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*Research Article*

# The Influence of changes in the dielectric constant on Return loss, Vswr, Isolation and Phase Difference Microstrip Hybrid Coupler For Coastal Radar Applications

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**Abstract**- This study aims to determine the effect of changes in perubahan value changes in the Hybrid coupler on the return loss, insertion loss, coupling factor and the isolation value at the 3 GHz frequency which is applied to coastal radar. the type of antenna used is a microstrip patch antenna. The material used to design the antenna is FR4 with a substrate thickness of 1.6 mm and has a value of εr r = 4.3. This study designed a microstrip branch line coupler with a T-Junction that works at a frequency of 3 GHz with both loss values for (Tx) and (Rx), namely 3 dB and a phase difference of 90 °. The steps taken are after obtaining the length and width values from the formula, then these values are simulated after obtaining the correct value of 3 GHz, then an experiment is carried out with the dielectric constant values of 4.1, 4.3 and 4.6.

**Keyword :** Coastal Radar, Dielecric constant and Hybrid Coupler

## 1. Introduction

Having a coastline of 81,000 kilometers is not easy for Indonesia to monitor illegal actions and the occurrence of accidents and marine pollution. By operating the radar, the patrol and coast guard can observe and then solve the problem quickly. Previous research [4] made a prototype long-range surveillance radar that works at the S-band frequency for maritime needs [5]. This radar prototype works with a transmit power of about 5 W

The existence of a radar system in monitoring sea and air traffic conditions is indeed very important to reduce accident cases in the transportation sector. Accidents at sea have the potential to cause pollution due to oil spills from ships

One way to increase the government's ability to supervise and protect Indonesian waters is through the use of a coastal surveillance radar. The radar can also be used to control and regulate the entry and exit of ships at the port, especially during bad weather, so that accidents or ship collisions can be avoided.

The antenna used in radar can consist of a transmitter or receiver. An important property of RF-frontend [6] or antennas used in a single carrier system frequency is its ability to separate the transmitted signal from the transmitted signal. One of the devices used as a separator between the transmitter and receiver is a circulator [7]. Circulators are used to isolate the transmitted signal from the received signal. [8] Mentioned that an antenna that transmits and receives waves with different polarizations is the right choice for obtaining a separate transmitter and receiver in the case of single carrier frequency [5]

The radars used for monitoring shipping traffic are out of date. In addition, the number and capabilities are also very limited. At present, with the increasing flow of marine traffic in the crowded shipping lanes in Indonesia, the support of the traffic control and monitoring system does not only need to be increased in number, but also in its capacity. Because the function of radar is very important for sea and air transportation, it is necessary to develop Indonesia's own domestic capabilities to provide radar independently.

In this study, a microstrip branch line coupler was designed for s-band radar applications that work at a frequency of 3 GHz with the CST 2020 simulation software. The type of substrate used is FR4 which has a dielectric constant of 4.3 and a thickness of 1.6 mm. This hybrid coupler on airborne RF radar is useful as a separator between the transmitter and the receiver [1].The thing that must be considered is the separation between the transmitted signal and the received signal. The coupler function on the RF radar is designed to separate the transmitted signal from the one received. On the branch line coupler, there are two outputs that have the same value with a phase difference of 90 ° [2]. This phase difference is used as a separator between the transmitter and the receiver.

The 3 dB or Quadrature (90-degree) hybrid coupler has an important role in various RF systems such as transmitters, receivers, signal processing circuits, phase shift, power combining and beam power sampling applications [3]. 3 dB couplers are generally used standalone and connected to other components using an RF cable. Besides, it is also used in conjunction with other microwave circuits such as amplifiers, mixers, and power dividers [4].

## 2. II. Theoretical background of the Hybrid coupler

### 2.1 Radar

Radar is a system of electromagnetic waves that is useful for detecting, measuring distances and making maps of objects such as airplanes, various motor vehicles and weather information (rain). The wavelengths emitted by the radar vary from millimeters to meters. Radio waves / signals emitted and reflected from a certain object will be picked up by radar. By analyzing the reflected signal. The reflector of the signal can be determined its location and through further analysis of the reflected signal can also be determined its type.

