© 2015 IJEDR | Volume 3, Issue 2 | ISSN: 2321-9939

Compact Harmonic Suppressed Coupler Using T-Stub Loaded Transmission Line

[1]Shaibaz, [2]Shravan Kumar B J, [3]Yugandhar B
1234Student, [5]Assistant Professor
Telecommunication Department
Dayananda Sagar College of Engineering, Bangalore, India

***Abstract* - in this paper the compact harmonic suppressed branch line coupler is designed at 375Mhz.the design topology is T-stub loaded transmission line, designed coupler provides 25dB isolation and exhibits equal power division at the output ports with quadrature phase difference of 90° and harmonics is suppressed up to 6th order**

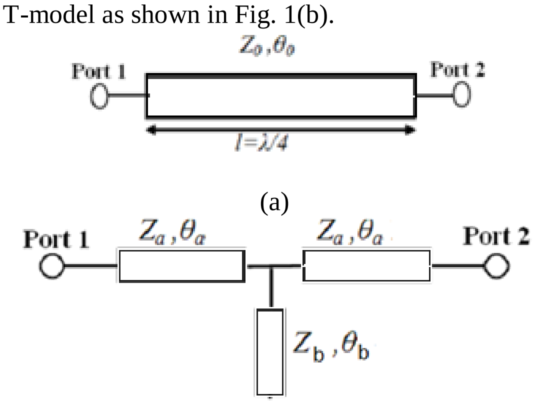
***Index Terms* – coupler, harmonic, miniature, stubs**

I. INTRODUCTION

A hybrid branch line is a special case of directional coupler with a coupling factor of 3 dB and a phase difference in the outputs of the through and couple arms . It has a high degree of symmetry since any port can be used as the input port , with output ports always being on the opposite side of the junction from the input port ,and the isolated port being on the same side as the input port. In 3db coupler when power entering at one port it is divided equally among two output ports with 90 phase shift .
The branch-line coupler can be used as a power divider, combiner or a part of mixer in microwave integrated circuits .Branch line coupler is widely implemented using strip line strip line [2], multilayer structures [3], micro strip [4] and finite-ground coplanar waveguide [5].the coupler has square shaped series and shunt arm that uses quarter wavelength transmission lines i.e. ($\lambda/4\times \lambda/4$) that is used for power dividing and power combining functions. At lower frequencies the size of conventional coupler becomes very large. the physical length of quart wavelength transformer depends on frequency as frequency increases the length of the quarter wavelength transformer increases.
There are many methods to decrease the size of branch line coupler .the design of coupler using only lumped components [6,7] there is significant reduction in size but there is difficulty in getting precise inductor based on measurements[8]. the use lumped capacitor along with short and high impedance transmission line[9,10] can be used to reduce the size of coupler but using metal-insulator-metal (MIM) increases the complexity of the circuit.
In this paper coupler is designed for 375 MHz frequency using open stubs with high and low impedance is introduced. there are two ways coupler can be designed using open stubs that is t-stub loaded transmission line and π -stub loaded transmission line .using π-stubs the width of stubs becomes very large at 375MHz frequency compared to transmission line and also performance is less compared to t-stubs so we are introducing coupler design using only T-stub loaded transmission line. it is possible to achieve 66% reduction in size compared to conventional coupler.

II. COUPLER DESIGN

A conventional branch line coupler is based on four quarter wavelength transmission lines which are composed of low impedance series arm of 35.35- and high impedance shunt arm of 50-. The transmission line model of such a quarter wavelength line is shown in Fig. 1(a),where the Z0 and µ0 is the characteristic impedance and the electrical length respectively. In order to reduce the size of each quarter wavelength branch arm, equivalent transmission lines that approximate the behaviour of a quarter wave transmission line is used. An e®ective approach for miniaturization is to replace the quarter wavelength branch arms with recursively loaded stubs in a sequential T-model as shown in Fig. 1(b).



(a)
(b)

Figure 1: equivalent circit of (a) quarter wavelength TL (b) T-stub loaded transmission line

The ABCD parameters for the conventional transmission line transformer are given as follows:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cos 90° & jZ_0 \sin 90° \\ jZ_0^{-1} \sin 90° & \cos 90° \end{bmatrix} = \begin{bmatrix} 0 & jZ_0 \\ jZ_0^{-1} & 0 \end{bmatrix}$$

