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An Novel Ultra Broad-Band Exponential Taper Transmission Line 8- Port Network

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Abstract: *An novel Ultra Broad-Band Exponential Taper Transmission Line 8- Port Networkis analyzed. The parameters of this developed network is calculated and its frequency responses are computed. Comparison between the simulated and measured parameters are presented.*
Keywords: *Exponential Taper; 8-Port network; Nonuniform Taper*

I. Introduction

Because of the great applications of the eight- port networks in microstrip line and microwave field, intensive work, research and effort have been conducted and devoted in order to improve thier performances and quality. For instance G. P. Riblet [1] has proposed a symmetrical eight-port ring composed of microstrip lines and slot lines on the face and back of the provided substrate. This proposed network found an important application as a phase comparator circuit in monopoles radar in order to control both the azimuth and the elevation of the target. While I, Ohta, T. Kawal, S. Shimahashi and K. Ho. [2] proposed a transmission line type microstrip eight port hybrid which is with the proper termination, it can be used as a phase comparator and a Four-way power combiner/divider. Also '1. Kawal, K. Ho, I. Ohta and T. Kaneko have proposed a branch line type eight-port comparator circuit which was composed of four 180' branch line couplers [3]. More recently, A. M. Affandi and G. M. Raw have proposed broadband microstrip eight-port hybrid ring [4] which with the proper terminations can be converted into a phase comparator, 4-way power combiner/divider or six-port reflectometer.

II. The Theoretical Analysis of The Non-Uniform Transmission Line Type Eight- Port Circuits

Four different configurations of non-uniform transmission line eight port networks are considered here, each one of them will be discussed in more detail latter on. There are two different approaches which be adopted in order to analyze the previous network . The first approach is to convert the proposed eight-port networks into 4-port symmetrical network by employing S. B. Karoomi and Y. Garaultg technique [5], while the second approach is to convert the eight-port circuit into two-port network by dividing the eight-port network about its two-fold symmetry, i.e, about the planes of AAI, and BBI with magnetic or electrical boundary [2], [3]. Once the property of the two planes boundary AAI, and BBI, are defined properly, (i.e. either AIA2, and B1B2, plane have magnetic walls or electrical walls or the combinations) the two port equivalent circuit is known and its scattering parameters can be easily found. The magnetic wall here represent an even-mode while the electrical wall denotes an odd-mode. The non-uniform transmission lines which have been selected here are exponential, linear and parabolic taper transmission lines.

III. TheTheoretical analysis of the proposed novel Ultra Broad-Band Exponential Taper Transmission Line 8- Port Network

The exponential taper eight-port hybrid is shown in Figure 1. This network is the best described by its scattering parameters which will be computed latter with the aid of the A B C D matrix.Figure 1b shows the photograph of the proposed of the novel Ultra Broad-Band Exponential Taper Transmission Line 8- Port Network. This proposed network is fabricated on Roger 4003 substrate with dielectric constant of 3.38 and the thickness = 0.203 mm.

