Hybrid Coupler Design: Enhancing Signal Isolation For Portable Radar and Wireless

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ABSTRACT:
The present paper deals with a hybrid microstrip coupler designed with 4 communication ports between the antenna. The telecommunication receiver system is utilized to transmit the signals from mobile, X radars with the X waveband (8-12GHz), and static systems. In this work, we used microstrip platform design techniques including Unequal-Split Rat-Race Couplers, Rat-Race Couplers, Wilkinson Power Split, and Line Impedance. These methods are utilized to determine the signal transmission power quantity. The presented design can be run in microwave frequency distances and long-range radars. The value S11 parameter is almost -5.68 dB that is improved compared to the former research. The hybrid coupler has general dimensions of 20 mm × 20 mm, which were decreased to the same size. The simulations were conducted in the CST software.

KEYWORDS: Unequal-Split Rat-Race Couplers Method, Hybrid Coupler - Rat-Race Couplers Method, Wilkinson Power Split Method Line Impedance Method

1. INTRODUCTION

Hybrid ring coupler is one among the foremost important passive devices in making mixers, multipliers and balanced antenna systems, etc. Many microstrip ring couplers are introduced and are moving towards broadband and downsizing. In recent years, several ring couplers supported integrated microstrip substrate technology are proposed [1]. However, the microstrip lengths between adjacent ports are reduced to ($\frac{5\lambda_g}{4}$) from the traditional length $\frac{\lambda_g}{4}$ within the paper [6], where λ_g is that the conduction wavelength at the central frequency and therefore the hybrid circular coupler structure is predicated On hard microstrip is extremely complex, which increases design and manufacturing time [1] [2].

The 90^0-hybrid ring coupler is predicated on the principle of the microstrip ring coupler with a length of $\frac{\lambda_g}{4}$ between the branches of the designed signals. Signal branching paths are designed to enhance signal transmission performance. In designing the geometry of the coupler bed, various methods are wont to reduce the size. For this purpose, to enhance the signal quantities and reduce its dimensions, combined methods are used for the rat-race method [3].

In designing transmission lines and creating resonant networks in passive microstrip substrates, this system is employed together with Wilkinson technique to scale back the size and weight of the substrate, and therefore the coefficient of signal quantities within the high waveband of the microwave is tailored and improved. it's also utilized in the planning of its geometry in reference to the utilization of radar and therefore the exchange of its signals in several transmitted and received powers [4] [5]. The proposed design is additionally used to simulate the structure of its geometry. The proposed design is implemented using CST design software.

2. ANALYSIS OF THE PROPOSED STRUCTURE

In measuring the values of scattering parameters, consistent with the IEEE standard rules, this quantity has values determined in dB units, the values obtained from the simulation and test of its sample construction should be from the required range or within the values; Otherwise, the designed sample has problems with high noise in signal exchange, signal mismatch, and isolation in ports, increasing the quantity of inductor and

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capacitance within the antenna bed [6]. within the design of passive circuits and microstrip couplers that have multiple ports; Their bandwidth is vital in terms of the number of ports and therefore the signal exchange platform in magnetic coupling. Also, wide bandwidth and application of signal isolation techniques and its coupling in creating standard bands during a wide frequency range should be used together of the foremost important multi-band design techniques in coupler design [6] [7]. By designing the geometric shapes of the coupler and determining its type within the microstrip bed, we will determine the signal isolation for every of the coupler ports and determine the bandwidth by creating geometric design models within the main shapes of the coupler; Which specifies the bandwidth for every port and doesn't create any restrictions. Now, consistent with the mentioned explanations, to enhance the signal isolation coefficient, the worth of the S12 parameter should be improved and therefore the amount of return signal losses compared to the S11 parameter should even be improved [8]. consistent with the Rate-Race technique, which is employed for circular geometry substrates in microstrip and stripline topologies and waveguides within the design of passive coupler substations, signal dividers, and signals path separators, the antenna uses a 90-degree phase within the geometry. The bed rotation between the input and output of every port is that the same and therefore the value of the input impedance is decided by its matching within the signal division within the coupler paths for each of the ports [9]. within the hybrid design of this system within the coupler hybrid, the quantity of input from port 1 received from the antenna and therefore the amount of signal collected (Sigma) in port 2 and port 3 receives 3dB, which is signal isolation and port 3 separator or it's an equivalent as subtraction (delta). this is often why port 2 is mentioned because of the summation port and port 5 because of the delta port, which is extremely important within the design of single-pulse comparators. Other techniques utilized in coupler design are spur track and Line Impedance; These two techniques are to make the adaptability of each of the straight lines from the middle circle of the coupler and to make matching between the lines and therefore the port, also on create the bed balance to match the surface of the coupler hybrid microwave. The port is transmitted. When dividing the transmission signal power and determining the central frequency of the coupler, we must concentrate on the numerical value of the frequency bandwidth to the signal power, which is about 3dB for the coupler hybrid; this is often because if this value isn't accurately measured relative to the cross-sectional area of the bed, which is Landa IV, we'll cause loss of signal strength within the bed and cause the output to possess a weakening time and delay the signal in reducing the output power in each Let's be coupler branches. Also, in applying the Rat-Race technique to calculate the impedance and impedance in Equations 1 to 21 [10] [9], the inconsistency of the impedance matrix (Z) and therefore the admittance (Y) of the substrate has been obtained, because if these values are calculated relative to the substrate To be. In signal division and signal strength, we'll have noise and distortion within the output of every port. consistent with another technique (Wilkinson) within the design of a coupler hybrid substrate, it causes that substrates like couplers that divide the signal during a curved substrate with branches of parallel and straight lines or a curve and spiral, completely increase the signal strength for every Transmit data from several output ports and therefore the platform that transmits the signal to the phase transition doesn't have a phase transition value of the signal. this system is widely utilized in hybrid couplers and frequency dividers and causes the passing signal to be transmitted with the smallest amount of attenuation compared to the sort of geometry of that signal.