To be equivalent to the λ/4 line, the T-stub loaded structure should be designed to have the same ABCD parameters given in (1). The ABCD matrix of open stub in parallel shown in Fig. 1(b) is given in the following form [9]

$$T_{st} = \begin{bmatrix} 1 & 0 \\ J\beta b & 1 \end{bmatrix}$$

$$\text{where } \beta b = \frac{Z_0}{\tan \theta_b}$$

Furthermore, the ABCD matrix for each of the two transmission line transformers that have a characteristic impedance of Z_a and electrical length of θ_a is given by:

$$T_s = \begin{bmatrix} cos\theta a & jZasin\theta a \\ \frac{j}{Za} sin\theta a & cos\theta a \end{bmatrix}$$

total ABCD matrix of the whole T-loaded structure is expressed as follows:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = T_s * T_{st} * T_s$$

$$\begin{bmatrix} 0 & jZ_0 \\ jZ_0^{-1} & 0 \end{bmatrix} = \begin{bmatrix} \cos\theta a & jZa\sin\theta a \\ \frac{j}{Za}\sin\theta a & \cos\theta a \end{bmatrix} X \begin{bmatrix} 1 & 0 \\ J\beta b & 1 \end{bmatrix} X \begin{bmatrix} \cos\theta a & jZa\sin\theta a \\ \frac{j}{Za}\sin\theta a & \cos\theta a \end{bmatrix}$$

$$A = cos\theta acos\theta a - \beta bZasin\theta acos\theta a - sin\theta asin\theta a \quad (1)$$

$$B = jZacos\theta asin\theta a - j\beta bZa^2 sin\theta asin\theta a + jZasin\theta acos\theta a \quad (2)$$

$$C = \frac{j}{Za} sin\theta acos\theta a + jcos\theta a\beta bcos\theta a + \frac{j}{Za} sin\theta acos\theta a \quad (3)$$

$$D = -sin\theta asin\theta a - Za\beta bcos\theta asin\theta a + cos\theta acos\theta a \quad (4)$$

by considering equation (1) and equating to parameter

$$0 = cos\theta acos\theta a - \beta bZasin\theta acos\theta a - sin\theta asin\theta a$$

$$cos2\theta a - \beta bZa \frac{sin2\theta a}{2} = 0$$

$$\frac{\beta bZa}{2} = cot2\theta a$$

$$\boldsymbol{\beta b} = \frac{\mathbf{2cot2\theta a}}{\mathbf{Za}} \quad (5)$$

$$\frac{tan\theta b}{Zb} * \frac{Za}{2} = cot2\theta a$$

$$\mathbf{Zb} = \frac{\mathbf{tan2\theta a\ tan\theta b\ Za}}{\mathbf{2}} \quad (6)$$

Consider equation (3)

$$jZ_0^{-1} = jYasin\theta acos\theta a + jcos\theta a\beta bcos\theta a + jYasin\theta acos\theta a$$

$$jcos\theta a(Yasin\theta a + \beta bcos\theta a + Yasin\theta a) = jY0$$

$$jcos\theta a(2Yasin\theta a + 2\frac{cot2\theta a}{Za} cos\theta a)$$

$$jcos\theta a\left(2Yasin\theta a + \frac{2cos2\theta acos\theta a}{2sin\theta acos\theta aZa}\right)$$

$$jcos\theta a\left(2Yasin\theta a + \frac{cos2\theta a}{sin\theta a} Ya\right)$$

$$jYacos\theta a\left(\frac{2sin^2\theta a + cos2\theta a}{sin\theta a}\right)$$

$$jYa\frac{cos\theta a}{sin\theta a}(2sin^2\theta a + 2cos^2\theta a - 1)$$

$$jYacot\theta a(2(1) - 1) = jY0$$

$$\frac{1}{Za} cot\theta a = \frac{1}{Z0}$$

$$Za = Z0cot\theta a$$

$$\mathbf{Za} = \frac{\mathbf{Z0}}{\mathbf{tan\theta a}} \quad (7)$$

by choosing $90° < \theta a < \theta b$ and, θb is selected odd multiple of 90° there is considerable reduction in size .using design equation for Za and Zb the impedances for equivalent 50Ω and 35.35 Ω transmission lines is calculated. Physical length and width of transmission line is calculated by considering FR4 substrate with relative permittivity of 4.3 and thickness of 1.6mm with loss tangent of 0.002 , θa is arbitrarily chosen as 50° and stub electric length θb is selected 15°. for 50Ω transmission line Za and Zb is 86.6Ω and 20.09Ω respectively and for 35.35Ω transmission line Za and Zb is 61.22Ω and 14.206Ω corresponding physical length and width is calculated using above equations in MATLAB.

physical length and width of transmission line for series and shunt and for open stubs is derived from ADS line calculator by impedance and electrical length of every transmission line in the design. Both side of through and shunt arm of the couplers were built on FR-4 substrate with permittivity, permeability, loss tangent and heights are 4.3, 1, 0.02 and 1.6mm, respectively. Table 1 tabulates the overall dimensions of coupler based on earlier calculations and figure 1 shows the layout of proposed coupler