Although the received signal is relatively weak, the radio signal can be detected and amplified by the radar receiver. The concept of radar is measuring the distance from the sensor to the target. The distance measure is obtained by measuring the time required for electromagnetic waves during their propagation from the sensor to the target and back to the sensor.

There are three main components that are arranged in a radar system, namely the antenna, transmitter (signal transmitter) and receiver (signal receiver). BLC Is very much needed in an S-band radar system, the role of BLC is as a phase reverser, so that when the signal transmitter and receiver meet each other there will be no aliasing signal and can still be processed in each part of the system.

The basic property of a branch line coupler is to divide the power input at one port into two equal outputs with a phase difference of + 90 ° or -90 ° [7]. It can be used to obtain right-hand and left-hand circular polarization by using a dual-input cross-polarized antenna. Adding two variable capacitance diodes to the hybrid circuit is useful as tunning to get a working frequency of 3 GHz. From the simulation results, the isolation between the transmitter and the receiver is obtained by 20 dB

Branch line coupler with two branch lines (N = 2) designed on the branch line coupler is applied in the form of microstrips. The results of the microstrip design are simulated using 3D simulation software which includes two simulation stages. The first simulation is to simulate the ideal branch line coupler. The next simulation result is that the previously designed branch line coupler circuit is given a T-junction circuit which is used as compensation for the T-junction discontinuity that occurs in the microstrip branch line coupler. The dimensions of the T-junction used are symmetrical with a 50Ω line width. Between the T-junction with the 35.35Ω line, a taper is added to compensate for the discontinuity that occurs due to changes in the width between the 50Ω line and the 35.35Ω line

The antenna that is located on the radar is a reflector antenna in the form of a parabolic plate that transmits electromagnetic energy from its focal point and is reflected through the parabolic-shaped surface. The radar antenna has two poles (polar). The incoming signal input is described in the form of a phased-array. This is the distribution of object elements captured by the antenna and then transmitted to the center of the radar system

### 2.2 Mikrostrip *Branch Line Coupler*

Hybrid coupler has several designs, namely using waveguides, and some using microstrip / stripline. Types of hybrid couplers that use microstrip / stripline are Coupled-Line Directional Couplers, Lange Directional Couplers, Hybrid Ring, and BranchLine Hybrid Couplers. port-1 is divided equally between port-2 and port-3, with a 90 ° phase shift between the two output. No power coupled to port-4 (isolated port)

Branch line couplers have a high degree of symmetry, so that all ports can work as inputs. The output port will always be on the side opposite the input port and the isolated port will always be on the side with the input port [9, 11].

Microstrip branch line coupler consists of two series line impedance channels connected by two branch line impedance channels as shown in the figure. To get a coupling value of 3 dB, the series line impedance (ZA) is equal to 1 / √2 of Zo and the branch line impedance (ZB) is equal to Zo [10]. The width for each impedance line is calculated using equation (1). While the length for each impedance channel has the same value which is stated by (2)

## III. Hybrid Coupler Analysis

### 3.1 Calculation

The length (L) of the coupler on the branch line and series line is usually chosen as ¼ of the wavelength design or it is called the quarter wavelength. Formula for wavelength by specifying the frequency. The width of the microstrip can be determined by finding the W / d ratio. Based on the selection of impedance lines in the series and branch microstrip transmission lines, if εr and Z0, then the W / d ratio is expressed by [4]:

Quardrature hybrids are 3 dB directional couplers with a phase difference of 90 ° on both outputs, through and coupled ports. This type of hybrid is usually made in the form of a microstrip or stripline and is commonly called a branch-line hybrid

a. Calculation Formula of the Length transmission line
(LA, LB, LC,WA, WB, WC)
quarter of wavelength which propagate in material as follow [10,11]:

$$\boldsymbol{\lambda}\text{g} = \frac{\text{c}}{\text{f} \times \sqrt{\varepsilon\text{r}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\frac{W}{d} = \frac{8_e a}{e^{2a} - 2} \quad \text{Untuk} \quad < 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

the look for the transmission width :

$$\frac{W}{d} = \frac{2}{\pi}\, b - a\, Ln\, [(2B - 1) + \frac{\varepsilon - 1}{2\varepsilon}\, [\ln \text{b} -1 + 0.39 - \frac{0.61}{\varepsilon}]\,]$$

for $\frac{w}{d} > 2$ ……………………………………………….(3)

$$a = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where $Z_o$ = 50 Ω and 35,35 Ω

εr is dielectric constant of the substrate . f is operating frequency of the coupler

To design a microstrip, it is necessary to determine the substrate used, which is then used in calculating the physical parameters of the 3 dB coupler microstrip designed. The working specifications of the 3 dB coupler to be designed with the objectives are as follows: Working frequency: at 3 GHz, Coupling value and phase difference: for both output ports are -3dB, phase difference 90 °, VSWR: 1-2, Return loss and isolation: a good coupler performance has a value of retun loss (S11) and isolation (S14) must be smaller than -26 dB. With a return loss of less than -26 dB, the VSWR is closer to ideal.

**Tab. 1.** Dimensions of Hybrid Coupler

| Dimension | Calculation (mm) | Simulation (mm) |
|---|---|---|
| LA | 11.66 | 10.66 |
| LB | 11.66 | 10.66 |
| LC | 11.66 | 11.50 |
| WA | 2.398 | 2.88 |
| WB | 2.398 | 2.88 |
| WC | 5.067 | 5.067 |

Tab.1 shows the value of the transmission line length A, B and C and the width of the transmission line A, B and C. The calculation value is obtained from the existing formula. This calculation value is then simulated but there is still a shift in frequency.

Geometry of the Hybrid coupler is showed in Fig.1. It is fed by 50Ω connector and designed on a FR-4 dielectric substrate of 4.6 with 1.3 mm thickness

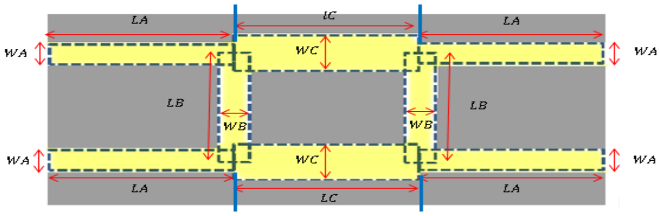

**Fig.1. Design Structure**
**Microstrip Coupler 3 Db [5]**

LA= length of A, LB= length of B, LC= length of C
WA= width of A, WB= width of B, WC= width of C,

The physical parameters of the width and length of the impedance line on the 3 dB coupler microstrip are determined based on the value of quarter wavelength (λ / 4). From Figure 3.1, there are two impedance channels used in designing the 3 dB coupler microstrip, namely Z0 and ZA where the magnitude of ZA = Z0√2. This impedance channel is converted into length and width units to be applied to the microstrip.The impedance line value for Z0 is chosen to be 50 Ω so that for Z0√2 it is 35.4 Ω.

The fabricated hybrid coupler can be seen at figure 2.

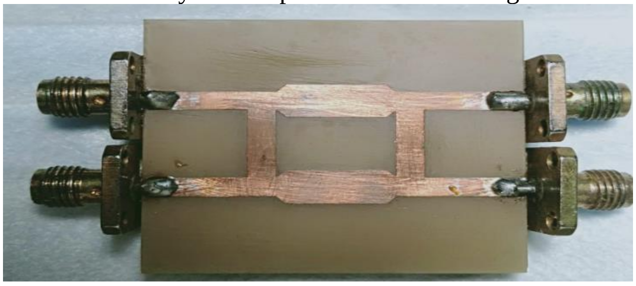

Fig.2. Photograph of the Hybrid coupler

*3.2 Simulation Result*

The simulation results at Ɛ = 4.1 are shown in Figure 3.