$$Z_c(f) = \sqrt{2Z_{c1}/2Z_{c2}}\sqrt{1-[2Z_{c1}/(2Z_{c2})][tan(\pi f/f_0)]^2} \tag{1}$$

$$Z_{c1}^{/} = Z_{C1} + Z_{c0} \tag{2}$$

$$Z_{c2}^{/} = Z_{c0}(Z_{C1} + Z_{c0})/(2Z_{C1}) \tag{3}$$

$$2\pi(f/f_0) + b(f) = \phi(f) \tag{4}$$

$$Z_c = \sqrt{\frac{(2L_2 - 2\omega^2 L_2 L_3 C_3 - \omega^2 L_2^2 C_3)}{[(1-\omega^2 L_2 C_1)(2C_1 + C_3 - 2\omega^2 C_1 L_3 C_3 - \omega^2 C_1 L_2 C_3)]}} \tag{5}$$

$$\theta = cos^{-1}[1 - 2\omega^2 L_2 C_1 + (\omega^4 C_1 L_2^2 C_3 - \omega^2 L_2 C_3)/(1-\omega^2 L_3 C_3)] \tag{6}$$

$$f_{tz} = 1/2\left(2\pi\sqrt{L_3 C_3}\right) \tag{7}$$

$$\begin{bmatrix} A_{eq} B_{eq} \\ C_{eq} D_{eq} \end{bmatrix} = \begin{bmatrix} cos\,\theta \; jZ\, sin\,\theta \\ j\frac{sin\,\theta}{Z} cos\,\theta \end{bmatrix} \tag{8}$$

$$\begin{bmatrix} A_{eq} B_{eq} \\ C_{eq} D_{eq} \end{bmatrix} = \Theta . \begin{bmatrix} 1 jX_{eq} \\ 01 \end{bmatrix} . \Theta \tag{9}$$

$$\Theta = \begin{bmatrix} cos\,\theta_{eq} \; jZ_{eq}\, sin\,\theta_{eq} \\ j\frac{sin\,\theta_{eq}}{Z_{eq}} cos\,\theta_{eq} \end{bmatrix} \tag{10}$$

$$\begin{bmatrix} A_{eq} B_{eq} \\ C_{eq} D_{eq} \end{bmatrix} = \begin{bmatrix} cos\,2\,\theta_{eq} - \frac{X_{eq}\,sin\,2\theta_{eq}}{2Z_{eq}} j\left(Z_{eq}\,sin\,2\,\theta_{eq} + X_{eq}\,cos^2\,\theta_{eq}\right) \\ j\left(\frac{sin\,2\theta_{eq}}{Z_{eq}} - \frac{X_{eq}\,sin^2\,\theta_{eq}}{Z_{eq}^2}\right) cos\,2\,\theta_{eq} - \frac{X_{eq}}{2Z_{eq}} sin\,2\,\theta_{eq} \end{bmatrix} \tag{11}$$

$$\begin{cases} tan\,\theta_{eq} = z\,tan\,\theta \\ x = (1-z^2)\,sin\,2\,\theta \end{cases} \tag{12}$$

$$z = \frac{Z_{eq}}{Z}, x = \frac{X_{eq}}{Z} \tag{13}$$

$$\frac{dZ_{eq}}{dX_{eq}} = \frac{-Z}{2Z_{eq}\,sin\,2\theta} \tag{14}$$

$$\frac{d\theta_{eq}}{dX_{eq}} = \frac{-\cos^2\theta_{eq}}{4Z_{eq}\cos^2\theta} \quad (15)$$