Table 1:dimensions of proposed coupler

Design parameters	**Length and width**
L1,w1	77.5mm,2.177mm
L2,w2	78.2mm.1.04mm
L3,w3	17.4mm,11.18mm
L4,w4	17.3mm,16.9mm

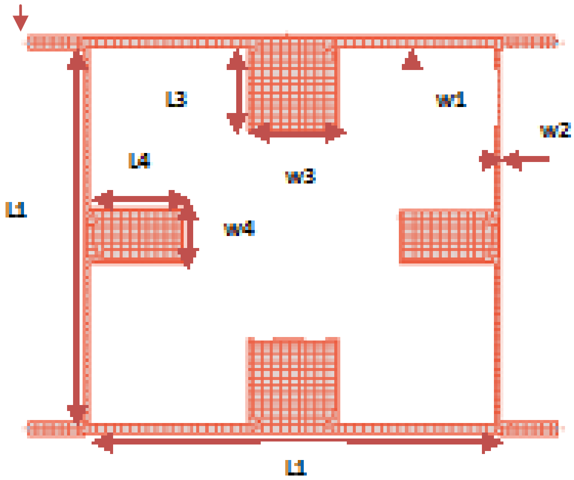


Figure 1: layout of proposed branch line coupler

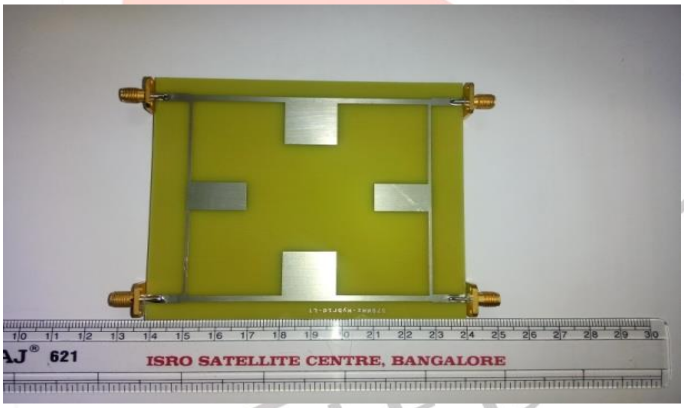


Figure 2: photograph of the proposed T-stub loaded miniaturized BLC

comparing physical length and widths of T-stub loaded transmission line with conventional coupler there is 66% reduction in size T-stub loaded transmission lined compared to conventional coupler . circuit design and simulation results are obtained in ADS software. and fabricated coupler results are compare with simulation results.

III. RESULTS

Planar circuit for proposed coupler and conventional coupler is drawn in ADS using various tools and FR4 substrate is selected with dielectric permittivity of 4.3 and thickness of 1.6mm and tangent loss of 0.02 EM simulated response is shown in table. the fabricated results are shown in the figure which is nearly same as simulation results

