Review paper on Microstrip Directional Coupler with High Directivity

Neeta Tripathi

M.Tech Scholar, Oriental Institute of Science and Technology Bhopal (M.P)India

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Abstract - This is the review paper which presents old and new approaches in microstrip coupled-line directional couplers how to reinforce their performance parameters by boosting directivity and coupling aspects to reimburse quality of communicating signals by suppressing noise power. This paper also encloses basic concepts of directional coupler and stubs. 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.

Key Words*: *coupled line; directional couplers; stub line; high directivity; microstrip design; strong coupling

1.INTRODUCTION

This is the review paper on directional coupler, microstrip directional coupler as the name suggests , it consists of two parallel coupled transmission line, main point is the transmission line must be unshielded, as we know that any transmission line's equivalent circuit has parallel passive components as conductance and capacitance and has series components as resistor and inductor.

Resistance in series is the primary cause of series voltage leakage . Conductance is the main cause of parallel current leakage in the transmission line . All passive components including mainly resistors, inductors, capacitors and Conductance are in Ohm per meter, Henry per meter, Farad per meter, mho per meter. It is very interesting to note that the same condition is spread through out the transmission line. Microstrip line is one type of transmission line .

Microstrip directional coupler used for coupling the signals in one direction with high directivity and for decoupling unwanted signals. It comprises of three layers upper layer is parallel conducting strips ,middle layer is any dielectric material whose permittivity must lies in the range 2 to 12. Mainly dielectric material with permittivity as 4.4 mostly used in the preparation of the substrate of the coupler. Bottom layer is ground mainly consists of conductive material as copper. Microstrip couplers performances are lower in comparison to waveguide coupler. The main reason is the inequality of even and odd mode velocities which makes it to underperformed with low directivity and low isolations [1][2][3].

The characteristic of an ideal coupler is to divide input power equally at output port and at coupled port. Point to noted, there must be no power reflected back at the same input port and no power must reach at the isolated port. For this performance all ports except input port at which power is injected must have characteristic impedance as 50 Ohms. While designing coupler we must care for boundary conditions as well ,so the boundary condition of the ground and conduction strips along with four feed lines must be assign with PEC, and the whole microstrip coupler must be encapsulated under air medium with boundary condition assigned as radiation.

2. Reason for low directivity of the coupler

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 8-40dB order[3].

To compensate this difference various methods have been proposed under couplers with tight coupling coefficient of 3dB,but it is difficult to realize due to the small gap usually under 0.1mm is difficult to etch on printed circuit board which is the main reason for low coupling level in the former microstrip coupled-line couplers[4]. Microstrip coupler has the mix of two dielectric material as it is uncovered from top part . This mix leads to inhomogeneous medium, which leads electric field to flow in air resulting high fringes, the more electric field lines in air or vacuum the more fringes would be formed, on the other hand the more electric field in dielectric medium value greater than one but less than twelve, the better performance possible for the microstrip coupler

3. Review of high directivity coupled line coupler with tight coupling

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This microstrip coupled-line coupler with tight coupling of 3 dB compensate the problem of retaining small gap usually under 0.1mm between the coupled lines is now easy to etch on printed circuit board. This method also compensate the difference between even-mode and odd-mode phase velocities. Therefore this method provides tight coupling of 3dB and directivity increases dramatically more than 60dB at optimum dimensions. The optimum dimensions of the directional coupler are shown in the top view design layout given in Fig 1. [4]

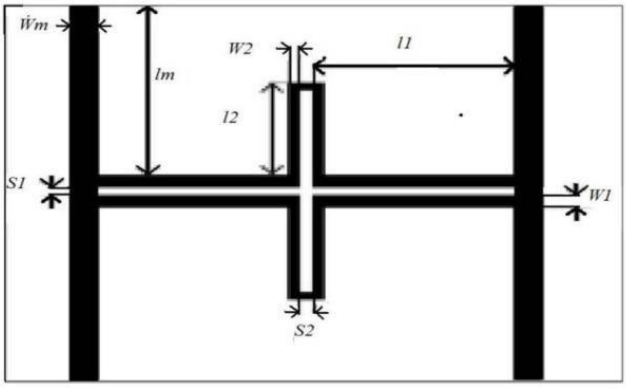

Fig. 1: Top view of the design layout of the earlier proposed high directivity and tight coupling coupler. [4]

Where , the dimensions of the microstrip coupler Fig. 1 given below [4].

l1 = 25mm

l2 = 14mm

lm = 20mm

s1 = 0.4mm

s2 = 1mm

w1 = 2.8mm

w2 = 1.8mm

wm = 5.5mm

This is the simulation of the above design in HFSS Microwave software with the same dimensions as shown in Fig. 2. [4][5].The s-parameters generated after plotting are shown in Fig. 3.[4][5] Coupling of 3dB was achieved and a directivity of 32 dB at 2.5 GHz frequency was achieved [4][5].

