IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 11, Issue 6 Ver. III (Nov. – Dec. 2016), PP 51-56
www.iosrjournals.org

An Improved Version of Exponential Taper Transmission Line Branch Coupler with Inductance Element

[1,]Adnan Affandi, [2,]Abdullah Dobaie, [3,]Yasser Gharbi
[1,2,3]Electrical and Computer Engineering Department King Abdul Aziz University

Abstract:*Novel exponential taper transmission line branch line coupler is presented.The ability of this proposed branch line coupler is demonstrated in this paper.The parameters of this network is calculated and its frequency responses is computed. Simulation design and manufacturing of microwave exponential taper transmission line branch couplers are presented.*
Keywords: *Exponential Taper; Branch Coupler ; Non-uniform Taper*

I. Introduction

Since the branch line couplers either in form of a hybrid or in a cascade are very important networks since they are used in a broadband range of applications such as mixers, data modulators, phase shifters, power combined amplifiers, PIN switches, detectors and patch antennas [8-9]. Microstrip branch line couplers are widely used because they are light weight, economical and readily reproducible by using photo graphic methods. Intensive works and researches had been spent in order to generate novel microstrip non-uniform transmission networks [1-3]. Although considerable amount of works have beendevotedin analysing non-uniform transmission, but unfortunately, the exact realization of this non-uniform branch line couples have not been achieved yet. The non-uniform tapered lines represent a practical and effective solution to impedance matching problems. Normally the reflection coefficients of the tapered lines decrease rapidly with frequency, and are more manageable than those from stepped transforms. Discontinuities do not exist, since the impedance change is continuous. The computer analysis is used as a part of an optimization procedure to obtain locally optimum designs, for both uniform and non-uniform (BLC) with and without resonant radial stubs. The branch coupler circuits in this chapter are simulated using ADS 2011 and fabricated on Roger 4003 substrate with dielectric constant of 3.38.

II. Exponential Taper Transmission Line Branch Coupler

Due to the high degree of symmetry of the BCL see Fig. 1, the even and odd modes concepts can be employed and the superposition theorems can be also used to formulate the scattering matrix of the proposed BLC. The even and odd modes concepts reduce the four port BLC into two port networks which makes the network easier to be analysed. Figure 1b shows the photograph of prototyped of the Exponential taper branch line coupler which fabricated on Roger 4003 substrate with dielectric constant of 3.38 and the thickness = 0.203 mm.

III. Even Mode Analysis

The even mode circuit of Fig. 1 is seeing in Fig.2. Which consists of four-exponential lines of lengths ℓ_1, ℓ_2, ℓ_3 and ℓ_4 and two open-circuited stubs of length ℓ_{1So} and ℓ_{2So} and two inductors L of value 10 pH. By using the even mode circuit of Fig. 2. The overall even mode matrices ATe BTe CTe DTe may be found as:

$$\begin{bmatrix} A_{Te} & B_{Te} \\ C_{Te} & D_{Te} \end{bmatrix} = Me1 * Me2 \qquad (1)$$

where $$Me1 = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_{S1e} & B_{S1e} \\ C_{S1e} & D_{S1e} \end{bmatrix} \begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \qquad (2)$$

and $$Me2 = \begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix} \begin{bmatrix} A_{S2e} & B_{S2e} \\ C_{S2e} & D_{S2e} \end{bmatrix} \begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix} \begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix} \qquad (3)$$

Where the ABCD matrices of the first and the second stubs may be represented respectively as:

$$\begin{bmatrix} 1 & 0 \\ C_{1so}/A_{1so} & 1 \end{bmatrix} \text{ and } \begin{bmatrix} 1 & 0 \\ C_{2so}/A_{2so} & 1 \end{bmatrix} \quad (4)$$

where

$$An = \frac{1}{Nn}(\cosh(\beta'\ell n) + \frac{\delta n \ell n}{2}\frac{\sinh(\beta'\ell n)}{\beta'\ell n})$$

$$Bn = jZ_{0n} Nn\beta'\ell n(\frac{\sinh(\beta'\ell n)}{\beta'\ell n})$$

$$Cn = j\frac{1}{Z0n} * \frac{1}{Nn}\beta'\ell n(\frac{\sinh(\beta'\ell n)}{\beta'\ell n})$$

$$Dn = Nn(\cosh(\beta'\ell n) - \frac{\delta n \ell n}{2}\frac{\sinh(\beta'\ell n)}{\beta'\ell n})$$