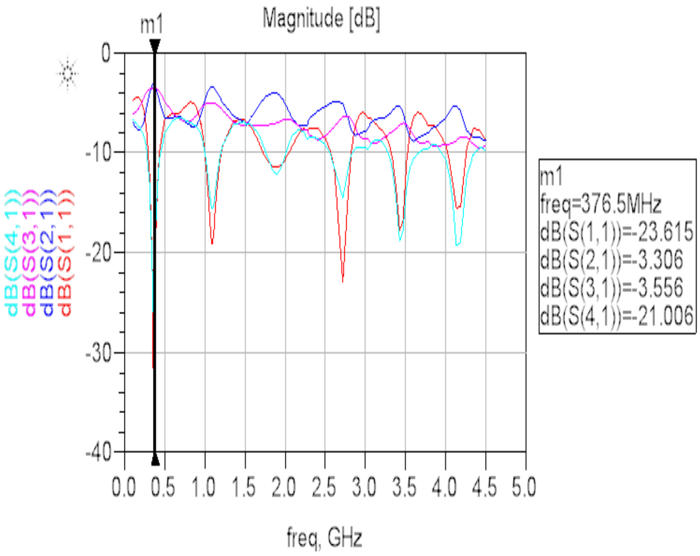


Figure 3:frequency response of conventional branch line coupler

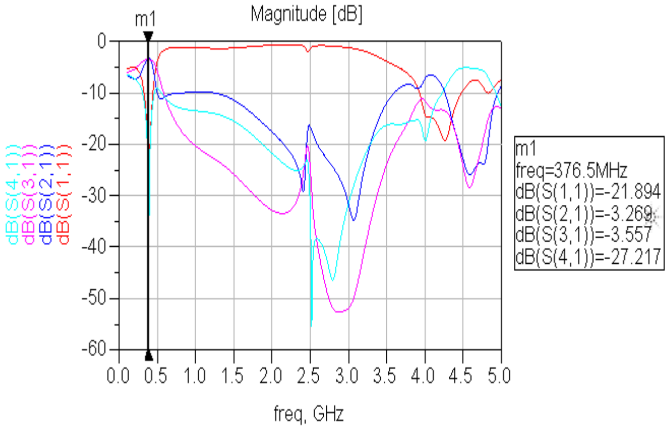


Figure 4:frequency response of miniature coupler

coupler results are analyzed for both proposed and conventional coupler from 0Ghz to 5Ghz at operating frequency 375Mhz the isolation factor S_{41} is -27.2 and reflection coefficient $S_{31}$is -21.8 which is comparable to conventional coupler ,coupling factor S_{21} and S_{31} approaching ideal value, -3dB,which determines the coupler's ability to divide the input signal equally which is -3.269 and -3.557 differences are within 0.3db. Harmonics can be observed in conventional coupler at odd multiples of frequencies but in t-stub loaded transmission line harmonics are suppressed up to 4Ghz since we are using 15° stubs that suppresses up to 6th 0rder harmonics. the below table shows comparison between miniature coupler and conventional coupler at 375Mhz.

Table2:conventional vs miniature BLC

parameter	**Conventional**	**miniaturized**
length	107.93mm	77.5mm
width	110.55mm	76.2mm
area	11922,9mm^2	5905.5mm^2

from table length and width of miniaturized branch line coupler is 107.93mm and 110.55mm respectively the total area is 107.93mm × 110.55mm i.e.11926mm^2 and that of miniaturized coupler physical length and width is 77.5mm and 76.2mm and total area is 5905.5mm^2 so there is 50% reduction in size compared to conventional coupler further size can be reduced by meandering the transmission line and also harmonics are suppressed up to 6th order

IV. CONCLUSION

Recently, miniaturization microwave circuit has been the main Target of many researchers to reduce cost. In this project, the Conventional branch line coupler and the proposed miniaturized one with Harmonic suppression were designed, simulated and fabricated at the frequency of 375 MHz using ADS software, both couplers were etched on the same FR4 substrate .size reduction up to 50% is achieved in proposed coupler compared to conventional coupler and harmonics up to 6th order is suppressed.

V. ACKNOWLEDGMENT

we acknowledge **Dr. A R Ashwatha** Head of department ,Telecommunication Engineering,DSCE,**Vamsi krishna veledi** ISRO scientist **and Basavaraj SM professor** Telecommunication Engineering, DSCE for their able guidance and valuble advice.

VI. REFERENCES

[1] Pozar, D. M., Microwave Engineering, 3rd edition, New York,Wiley, 2005.

[2] Riblet, G. P., \A directional coupler with very °at coupling,"IEEE Trans. Microw. Theory Tech., Vol. 26, No. 2, 70{74,Feb. 1978.

[3] Banba, S., T. Hasegawa, and H. Ogawa, \Multilayer MMICbranch-line hybrid using thin dielectric layers," IEEE Microw.Guided Wave Lett., Vol. 1, No. 11, 346{347, Nov. 1991.

[4] Muraguchi, M., T. Yukitake, and Y. Naito, \Optimum design of3-dB branch-line couplers using microstrip lines," IEEE Trans.Microw. Theory Tech., Vol. 31, No. 8, 674{678, Aug. 1983

[5] Lin, C. T., C. L. Liao, and C. H. Chen, \Finite-ground coplanar-waveguide branch-line couplers," IEEE Trans. Microw. WirelessCompon. Lett., Vol. 11, No. 3, 127{129, Mar. 2001.

[6] Caulton, M., B. Hershenov, S. P. Knight, and R. E. Debrecht,\Status of lumped elements in microwave integrated circuit-present and future," IEEE Trans. Microw. Theory Tech., Vol. 9,No. 7, 588{599, Jul. 1971.

[7] Chiang, Y. C. and C. Y. Chen, \Design of a wide-band lumped-element 3-dB quadrature coupler," IEEE Trans. Microw. TheoryTech., Vol. 49, No. 3, 476{479, Mar. 2001

[8] Hirota, T., A. Minakaw, and M. Muraguchi, \Reduced-sizebranch-line and rat-race hybrids for uniplanar MMIC's," IEEETrans. Microw. Theory Tech., Vol. 38, No. 3, 270{275, Mar. 1990.

[9] Singh, R. B. and T. M.Weller, \Miniaturized 20GHz CPWquadrature coupler using capacitive loading," Microw. Opt.Technol. Lett., Vol. 30, No. 1, 3{5, Jul. 2001.