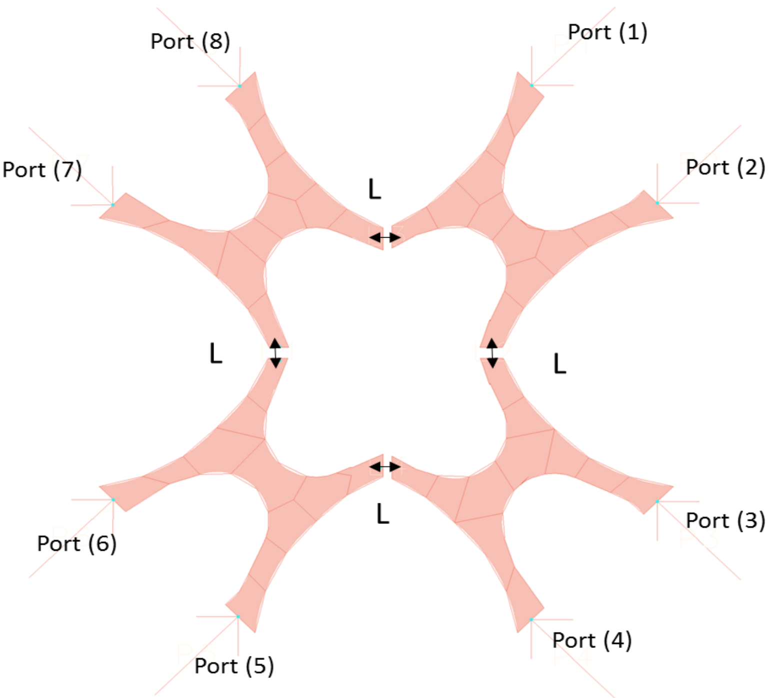

Figure 1ashows the layout of the Novel Ultra Broad-Band Exponential Taper Transmission Line 8- Port Network

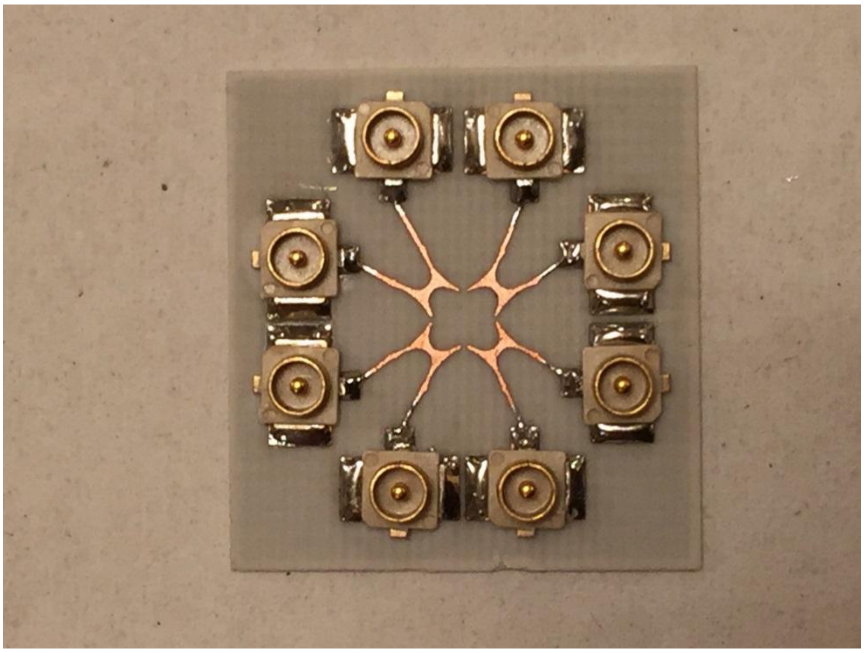

Figure 1b. The photograph of the proposed of Nnovel Ultra Broad-Band Exponential Taper Transmission Line 8- Port Network

The ABCD matrix parameters for the exponential taper transmission line are given as: [6-7]

$$A = \frac{1}{N}(\cosh(\beta'\ell) + \frac{\delta}{2}\frac{\ell\sinh(\beta'\ell)}{\beta'\ell}) \quad (1)$$

$$B = jZ_0 N\beta'\ell(\frac{\sinh(\beta'\ell)}{\beta'\ell}) \quad (2)$$

$$C = j\frac{1}{Z_0} * \frac{1}{N}\beta'\ell(\frac{\sinh(\beta'\ell)}{\beta'\ell}) \qquad (3)$$

$$D = N(\cosh(\beta'\ell) - \frac{\delta\ell}{2}\frac{\sinh(\beta'\ell)}{\beta'\ell}) \qquad (4)$$

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

$$\delta = \ln\frac{Z_L}{Z_0} \ , \ \beta'\ell = \sqrt{(\frac{\delta\quad \ell}{2})^2 - (\beta\ell)^2}$$

Where Z0, ZL, λ and ℓ are the input, output impedances, wavelength and the length of the transmission line. The theoretical analysis of the exponential 8-port network is best analyzed in terms of the modes analysis. The selected mode are:-

Even – even mode.
Even – Odd mode.
Odd – Even mode.
Odd – Odd mode.

