Coplanar Microstrip Directional Coupler with High Isolation and good Directivity

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Abstract - *Microstrip coupler operates in quasi TEM mode here quasi means equivalent to TEM mode but not equal to pure TEM modes as in waveguides. This behavior of the coupler is due to the presence of two mediums, one is above conducting strip which is air with dielectric constant value as 1 and other one is below the main strip whose dielectric constant is greater than 1, here it is 4.4, which give rise to unequal even and odd mode propagation velocities which is the main reason for the poor performance of the coupler. In this paper new design has been proposed for 9.8 dB coupler at 3.2 GHz with high directivity of about 61.2 dB and good isolation of 71 dB.*

Key Words: coupled line, microstrip coupler, high directivity, high isolation, directional coupler.

1. INTRODUCTION

The microstrip directional coupler is a reciprocal 4-port network formed by two coupled lines close enough to each other to be coupled with electric and magnetic fields. Directional coupler is used for division and addition of microwave signals. Directional coupler is designed to a have high signal to noise ratio by means of strong coupling and high directivity aspects of the coupler in order to suppress the standing wave ratios to improve quality of the communication. Directional coupler can be used to analysis the frequency, power and standing wave ratio of the intended transmitted signal, also it can improve intermodulation properties between transmitter and receiver by connecting directional coupler to a linear amplifier [1].The performance parameters of the directional coupler are coupling factor (C), directivity (D), isolation (I), return loss (R).If port-1 is input port, then port- 2 (opposite to port-1) will be through port, port-3 (adjacent to port-1) will be isolated port, port-4 (adjacent to port-2)will be coupled port. Expressions are as follows [2]. :-

$$C(dB) = 10\log_{10}\left(\frac{p_1}{p_4}\right) \quad (1)$$

$$D(dB) = 10\log_{10}\left(\frac{p_4}{p_3}\right) \quad (2)$$

$$I(dB) = 10\log_{10}\left(\frac{p_1}{p_3}\right) \quad (3)$$

$$R(dB) = 10\log_{10}\left(\frac{p_1}{p_r}\right) \quad (4)$$

Where, P1 is the input power at port-1, P2, P3, P4 , are output powers at respective ports and Pr is the output power at port-1. This paper proposed new design to increase Directivity of the microstrip coupled line coupler for good return loss and strong coupling parameters.

The main reason for low directivity in the former microstrip coupled-line coupler is the difference between odd-mode and even-mode phase velocities and has directivity of 8-38 Db order [3]. To compensate this difference, the discontinuity in the transmission line is due to sudden change in the physical configuration of the transmission line due to which directivity and coupling aspects of the transmission line detoriates, which will decrease the quality of the transmission signals by increasing standing wave ratio. So, to eradicate this practical problem, practical solution has been provided in which by trial and error method 45 degree cut is provided at the point of discontinuity [7], [9], [4], [5], and [6]. This method will improves the s parameters and the directivity improves by around 5dB [6], and respective s parameter plot shown in Fig .5 [5], [6]. The new directivity is around 36dB [4], [8], [1], [2].

2. DESIGN TEORY OF MICROSTRIP COPLER

When we consider coupling between two transmission lines with characteristic impedance (z_o) phase velocity (v_p), standing wave ratio (ρ), reflection coefficient (γ), input impedance $(z_i = z_{oo})$, the coupling coefficient (k), (l) length of the coupler, where (λ) is wavelength, (f) is operating frequency in Hz, (ξ_{reff}) is the effective dielectric constant of the coupler, (t) is the thickness of the conductor, $(c = 8*10^8 m/s)$ the characteristic impedances of even and odd modes (z_{oe}) and (z_{oo}) respectively) are as follows [4], [6], [9], [10]:

$$V_p = \left(\frac{\omega}{\beta}\right) \quad (5)$$

$$z_{oe} = z_o\sqrt{\frac{1+c}{1-c}} \quad (6)$$

$$Z_{oo} = Z_o\sqrt{\frac{1-c}{1+c}} \quad (7)$$

$$\frac{w}{h}=\left(\frac{\sqrt{\left(\exp\left(\frac{r}{42.4}\sqrt{\epsilon_r+1]-1}\right)\right)\left(\frac{7+\frac{4}{\epsilon_r}}{11}\right)+\frac{1+\frac{1}{\epsilon_r}}{0.81}}}{\left(\exp\left(\frac{r}{42.4}\sqrt{\epsilon_r+1}\right)-1\right)}\right) \quad (8)$$

$$l=\frac{\lambda}{4}=\frac{c}{4f\sqrt{\epsilon_{reff}}} \quad (9)$$

$$\epsilon_{reff}=\frac{\epsilon_r+1}{2}+\frac{\epsilon_r-1}{2}\left(F\left(\frac{w}{h}\right)\right)-\left(\frac{\epsilon_r-1}{4.6}\right)\left(\frac{\frac{t}{h}}{\sqrt{\frac{w}{h}}}\right) \quad (10)$$

$$F\left(\frac{w}{h}\right)=\left(1+\frac{12}{\frac{w}{h}}\right)^{-0.5}+0.04\left(1-\left(\frac{w}{h}\right)\right)^{2} \; for\frac{w}{h}\leq 1 \quad (11)$$

$$F\left(\frac{w}{h}\right)=\left(1+\frac{12}{\frac{w}{h}}\right)^{-0.5} \; for\frac{w}{h}\geq 1 \quad (12)$$