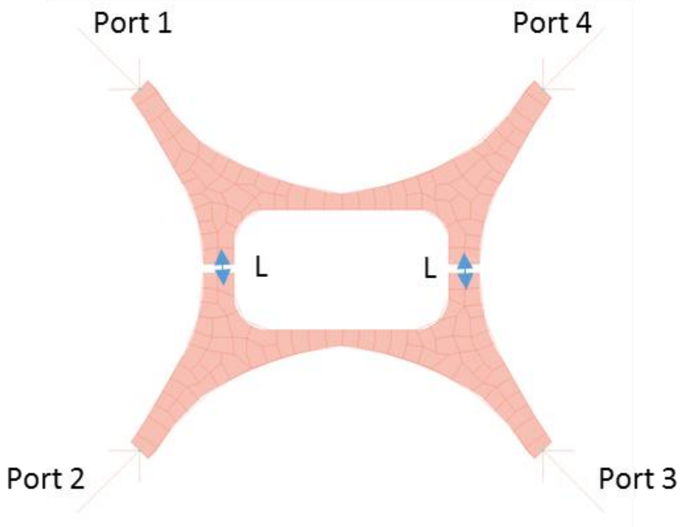

Figure 1a The Exponential taper branch line coupler

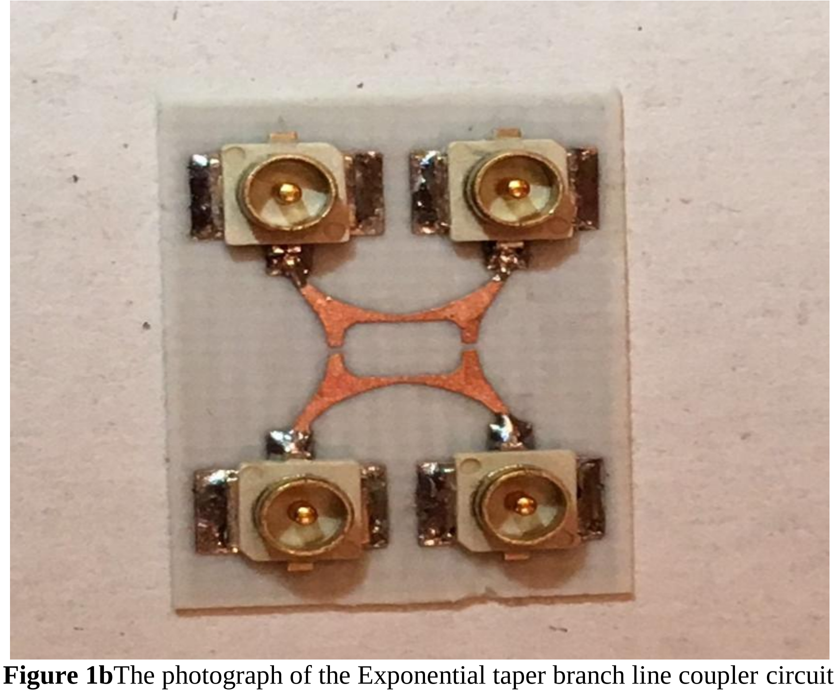

Figure 1b The photograph of the Exponential taper branch line coupler circuit

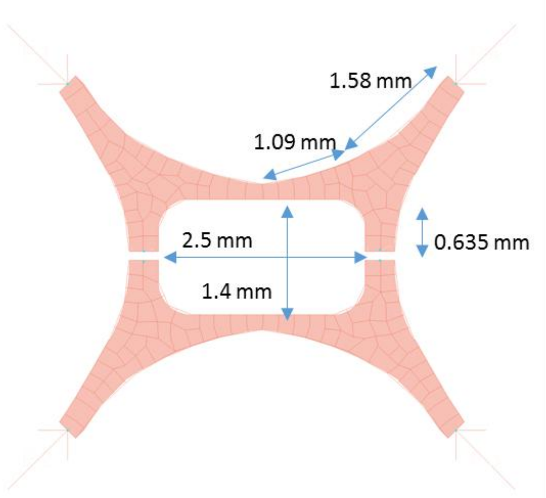

Figure 1c The Exponential taper branch line coupler circuit dimension

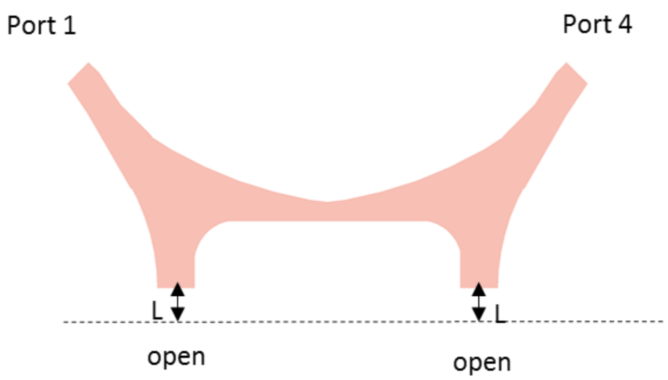

Figure 2 The even mode equivalent circuit of the exponential branch line coupler

where n = 1, 2, 3 and 4

Where $\beta\ell_n = \dfrac{2\pi\ell_n}{\lambda}$, $N_n = e^{\delta_n \ell_n / 2}$ where δ is the line taper and $\omega = 2\pi f$

$\delta_n = \ln \dfrac{Z_{Ln}}{Z_{0n}}$, $\beta'\ell_n = \sqrt{(\dfrac{\delta_n \ell_n}{2})^2 - (\beta\ell_n)^2}$

Where Z0n, ZLn, λ and ℓ_n are the input, output impedances, wavelength and the length of the nth branch coupler line.

and where

