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JUNCTION BRANCH LINE COUPLER FOR RADAR S-BAND 3 GHZ

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Keywords:Pulse Radar, Branch Line Coupler, Duplexer.

ABSTRACT

Branch Line Couplers have an important role in various RF systems such as transmitters, receivers, signal processing circuits, phase shift, coupling.This research discusses the design of the microstrip 3 dB Branch Line Coupler with π-junction that works at a frequency of 3 GHz using FR4 substrate. The design was carried out with the help of simulation software Computer Simulation Technology 2019. Branch Line Coupler is part of a duplexer to be applied to a pulse radar operating at a frequency of 3 GHz, while the insertion loss to be achieved is <1 dB, isolation between ports to be achieved <- 20 dB, the amount of VSWR to be achieved is ≤ 1.5 and the coupling factor to be achieved is -3 dB.The results of this research are the microstrip branch line coupler that is designed to work at a frequency of 3 GHz using the EPOXY FR4 substrate, εr = 4.6 from the simulation, the return loss value (S11) = -61.46 dB, Insertion loss (S21) = -3.29 dB, Coupling Factor (S31) = -3.66 dB, Insulation Value (S14) = -31.12 dB.

Keywords: Pulse Radar, Branch Line Coupler, Duplexer.

1. INTRODUCTION

Radio Detection and Ranging (Radar) is an object detection system that uses electromagnetic waves to identify distance, direction, or speed, both moving and stationary objects [1] such as aircraft, ships, vehicles, conditions weather, and terrain.

Radar technology is a very important technology, so many radar functions are used to meet information and human needs and even the natural environment [2]. For example, weather radar which has a role to conduct studies on weather, rain and so on, while surveillance and navigation radar used for surveillance, control and monitoring purposes uses microwave frequencies, as well as military radars which have enormous benefits for survival. humans and even the environment.

The antenna used in radar consists of a transmitter and receiver [1]. An important property of the RF-frontend or antenna used in a system with a single carrier frequency is its ability to separate the transmitted signal from the received signal. One of the devices used as a separator between the transmitter and receiver is a duplexer or circulator.

Branch Line Coupler is part of the Duplexer; this Branch line coupler works at a frequency of 3 GHz. which has four terminals that have 4 symmetrical linear arms to be able to produce a 90 degree different phase output signal, separated by the phase difference between the two. The number of branches is two branches, and in the branch line coupler series a π-junction is added which is useful as a compensation for discontinuity that occurs in the microstrip.

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Branch Line Coupler is one of the telecommunications equipment and has an important role in various applications in microwave devices, designed in a microstrip manner, with the following advantages; low cost, is a complete circuit on a substrate and is very suitable for the integration of integrated microwave circuits, the material used is FR4 which has a thickness of 1.6 mm with a dielectric constant of 4.6.

There are 3 parameters used to analyze the hybrid coupler characterization, namely the isolation factor, reflection factor and coupling factor [3]. If port 1 and port 2 are input ports and port 3 and port 4 are output ports, then the isolation factor is the parameter measured between the two input ports (S12, S21) and between the two output ports (S31, S13). Reflection factor is measured with parameters S11, S22, S33, S44.

The working principle of the coupler [4] branch line is as follows, with all ports matched, the power entering port-1 is divided equally between port-2 and port-3, with a 90 ° phase shift between the two outputs. No power is coupled to port-4 (isolated port). Substrate thickness is important to consider when designing microstrip antennas. Most substrates that are desirable for the reliability of an antenna are selected thick ones with low dielectric constant. [9] This tends to produce antennas with wide bandwidth and high efficiency due to being free of edge field jumps originating from the patch and propagating into the substrate [5].

However, this causes the antenna volume to become large and increases the probability of surface wave formation. [10] On the other hand, a thin substrate with a high dielectric constant reduces the antenna size. However, due to the higher dissipation factor, the efficiency is low and the bandwidth is small. Hence, there are tradeoffs.

This duplexer is one part of the pulse radar which is used to send and receive signals simultaneously from one antenna [2]. The duplexer is designed for various applications based on operating frequency and utility. All duplexers are designed to provide high isolation between send and receive ports. This pulse radar operates at the s band frequency, namely 3 GHz. The pulse radar has only one antenna, the antenna used to transmit and receive signals is the same antenna. The most important thing in a duplexer is the decenticity on the RX because of the overflow of signals from TX. Thus a duplexer must be designed that can isolate perfectly between TX and RX.