Based on simulations using software The simulation results carried out in Figure 4 explain the simulation results S11 which has a frequency scale of 2 GHz to 4 GHz with the y axis is S11. The result is shown in Figure 3 (a)

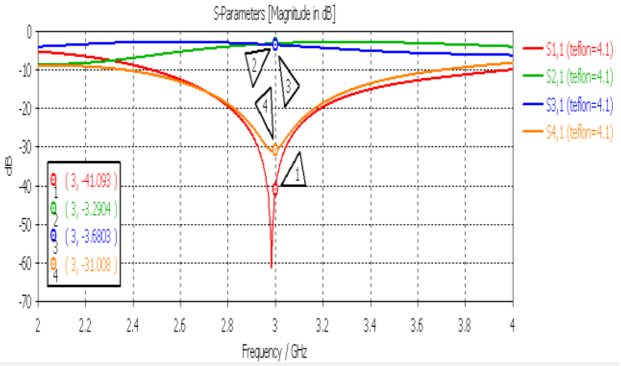

Fig.3.(a) Simulation result s parameter at Ɛ = 4.1

Return Loss (S11) = -41.099 dB, Insertion Loss (S12) = -3.290,
Coupling Factor (S1.3) = 3.368 dB, Isolation (S14) = -31.008 dB
Dengan Ɛ = 4.1

It can be seen that the best return loss value is not right at the 3 GHz frequency, while the isolation value at the 3 GHz frequency is almost close to the lowest value

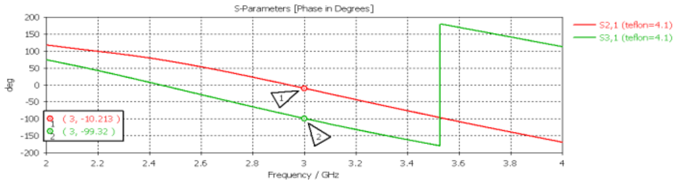

Fig. 3(b). Simulated S-parameters response of phase difference at Ɛ = 4.1

Based on the simulation results, the S21phase (S21) shifted -10,213 degrees. and S31 has a phase of -99.32 degrees on the coupler at a frequency of 3 GHz as marked on the marker. The phase difference of 89,107 degrees, this value is close to 90 degrees, the simulation results are very good, according to the desired specifications.

To determine whether a telecommunication installation is good or not, VSWR measurement is very necessary, because the purpose of VSWR measurement is to find out how much voltage is used and what is being wasted.

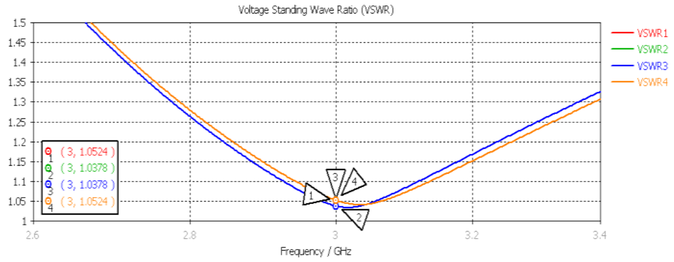

Fig.3(c). Simulation result of vswr (Ɛ = 4.1)

The value of vswr obtained by vswr 1 = vswr 4 = 1.0524, while vswr 2 = vswr-4 = 1.0378. Based on the simulation, the simulation results carried out in the image above, a transmission line with a line impedance that does not match (mismatch) with the load impedance, then in the transmission line there is a forward voltage V + and a reflected voltage V-, resulting in interference-accumulation between V + and V forming a standing wave [2]. The parameter that states the quality of the transmission line / feeder (standing waves) is called the Voltage Standing Wave Ratio (VSWR).