$$\Delta Z_{eq} \approx \frac{-ZX_{eq}}{2Z_{eq}\sin 2\theta}\left(\pm\frac{\Delta L}{L}\right) \quad (16)$$

$$\Delta\theta_{eq} \approx \frac{-\cos^2\theta_{eq}X_{eq}}{4Z_{eq}\cos^2\theta}\left(\pm\frac{\Delta L}{L}\right) \quad (17)$$

$$Z_{hor} = Z_0 \times \left(\frac{P_A/P_B}{1+(P_A/P_B)}\right)^{0.5} \quad (18)$$

- $$Z_{ver} = Z_0 \times \left(\frac{P_A}{P_B}\right)^{0.5} \quad (19)$$

$$Z_{arm2} = Z_{arm4} = Z_0 \times \left(\frac{1+(P_A/P_B)}{P_A/P_B}\right)^{0.5} \quad (20)$$

$$Z_{arm1} = Z_{arm3} = Z_0 \times \left(1+\frac{P_A}{P_B}\right)^{0.5} \quad (21)$$

3. SIMULATION RESULTS

The proposed design is meant within the X waveband (8-12GHz) during which the wide waveband, the frequency range of the band of various remote microwave radars are located. within the mentioned waveband, there are several different ranges of static and portable navigation and radar telecommunication communication bands, during which the quantity of measurements is decided consistent with the target sort of the waveband. The waveband specification of the hybrid coupler is given in Table 2. These sufferings are studied concerning the new research and its performance in civilian portable radar systems. By determining it, we will improve it within the new design of the coupler hybrid and make definite suffering in adjacent bands within the sort of typical band. within the simulation, Rogers RO5880 substrate with a thickness of two.2 mm and a permeability constant of three.38 was used. the general recommended dimensions are 20 mm × 20 mm, which is smaller than the previous similar models. In design, we've tried to scale back the target value (parameter S11) compared to previous studies, also because of the dimensions of a smaller coupler hybrid and therefore the internal geometric structure of the microstrip substrate is simpler and unambiguously in imaginary calculations of frequency versus time and frequency relative to noise. Interior design. The frequency range of the coupler design generally has large dimensions, which by designing a mixture of various coupler design techniques within the coupler hybrid structure reduces the dimensions of the coupler hybrid and successively, reduces the quantity of impedance and admittance and therefore the capacitive mode of the microstrip bed. Find. Now, consistent with the sort of design, the techniques of this proposed structure are described in Table 3. consistent with the concept of signal scattering parameters (S Parameter), the simulation results are determined consistent with the quality design principles and indicate that in each port, the quantity of return signal is a smaller amount than the required limit of 1dB, which makes the planning the proposal has been improved for the S11 parameter. Parameter S31 also indicates that during this design, its numerical value is negative and little that the output power won't be reflected within the input, which can cause attenuation; With this mention, this parameter has been improved. Now by measuring the worth of parameter S21, which is said to the effective power in active circuits and determining the quantity of high efficiency to scale back the output power to the signal input in passive circuits; This parameter is additionally obtained within the specified function compared to the S22 parameter, whose numerical value is little, which indicates a discount within the attenuation of the transmission signal at the port. Now, consistent with the simulation results, the relevant diagrams are obtained from the proposed design; Figure 1 shows the schematic image and therefore the construction image of the proposed design within the substrate design of Koppler hybrid microstrip technology. Figure 2 also shows the number of the scattering parameters relative to the particular value of the return signal attenuation amplitude and therefore the signal isolation parameter for each of the ports; Whose numerical value is below zero and negative, which indicates rock bottom state during this parameter and its attenuation is reduced during this model; And Figure 3 shows the quantity of phase transition at 90 degrees, this frequency phase transition to the difference equation in terms of delta and its sum is additionally calculated in terms of sigma, the worth of which is obtained as a matrix operation in determining the quantity of output and therefore the amount of output it's obtained in determining the numerical phase value concerning the change of frequency bandwidth and concerning the output of the ports. this sort of phase change per unit (theta and fi) is measured within the matrix operation equation per unit signal of every port relative to every other, which is calculated relative to the numerical value of the unit signal within the coupler hybrid.

Table 1. frequency bandwidth of proposed design.

Side Band, Down	Side Band, UP	Frequency Wideband Purpose	Width band Frequency
5, 8 (GHz)	12, 15 (GHz)	8, 12 (GHz)	5, 15 (GHz)

Table 2: Technical structure of proposed design.