3. Simulated results

The coupler consists of two conductor layers viz. top and bottom and one middle layer that is dielectric substrate with length as $l_s = 88.5mm$, width as $w_s = 45.52mm$ and height as $t_s = 2mm$. The top layer includes four ports 1, 2, 3 and 4, connects four microstrip feed lines, length as $l_f = 20mm$, width as $w_f = 5.5mm$, thickness as $t_f = 0.017mm$ and two main strips length as $l_{ms} = 54.5mm$, width as $w_{ms} = 2.66mm$, thickness as $t_{ms} = 0.017mm$ and also contains eight sub strips of equal length, width and height as $l_{ss} = 14mm$, $w_{ss} = 2mm$, $t_{ss} = 0.017mm$. These sub strips are arranged perpendicular with respect to both main strips. The bottom layer is ground length $l_s = 88.5mm$, width $w_s = 45.52mm$, height $t_s = -0.017mm$, spacing between sub strips $s_1 = 2mm$, spacing between main strips $s_2 = 0.2mm$, some extra detailing $s_3 = 6mm$, l as 7.25mm, 9.25mm. All the dimensions of the proposed couple are shown in mm in Fig. 1. The dimensions of the substrate, main strip lines , ground , sub strip lines has been determined by using standard formulas which are equations from (5) to (12) such as those presented in [4], [5], [6]. The simulations have been performed using High Frequency Structure Simulator $(HFSS)$ software. The parameter s_2 has been optimized for higher directivity and high isolation in simulations. After optimization, the final simulated result has been achieved for proposed coplanar microstrip directional coupler with high directivity and isolation by reimbursing discontinuities in the microstrip lines in Fig. 2.

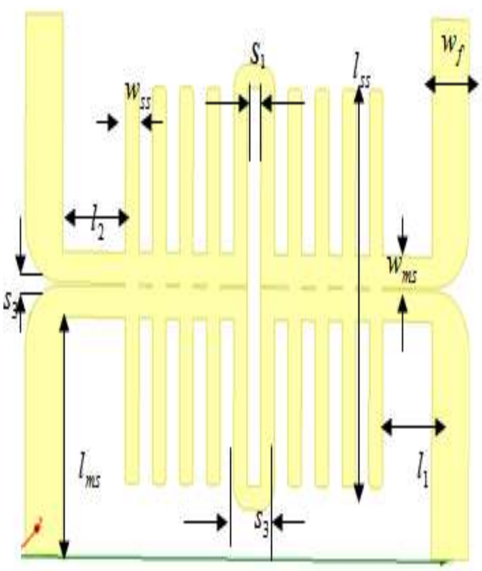

Fig. 1. Layout of the proposed coplanar microstrip coupler.

From, Fig. 2. Which is the final simulated result of the proposed coupler after performing optimization, from this proposed coupler we can achieve a maximum isolation of 71 dB at 3.2 GHz. The simulated coupling is 9.8 dB at 3.2 GHz. A maximum directivity of 61.2 dB is obtained at 3.2 GHz.

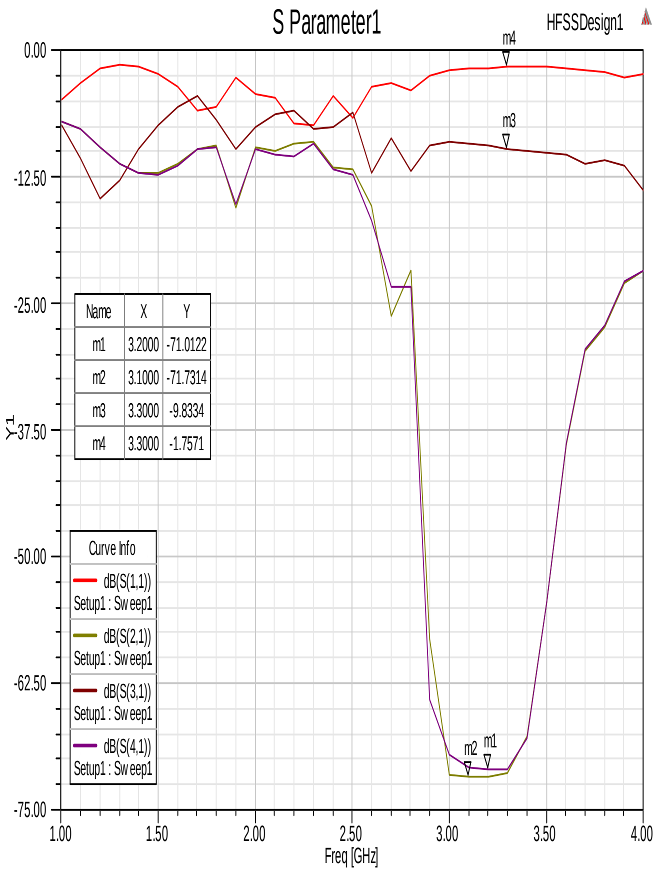

Fig. 3. The final simulated s parameters of the proposed coupler in dB.

4. CONCLUSIONS

In this paper, new design of microstrip coupler has been proposed and the result has been verified by using HFSS software. By using this proposed design one can design 9.8 dB coupler at operating frequency 3.2 GHz. A high isolation of 71 dB at 3.2 GHz and maximum directivity of 61.2 dB is obtained at 3.2 GHz, which is necessary for improving quality of the transmitted signal in any communication system, like in mobile communication systems, satellite and deep space research system, microwave electronics etc. This will strengthen power of the intended transmitting signal and destrengthen power of the noise. The noise is basically unintended signals with same frequency of the intended transmitted signal which degrade the quality of the signal by interfering with intended signal. So this proposed design can be used in high directivity and good isolation required situations.

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