Then [13], has designed a duplexer using the Tandem Coupler method and Bandstop filter based on Open-Loop Resonators by getting the specifications according to the design. The duplexer consists of two tandem couplers and two bandstop filters which are separated by couplers and connected by a soldering process.

Conventional Branch Line Couplers have a fairly large size and their isolation value <-20 dB with an isolation value of this size at high frequencies cannot be used because there are so many signals with different phase angles [3]. The purpose of this research is that the branch line coupler as part of the duplexer can be used. For this purpose, the performance must be good, especially the isolation.

In [6] the coupler operates at a frequency of 2.2 GHz from the simulation obtained S11 = -22.99 dB, S12 = -2.96 dB, s13 = -3.24 dB is used for Long Term Evolution (LTE) applications using high and low impedance meander lines to shrink the Branch Line Conventional couplers Bandwidth and Compactness are the factors that determine performance.

In research [7] there was a reduction in size by substituting an inductor, a capacitor, and 2 stubs which were placed diagonally at an angle. This method has succeeded in reducing the dimensions <30% but this method makes the fabrication not easy. Meanwhile, research [8] [9] succeeded in reducing the dimensions but the impedance bandwidth was ≤ 10% for VSWR = 1.5. Several studies were conducted to obtain band characteristics with an impedance bandwidth of ≥ 10% with VSWR = 1.5, among them were conducted in research [10] - [12].

In [4] the coupler uses shunt stubs artificial transmission lines with impedance regulation with the Fr4 substrate with the aim of obtaining a compact size and good performance from the simulation obtained S11 = 23.36 dB, S14 = -24.13 dB.

In [14] his research has the advantage of lower power consumption such as [10] more compact size and lighter weight, a higher level of integration in [8].

In [15] branch-line coupler is used on the antenna as a separator between the sender and receiver, but has a different polarization. The process of modifying the dimensions of the branch-line coupler at the T junction with the simulation results obtained by the isolation value of -31,185 dB.

2. METHODOLOGY

2.1 Theory of Microstrip

Ordinary microstrip antenna which consists of a pair of parallel conductor layers separated by a dielectric medium known as a substrate [11]. In this arrangement, the top conductor layer or "patch" serves as a radiation source where the electromagnetic energy travels along the edge of the patch into the substrate. The bottom conductor layer acts as a perfect reflecting ground plane, returning energy back through the substrate to free air.Physically the patch is a thin conductor which is part of a wavelength that forms the area, which is parallel to the ground plane. The patch shape can be in various shapes such as rectangle, circle, triangle and so on.

2.2 Design

The design of a duplexer is done by combining two couplers and two Bandstop filters. The coupler to be designed uses the Hybrid Coupler 90º method, which is a Coupler that has a -3 dB coupling and a 90º phase difference at the output. As for the Bandstop filter based on the Split Ring Resonator which has the advantage that the filter size can be reduced so that the overall size of the tool becomes smaller.

In designing a microstrip, it is necessary to determine the type of substrate used. The substrate used in this study is FR4 (evoxy) which has a material dielectric constant $\varepsilon r = 4.6$. The thickness of the substrate to be designed is 1.6 mm. fig 1. Shows the initial design of the microstrip branchline coupler.

To design the duplexer, the first thing to do is determine the working frequency or system design, then calculate the length and width for the microstrip channel. The design of the Branch line coupler is done in order to obtain good performance, the coupler works at an operating frequency of 3 GHz and is implemented in frequency of the S band.

The use of the CST Simulator aims to see the results of the Coupler response. Then adjust the length and width of the microstrip channel in order to get the expected response results. Then implement it by printing on the PCB and combining the microstrip channel for the Coupler and Bandstop filter to become a duplexer with the soldering process. Then measure the results of the implementation and measure to find out the results of the response output.