HFSS is high frequency structured simulator for electromagnetic applications that is for designing and also simulation of the waveforms can be easily performed of s parameter, y parameters, z parameters, real part of gamma, imaginary part of gamma, active z parameters, voltage standing wave ratio and current standing wave ratio curves can be easily verified, analyzed, optimized etc.

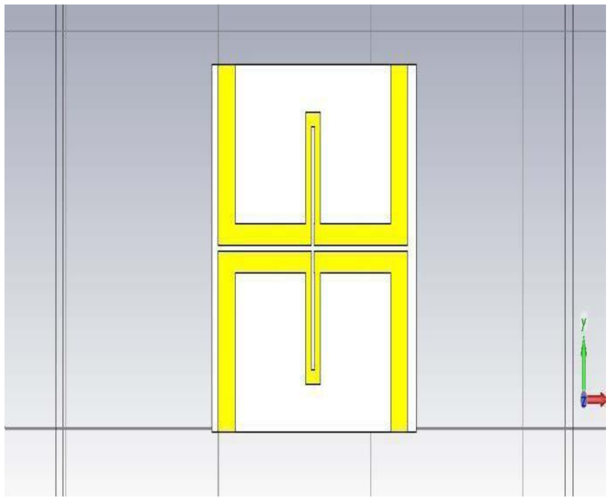

Fig. 2. Simulation of the design layout in HFSS Microwave Software.

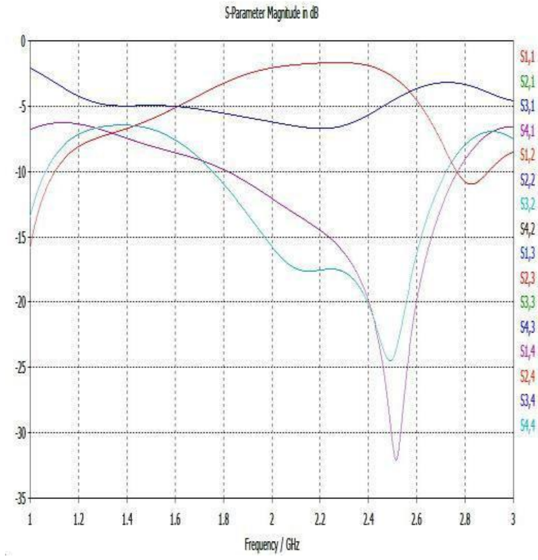

Fig. 3: . S-parameters from the simulation of the design layout in HFSS Microwave Software[4][5].

By using two port network termination involved open circuit and short circuit only for the calculation of voltage and current, but it is impossible to achieve good quality results for operating frequency greater than one gigahertz. As, this can damage the microwave device because of standing waves formed within the device.

This is serious problem, so to eradicate this problem s parameters can be used effectively for the measurement of reflection coefficient, transmission coefficient, voltage and current standing wave ratios, insertion loss, directivity, coupling coefficient, isolations, power at input port, power at through port, power at isolation port and power at coupling port can be find very easily .

After calculation of these parameters we can easily calculate voltage and current as derived parameters without bearing the cost of damaged device. 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 the point of discontinuity. This is shown in Fig.4[5][6].This method will improves the sparameters and the directivity improves by around 5dB[6]. And respective sparameter plot shown in Fig.5[5][6]. The new directivity is around 36dB.

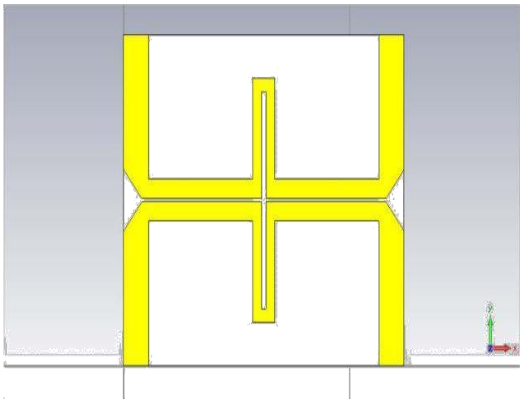

Fig. 4. Coupler edges cut at 45° angle.