$$A_{nso} = \frac{1}{N_{nso}}(\cosh(\beta\ell_{nso}) + \frac{\delta\ell_{nso}}{2}\frac{\sinh(\beta\ell_{nso})}{\beta\ell_{nso}})$$

$$C_{nso} = j\frac{1}{Z_{nso}} * \frac{1}{N_{nso}}\beta\ell_{nso}(\frac{\sinh(\beta\ell_{nso})}{\beta\ell_{nso}})$$

Where nso = 1, 2 and o is for open circuit and s is for stup. The even mode reflection and transmission coefficients are expressed as :

$$\rho_e = \frac{Z_L A_{Te} + B_{Te} - Z_L Z_S C_{Te} - Z_S D_{Te}}{Z_L A_{Te} + B_{Te} + Z_L Z_S C_{Te} + Z_S D_{Te}} \quad (5)$$

$$\tau_e = \frac{2\sqrt{Z_S Z_L}}{Z_L A_{Te} + B_{Te} + Z_L Z_S C_{Te} + Z_S D_{Te}} \quad (6)$$

IV. Odd Mode Analysis

The odd mode circuit of Fig. 1.is shown in Fig. 3. Which consists of four-exponential lines of lengths $\ell 1$, $\ell 2$, $\ell 3$ and $\ell 4$ and two short-circuited stubs of length $\ell 1So$ and $\ell 2So$ and two inductors L of value 10 pH. The overall odd mode ATo BTo CTo DTo matrices may be found as:

$$\begin{bmatrix} ATo & BTo \\ CTo & DTo \end{bmatrix} = Mo1 * Mo2 \qquad (7)$$

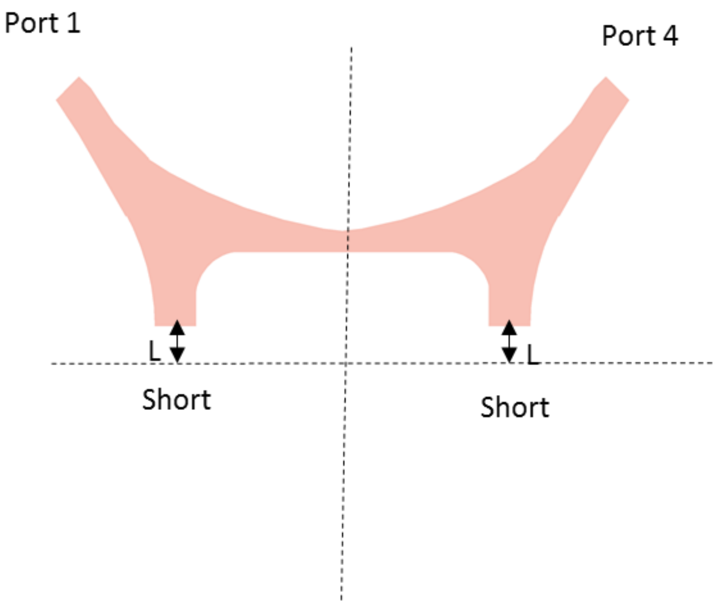

Figure 3 The odd mode equivalent circuit of the exponential branch line coupler

where $Mo1=\begin{bmatrix} A1 & B1 \\ C1 & D1 \end{bmatrix}\begin{bmatrix} AS1o & BS1o \\ CS1o & DS1o \end{bmatrix}\begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix}\begin{bmatrix} A2 & B2 \\ C2 & D2 \end{bmatrix}$ (8),

and $Mo2 = \begin{bmatrix} A3 & B3 \\ C3 & D3 \end{bmatrix}\begin{bmatrix} AS2o & BS2o \\ CS2o & DS2o \end{bmatrix}\begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix}\begin{bmatrix} A4 & B4 \\ C4 & D4 \end{bmatrix}$ (9)

Where the ABCD matrices of the first and the second stubs may be represented respectively as:

$$\begin{bmatrix} 1 & 0 \\ D1ss/B1ss & 1 \end{bmatrix} \text{ and } \begin{bmatrix} 1 & 0 \\ D2ss/B2ss & 1 \end{bmatrix} \qquad (10)$$

where

$$An = \frac{1}{Nn}(\cosh(\beta'\ell n) + \frac{\delta n\ell n}{2}\frac{\sinh(\beta'\ell n)}{\beta'\ell n}), \quad Bn = jZ_{0n}Nn\beta'\ell n(\frac{\sinh(\beta'\ell n)}{\beta'\ell n})$$

$$Cn = j\frac{1}{Z0n} * \frac{1}{Nn}\beta'\ell n(\frac{\sinh(\beta'\ell n)}{\beta'\ell n}), \quad Dn = Nn(\cosh(\beta'\ell n) - \frac{\delta n\ell n}{2}\frac{\sinh(\beta'\ell n)}{\beta'\ell n})$$

Where n = 1, 2, 3 and 4

Where $\beta\ell_n = \frac{2\pi\ell_n}{\lambda}$, $N_n = e^{\delta n\ell n/2}$ where δ is the line taper

$$\delta_n = \ln\frac{Z_{Ln}}{Z_{0n}}, \quad \beta'\ell_n = \sqrt{(\frac{\delta_n\ell_n}{2})^2 - (\beta\ell_n)^2}$$

Where Z0n, ZLn, λ and ℓn are the input, output impedances, wavelength and the length of the nth branch coupler line.

$$B_{nss} = jZ_{nss} N_{nss} \beta' \ell nss(\frac{\sinh(\beta' \ell nss)}{\beta' \ell nss})$$

And where

$$D_{nss} = N_{nss}(\cosh(\beta' \ell nss) - \frac{\delta \ell nss}{2}\frac{\sinh(\beta' \ell nss)}{\beta' \ell nss})$$

Where nss = 1, 2 and s is for short circuit and s is for stup. while ss for the short - circuited ETL stubs .
The odd mode reflection and transmission coefficients are expressed as :

$$\rho_o = \frac{Z_L A_{To} + B_{To} - Z_L Z_S C_{To} - Z_S D_{To}}{Z_L A_{To} + B_{To} + Z_L Z_S C_{To} + Z_S D_{To}} \quad (11)$$

$$\tau_o = \frac{2\sqrt{Z_S Z_L}}{Z_L A_{To} + B_{To} + Z_L Z_S C_{To} + Z_S D_{To}} \quad (12)$$

The elements of the four-port scattering matrix, Sij are related to the two-port scattering matrices as follows:

$$S11 = \frac{\rho_e + \rho_o}{2} \quad (13)$$

$$S21 = \frac{\tau_e + \tau_o}{2} \quad (14)$$

$$S31 = \frac{\rho_e - \rho_o}{2} \quad (15)$$

$$S41 = \frac{\tau_e - \tau_o}{2} \quad (16)$$

Fig. 4 show the frequency response of the experimental and simulation of the proposed exponential taper branch line coupler which was fabricated on Roger 4003 substrate of dielectric constant εr = 3.38 and thickness of 0.203 mm. It is clear of the plot that this proposed branch coupler provides 15 GHz bandwidth for -20dB taken as a reference for the return loss S_{11} and more than 40 GHz bandwidth for isolation S_{31} and S_{21}. While the insertion loss of 0.5 dB for S41 were observed over the same bandwidth15, GHz. Full agreement between the theoretical and experimental works have been successfully achieved.