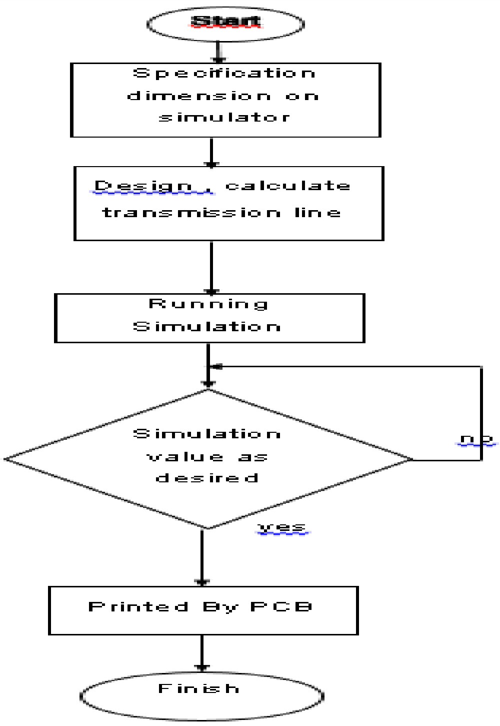

Fig. 1:Optimization Flow Chart of Branch LineCoupler

To design the Microstrip Branch Line Coupler, there are several steps, namely determining the specifications of the coupler, such as the type of substrate to be used, the coupler geometry design is designed and then calculating the physical parameters of the coupler is designed using the formula for the microstrip design. Then simulated using the 2019 Computer Software Technology (CST) simulation.

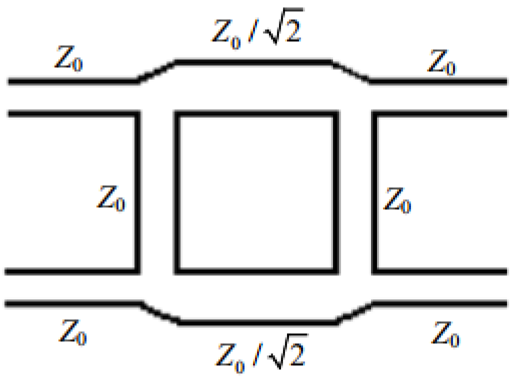

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Fig.2: Conventional 3 dB branch-line coupler

3. RESULTS AND DISCUSSION

This branch line coupler is designed at an impedance of 50 ohms. Therefore, the quarter-wavelength portion of the device has impedances of 50 ohms and 35.35 ohms. The coupler will be made from microstrip on the FR4 (Epoxy) substrate. For the first design, the transmission line width is calculated using the formula in [3].

$$W_{lst} = \frac{2 \times h}{\pi} \times \left[B - 1 - \ln(2B - 1) + \frac{\varepsilon r - 1}{2 \times \varepsilon r} \times \left[\ln(B - 1) + 0{,}39 - \frac{0.61}{\varepsilon r}\right]\right]$$

where εr is the relative dielectric constant

$$B = \frac{60 \times \pi^2}{Z_0 \times \sqrt{\varepsilon r}}$$

Then, to calculate the length of the coupler:

$$\boldsymbol{\lambda}g = \frac{c}{f \times \sqrt{\varepsilon r}}, \boldsymbol{\lambda}d = \frac{\lambda g}{4}$$

$$a = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right)}$$

Fig. 3: Photograph of fabricated of the BLC

In figure 3 is the result of fabrication. Where when choosing the type of connector, and the process of installing the connector, namely soldering, greatly affects the measurement results.

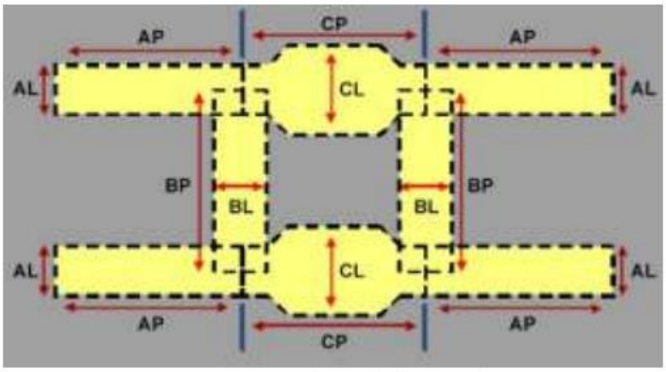

Fig. 4: The layout of the proposed BLC

From simulation
AP=Length of the transmission line A = 10.66 cm
BP= Length of the transmission line B = 10.66 cm
BP= Length of the transmission line C = 10.40 cm
AL = Width of the transmission line A = 2.88 cm
BL = Width of the transmission line B = 2.88 cm
CL = Width of the transmission line C = 5.067 cm