Model	Branch	F Divider	Ports	Mode	Substrate
Coupler	Hybrid	Circular	4	Passive	Rogers 5880

Microstrip Substrate of Techniques	
Rat-Race Couplers (RRC)	Unequal-Split rat-race couplers (USRRC)
Branch Line & Line Impedance (BLLI)	Wilkinson Power Split (WPS)

Table 3. Scattering parameter values of proposed design

F_{BW} (GHz) Min, Max	S11 (dB) Min, Max	S21 (dB) Min, Max	S31 (dB) Min, Max	S41 (dB) Min, Max
5, 15	-5.68, -2.74	-14.73, -4.82	-5.79, -5.14	-15.4, -6.25

Table 4. Comparison between proposed and previously reported designs

Model	S11 (dB)	S21 (dB)	S31 (dB)	S41 (dB)	Martial	VSWR (dB)	Ref
Coupler	-5.23	-12.85	-4.95	-13.04	Ro.4003	5.92	[1]
Coupler	-4.57	-13.-16	-4.85	-12.86	Ro.4003	4.37	[2]
Coupler	-5.21	-8.25	-5.48	-9.47	Ro.5880	3.49	[3]
Coupler	-3.45	-14.32	-4.07	-13.98	Ro.4003	5.27	[4]
Coupler	-4.76	-11.73	-5.67	-12.97	FR4	4.95	[5]
Coupler	-5.68	-14.73	-5.79	-15.48	Ro.5880	6.37	This Work

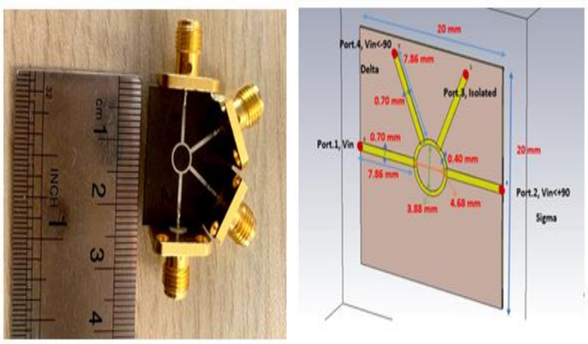

Fig. 1. The schematics of simulated and fabricated of proposed design.

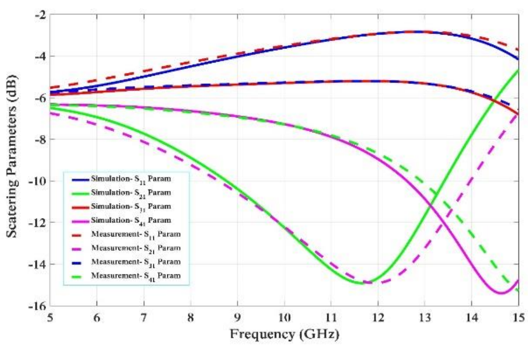

Fig. 2. diagram of scattering parameters (S11 and S21)and(S31 and S41).

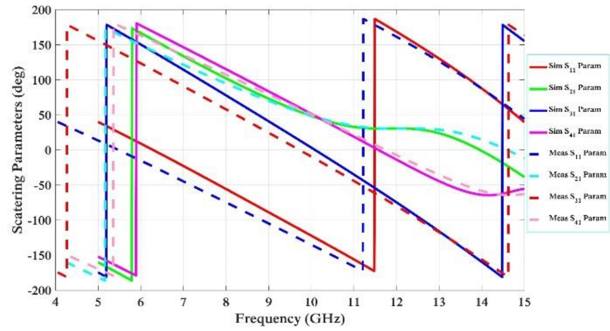

Fig. 3. Phase diagrams of scattering parameters in 90 degree frequency phase.

4. CONCLUSION

In the research, the design of the hybrid coupler aims to scale back the return signal and improve the signal isolation coefficient. This structure has two geometric parts (circular and straight lines); within the technical design of this platform, Rat-Race techniques for the circular a part of the coupler and determining the paths of straight and parallel lines of the coupler, spur track technique for designing straight and parallel lines from the circular part to the input and output ports, Line Impedance technique for Creating an impedance matching line in determining the quantity of linear impedance within the substrate, Unequal Splitter Rat-Race technique in determining the mode of inhomogeneity matrix and phase transition in transmitting signal power from circular to the line, Wilkinson technique to work out a separate substrate and linear matching finished signal transmission. The proposed scheme is about within the X waveband (8-12GHz). within the simulation, we use the UWB frequency bandwidth (5-15GHz) consistent with the low and high side-channel bands. Transmission power is taken into account within the proposed 3dB design, which is widely utilized in short power and medium-range radars. In studies where new technologies aren't available, several techniques are wont to prevent interference and noise of instantaneous signal voltage and lack of instantaneous gain across the hybrid coupler.

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