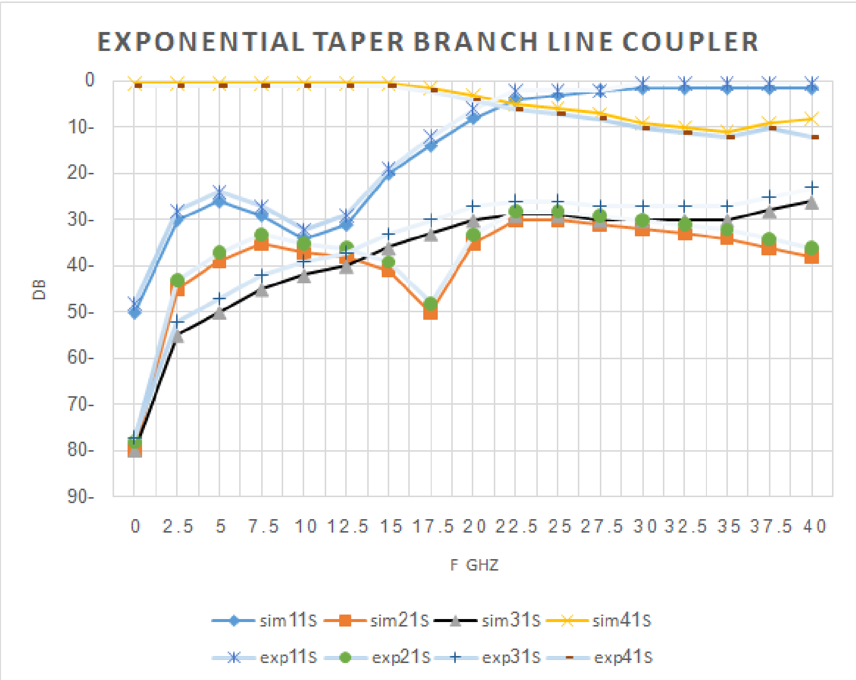

Figure 4. Experimental and simulation frequency response of exponential branch line coupler

V. Conclusion

The proposed four port exponential branch line coupler reveals that ultra-broad band operation has been achieved, therefore this proposed branch line coupler can find several application in microstrip field..

References

[1] *K. Koboyashi, Y. Nemoto, and R. Sato, " Equivalent circuits of binomial form non uniform transmission lines and their application," Trans. IECE, Japan, vol. 63-a, no. 11, pp. 807- 814, Nov. 1980.*

[2] *M. I. Sobhy and E. A. Hosny,″The design of directional couplers using Parabolic lines in homogeneous media ″ IEEE Trans. Microwave Theory Tech., vol. MTT-30, pp.71-76, Jan. 1982.*

[3] *A. M. Affandi, S. Mahdi, M.M Almoabadi, * Analysis of some non- uniform transmission lines with selected applications * ICECS`94, pp. 153- 162, December 19-22, 1994, Cairo, EGYPT.*

[4] *I. Oiita, T. Kawai, S. Shimahasih, K. Ho, " A Transmission line type eight port hybrid " IEEE. Trans. Microwave Theory Tech., Vol. MTT- S Digest pp.119 - 122, 1992.*

[5] *Steven. L. March " Analyzing Lossy Radial - Line Stubs “, Microwave Theory Tech., vol. MTT-33, No. 2, pp 269-271, March 1985. IEEE , Transmission Line Theory, Waves, vol. 128, Pt. H, No. 2, APRIL, 1981.*

[6] *D. Lacombe and J. Cohen,“ Octave - Band DC Blocks “, IEEE Trans.m.Microwave Throry Teach., Vol MTT, pp. 55 - 56 Aug 1972.*

[7] *F. Takada and M. Matsunaga “ Small - Sized Diode Phase Shifter “, 11th EUMC, pp. 833 - 838, Amsterdam 1981.*