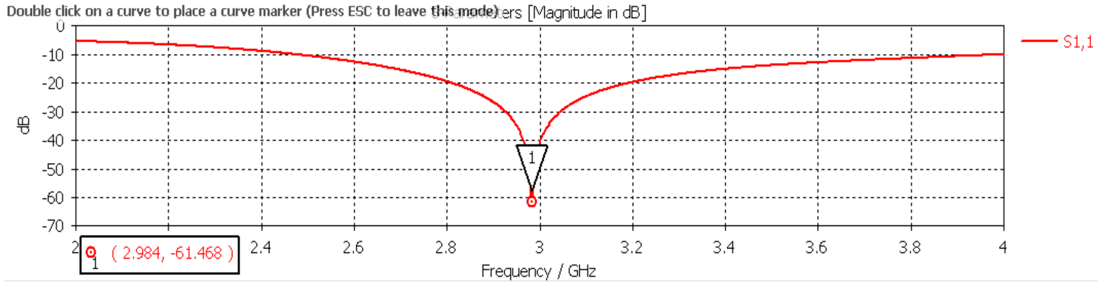

Fig. 5:The return loss of the output ports of the BLC

The above figure shows the value at S11 (return loss) is below - 26 dB. The lowest and deepest points are shown on the frequency. From the picture above, you can see the value of return loss (S11) = -61.46 dB. 3 GHz, which means that the frequency is the working frequency and is matched with an impedance of 50Ω. Return loss can occur due to discontinuity between the transmission line and the load input impedance. Return loss can occur due to mismatched circuit conditions. If the power transmitted by the source is PT and the reflected power is PR, then the return loss is the division between PR and PT. For maximum power transferred, the return loss must be as small as possible. That means PR / PT must be as small as possible.

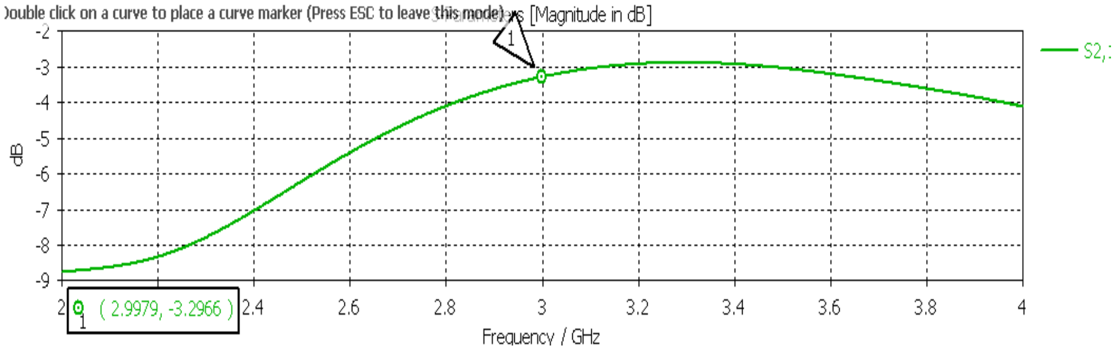

Fig. 6:The insertion return loss of the output ports of the BLC

Fig. 6 shows the simulation measurement results on port-1 and port-2 of about - 3,296 dB. This shows that the 3 dB coupler microstrip design is as desired.