IV. Even-Even Mode Analysis of Fig. 1.

When the planes boundary AA1 and BB1 have both magnetic walls an even-even mode network is resulted. The even-even mode equivalent circuit of fig. 1 is shown in fig. 2. This network consists of three-exponential lines of lengths $\ell 1$, $\ell 3$, and $\ell 5$ two open-circuited exponential taper line stubs of lengths $\ell 2$ and $\ell 4$.

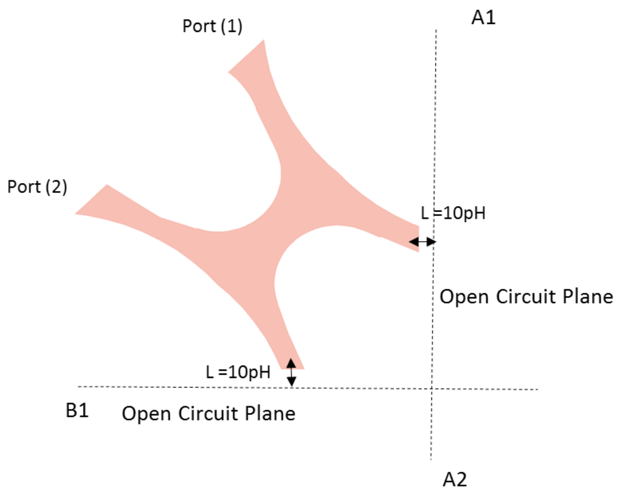

Figure 2 shows the even-even mode equivalent circuit of figure 1 i.e. both planes A1 A2 and B1 B2 are having magnetic walls properties

The ABCD matrix for even-even mode are given as:

$$\begin{bmatrix} A_{Tee} & B_{Tee} \\ C_{Tee} & D_{Tee} \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix}\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}\begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix}\begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix}\begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix}\begin{bmatrix} A_5 & B_5 \\ C_5 & D_5 \end{bmatrix}\begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix} \qquad (5)$$

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

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} As_1 & Bs_1 \\ Cs_1 & Ds_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ C_{1so}/A_{1so} & 1 \end{bmatrix} \qquad (6)$$

$$\begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix} = \begin{bmatrix} As_2 & Bs_2 \\ Cs_2 & Ds_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ C_{2so}/A_{2so} & 1 \end{bmatrix} \qquad (7)$$

Where $A_i = \frac{1}{N_i}(\cosh(\beta\ell_i) + \frac{\delta\ell_i}{2}\frac{\sinh(\beta\ell_i)}{\beta\ell_i})$

$$B_i = jZ_i N_i \beta\ell_i \left(\frac{\sinh(\beta\ell_i)}{\beta\ell_i}\right)$$

$$C_i = j\frac{1}{Z_i}\frac{1}{N_i}\beta\ell_i \left(\frac{\sinh(\beta\ell_i)}{\beta\ell_i}\right)$$

$$D_i = N_i\left(\cosh(\beta\ell_i) - \frac{\delta\ell_i}{2}\frac{\sinh(\beta\ell_i)}{\beta\ell_i}\right)$$

Where i = 1, 2, 3, 4, and 5.

$\beta' = \frac{2\pi}{\lambda m}$ where λm is the microstrip wavelength

$N_i = e^{\delta\ell_i/2}$ where δ is the line taper

$$\delta_i = \ln\frac{Z_{Li}}{Z_{0i}}$$

$$\beta'\ell_i = \sqrt{\left(\frac{\delta\ell_i}{2}\right)^2 - (\beta'\ell_i)^2}$$

Where Z0i, ZLi, λ and ℓ are the input, output impedances, wavelength and the length of the ith transmission line.