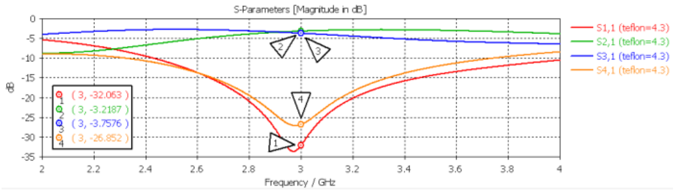

Fig.4 (a). Simulated S-parameters response at Ɛ = 4.3

The figure above is the simulation result where Ɛ = 4.3 the following results are obtained: Return Loss (S11) = -32.063 dB, Insertion Loss (S12) = 3.2187 , coupling Factor (S1.3) = -3.7576 dB, isolation (S14) = -26.852 dB

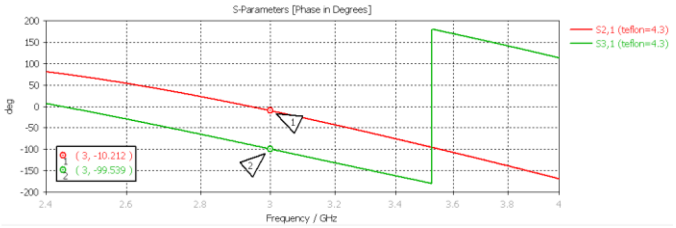

Fig .4(b). The phase difference between port 2 and 3 at Ɛ = 4.3

The figure above shows the phase (S21) shifted -10,212 degrees. and S31 has a phase of -99,539 degrees on the coupler. is at a frequency of 3 GHz as marked on the marker. The 89,327 degree difference in phase value is close to 90 degrees

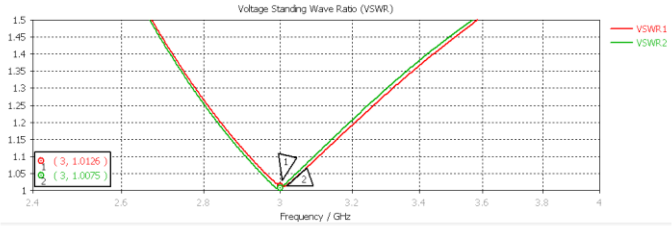

Fig .4(c). Simulation result of vswr at Ɛ = 4.3

From the figure above, it can be seen that the vswr value is obtained vswr 1 = 1.0126, vswr 2 = 1.0075. this value is very good.

VSWR is defined as the ratio or ratio between the minimum maximal rms voltage that occurs on non-matched channels. If the load and wave impedance transmission lines are not the same and continue to be reflected, then the voltage is formed V + and V- which form waves

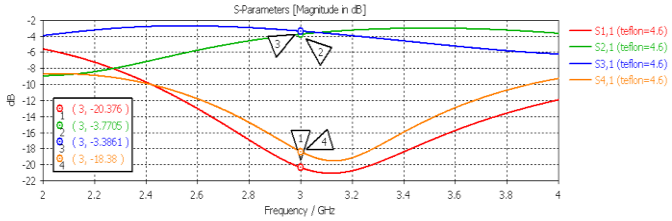

Fig .5(a) Simulated S-parameters response at Ɛ = 4.6

From fig 5(a) it can be seen Return Loss (S11) = -20.376 dB, Insertion Loss (S12) = -3.7705 , Coupling Factor (S1.3) = -3.3861 dB, Isolation (S14) = - 18.38 dB

Actually the scattering parameter can be applied to any frequency but the more common ones are RF and microwave frequencies. S parameter describes the electrical behavior of a linear electrical network. The S parameter can be used to express VSWR, gain, return loss, transmission coefficient, reflection coefficient.