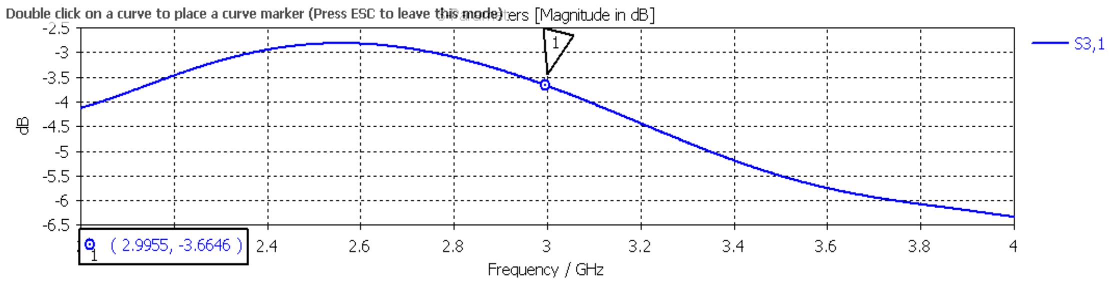

Fig. 7:The coupling factor of the output ports of the BLC

Fig. 7 shows the simulation measurement results on port-3 and port-1 of about - 3.66 dB. This shows that the 3 dB coupler microstrip design fits the parameters.

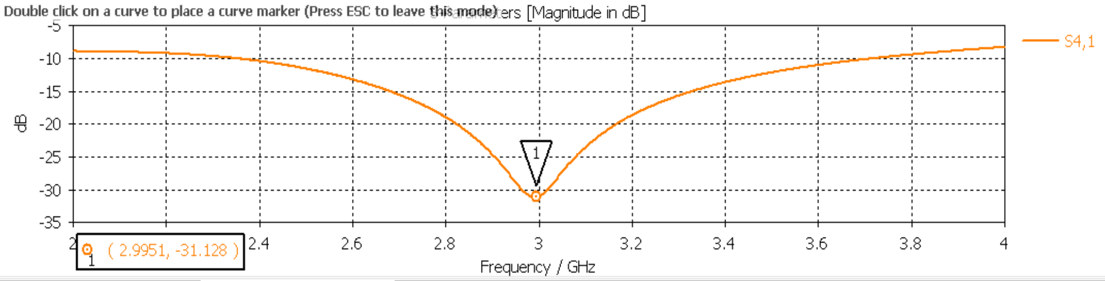

Fig. 8:The isolation of the output ports of the BLC

From the picture above, it can be seen that the isolation value is -31,128 dB, with an isolation value of this size is good enough if applied as a duplexer. Isolation on a coupled branch line can be defined as the difference in signal level in dB between the input port and the isolated port when the two output ports end with a matched load.

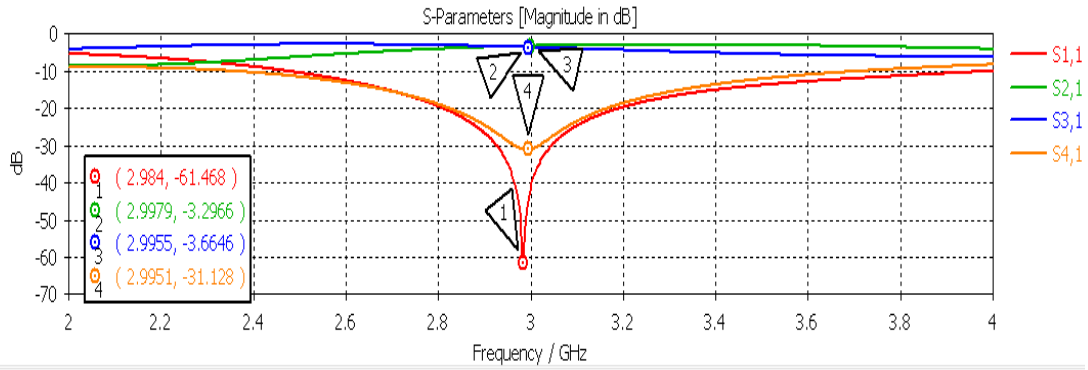

Fig.9: The scattering parameters of π BLCSimulated and S-parameters response of design B: S11, S21, S31, S41.

4. CONCLUSION

In this paper, research has been carried out on π Junction Branch line coupler which is applied to radar pulses operating at a frequency of 3 GHz, from the simulation results in the value of return loss (S11) = -61.46 dB, Insertion loss (S21) = -3.29 dB, Coupling Factor (S31) = -3.66 dB, Isolation (S14) = -31.12 dB. From the research conducted, it was found that the Branch line coupler π shape junction designed according to the wishes gave good results. = -31.12 dB.

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