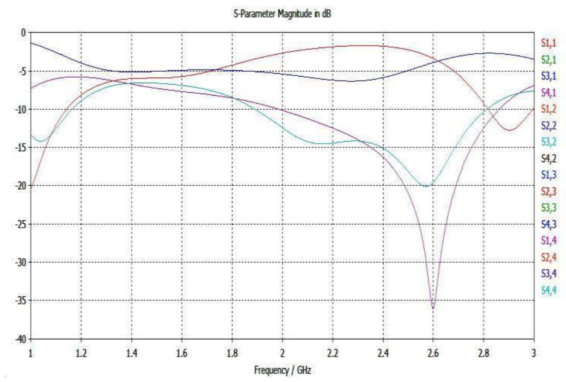

Fig. 5. S-parameter results of the simulation in HFSS microwave software of the directional coupler cut at 45° angle at edges

4. Theoretical approach to stubs

A stub is a short circuit section of a transmission line which is connected in parallel to the main transmission line. A Stub is placed at a pre calculated position of pre calculated length from the load so that the line is matched from the stub to the source, such that the net impedance appear to the further side of the stub is equal to Zo.

The main aim of stub matching technique is that no reflection should be face by the source. For this purpose a stub is connected to the main line. The reflected waves from the short circuit end of the stub and the reflected wave from the load on the main line completely cancel each other ,so that the reflection face by the transmitter must be nullified [7][8]. The stub and resonant stub is similar in its working and also in geometrical configuration and widely used in transmission lines for transmitting microwave and radio-frequency waves. The input impedance of stub is either capacitive or inductive only. This input impedance is decided by the stub length as: [7][8]. At high frequency, the length of the components become small as frequency is inversely proportional to wavelength , this means that stub length is also becomes small, this can be practically used in microwave electronics to compensate discrete reactive components and lumped components which affect the performance due to parasitic resistance [7][8]. The stubs can be made out of wide variety of transmission lines of waveguides. Their length is determined by using a Smith chart.

5. Review of coupler after introduction of stubs for impedance matching

Stub line which is used for matching load impedance to characteristic impedance by placing stub at pre calculated distance from the load and this pre calculated distance must be placed such that the real part of the characteristic (Zo) must be equal to the real part of the load impedance(Zl) and the reactive part of the load impedance(Zl) cancelled out by the pre calculated length of the stub line [9].

Here stub line is used for compensating the difference between even mode and odd mode phase velocity[5].Four stubs of same geometrical dimension ,with length and the width of the stubs are 14 mm and 1.9 mm respectively [5].

The gap between the coupled lines and the stubs is 12 mm [5]and the same gap is between the port lines and the stubs[4], have been added to the former microstrip coupled-line coupler[4] with same dimensions as shown in Table.1 is shown in Fig.6. and respective sparameters plot in Fig.7. The new directivity of the coupler is around 68dB[5].

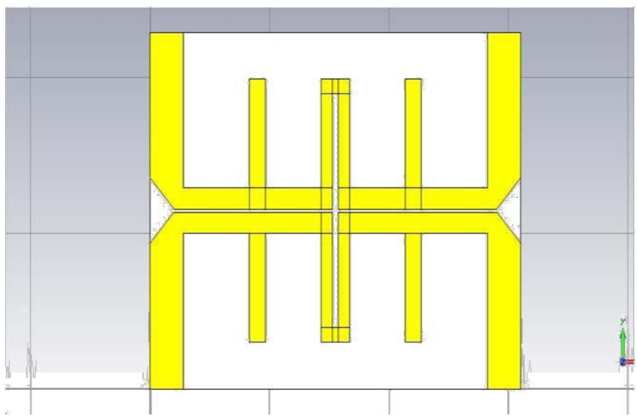

Fig. 6. Proposed stub-based design of directional couplers.[5]

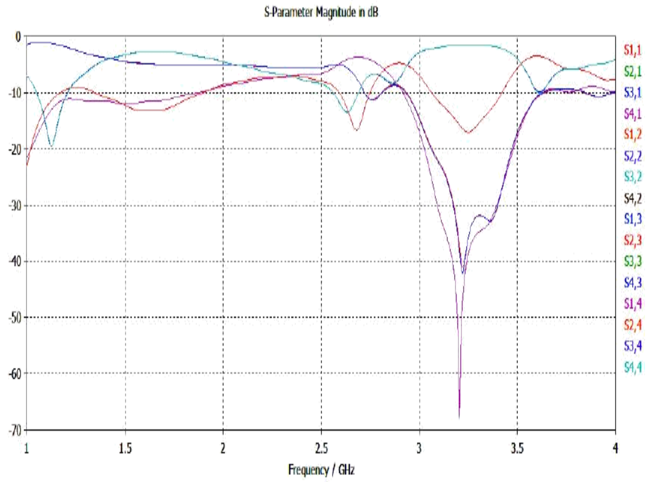

Fig. 7. S-parameter results of the proposed stub based directional coupler [5].

3. CONCLUSIONS

This is review paper made for reviewing how to increase directivity by various compensating techniques for compensating odd mode and even mode phase velocity which is the main reason for the poor performance of the directivity of the microstrip coupled-line coupler as shown in Table 2.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. This paper also reviews the basic concepts of the directional coupler and stub line.

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