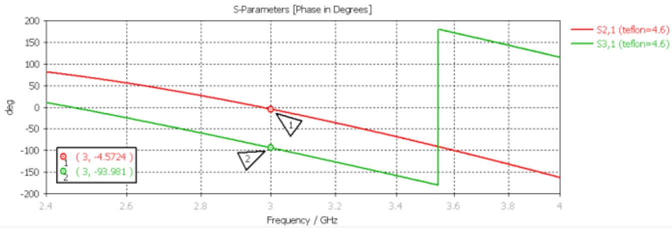

Fig .5(b). The phase difference between port 2 and 3 at Ɛ = 4.6

From Fig. 5 (b) shows the phase (S21) shifted -4.5724 degrees. and S31 has a phase of -93,981 degrees on the coupler at a frequency of 3 GHz, a phase difference of 89,327 degrees this value is close to 90 degrees

Standing wave ratio abbreviated as SWR is sometimes abbreviated as VSWR (Voltage Standing Wave Ratio). If the impedance of the transmission line does not match the transceiver, there will be a reflection power (reflected power) in the line that interferes with the forward power. This interference produces a standing wave, the magnitude of which depends on the magnitude of the reflection power.

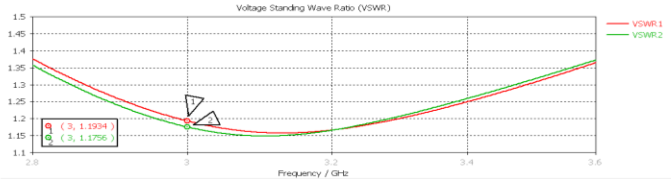

Fig.5 (c ). Simulation result of vswr at Ɛ = 4.6

Figure 5 (c) describes the VSWR simulation results has a frequency scale of 2.6 GHz to 3.8 GHz where the y axis is VSWR. Simulation results states that the VSWR obtained is 1.007 The value of vswr obtained by vswr 1 = 1.1934, vswr 2 = 1.1756

This value is already good. Low VSWR value (below the VSWR threshold of 1.04) indicates that the reflected waves are very small.

Tab2. Comparisons of performance wideband BLC with the proposed one.

| Parameter | Ɛ = 4.1 | Ɛ = 4.3 | Ɛ = 4.6 |
|---|---|---|---|
| S11 | -41.099 | -32.063 | -20.376 |
| S21 | -3.290 | -3.2187 | -3.7705 |
| S31 | 3.368 | -3.7576 | -3.3861 |
| S41 | -31.008 | -26.852 | -18.38 |
| Phase at port S21 | -10.213 | -10.212 | -4.5724 |
| Phase at port S31 | -99.32 | -99.539 | -93.981 |
| Phase Difference | 89.107 | 89.327 | -93.981 |
| Vswr | 1.0524 | 1.0126 | 1.1934 |

- Tab. 2 shows the value of the return loss, insertion los, coupling facor, isolation, phase difference and vswr of each in the dielectric contant

From table 2, it can be seen that the dielectrict constanta Ɛ = 4.1 the best return loss (S11) is at Ɛ = 4.1, and the isolation value -3 dielectrict constant is 1.008, while the vswr value that approaches the value 1 is Ɛ = 4.3, at a phase difference approaching 90 degree is Ɛ = 4.3

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## 3. Conclusion

From Tab.2 the simulation results are dielectrict constanta Ɛ = 4.1, the best return loss (S11) is at Ɛ = 4.1, and the isolation value is -3 dielectrict constant 1,008, while the vswr value that approaches the value 1 is Ɛ = 4.3. From all good simulations for the dielectrict contant value Ɛ = 4.1, Ɛ = 4.3, Ɛ = 4.6, all of them meet the requirements.

Phase is a major factor that needs to be considered in coupler design. The designed phase is expected to shift ½ lamda or 90◦, between port 1 to 2 and port 1 to 3, and vice versa. This shift gives a delay to one of the signal outputs. Based on the simulation results, the phase shifted 89 or close to 90 From the design and simulation results obtained for the 3 dB coupler microstrip, it was designed to meet and approach the expected specifications.

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