is 180^0 for difference channel two ports are in same phase and other two ports are out of phase.

S11= -12.5dB	S21= -12.5dB	S13= -6.85dB
S14= -6.4dB	S51= -18dB	S16= -35dB
S17= -6.7dB	S18= -6.8dB	S22= -17.8dB
S33= -17.8dB	S44= -15dB	S55= -32dB
S66= -19.9dB	S77= -20.5dB	S88= -15.5dB

VII. Conclusion

In this paper hybrid coupler, mono pulse comparator with compact sized is designed and simulated. 3dB, 6dB attenuation and phase difference is observed from the s parameter graphs. In out ports 7^{th} port is all are in same phase that means it is sum port, 8^{th} and 3^{rd} ports are elevation, azimuth ports that means two ports are in same phase and remaining two ports out of phase, 4^{th} port is termination port. Further improvement can be possible by using better optimization technique. Hybrid coupler, Mono pulse comparator by using micro strip line is designed with RT/DUROID 5880 substrate. Simulation is done in CST software. We can believe that given coupler can plays different tracking applications i.e. in Missile, Aircraft, satellite communication.

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