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

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

Where nso = 1, 2 and o is for open circuit and S is for stup.

The reflection and transmission coefficients of the even - even mode can be calculated as:

$$\rho_{ee} = \frac{Z_L A_{Tee} + B_{Tee} - Z_L Z_S C_{Tee} - Z_S D_{Tee}}{Z_L A_{Tee} + B_{Tee} + Z_L Z_S C_{Tee} + Z_S D_{Tee}} \qquad (8)$$

$$\tau_{ee} = \frac{2\sqrt{Z_S Z_L}}{Z_L A_{Tee} + B_{Tee} + Z_L Z_S C_{Tee} + Z_S D_{Tee}} \qquad (9)$$

V. Even-Odd Mode Analysis of Fig. 1.

The Even-Odd equivalent of figure. 4.1 is shown in figure. 4.3, which consists of three-exponential lines of lengths ℓ_1, ℓ_3, and ℓ_5, and two stubs (open and short circuited)of lengths ℓ_2 and ℓ_4, two inductors L of value 10 pH.

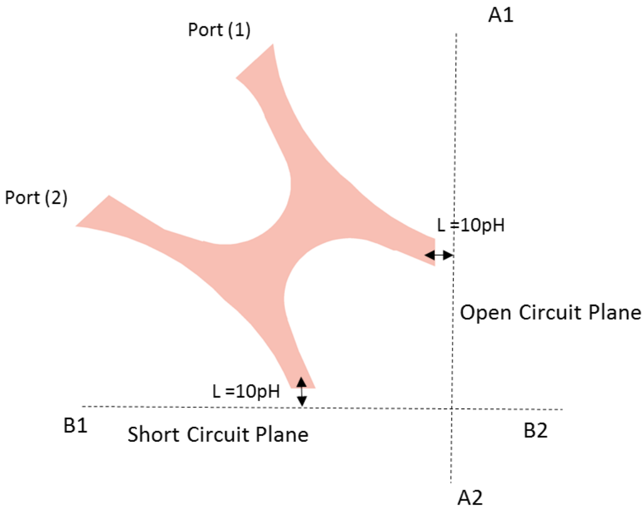

Figure 3 shows the even-odd mode equivalent circuit of figure 1 i.e. both planes A1 A2 unopened circuit property (even mode) while plane B1 B2 is having short circuit property (odd mode property)

The ABCD matrix for Even- Odd mode are given as:

$$\begin{bmatrix} A_{Teo} & B_{Teo} \\ C_{Teo} & D_{Teo} \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix} \begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix} \begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix} \begin{bmatrix} A_5 & B_5 \\ C_5 & D_5 \end{bmatrix} \begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix} \quad (10)$$

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

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ D_{1ss}/B_{1ss} & 1 \end{bmatrix}$$

$$\begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ C_{2so}/A_{2so} & 1 \end{bmatrix}$$

Where An Bn Cn Dn are defined last section and where

$$B_{nss} = jZ_{nss} N_{nss} \beta\ell_{nss} \left(\frac{\sinh(\beta\ell_{nss})}{\beta\ell_{nss}}\right)$$

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

Where $A_i = \frac{1}{N_i}\left(\cosh(\beta\ell_i) + \frac{\delta\ell_i}{2}\frac{\sinh(\beta\ell_i)}{\beta\ell_i}\right)$

$$B_i = jZ_i N_i \beta\ell_i \left(\frac{\sinh(\beta\ell_i)}{\beta\ell_i}\right)$$

$$C_i = j\frac{1}{Z_i}\frac{1}{N_i}\beta\ell_i\left(\frac{\sinh(\beta\ell_i)}{\beta\ell_i}\right)$$

$$D_i = N_i\left(\cosh(\beta\ell_i) - \frac{\delta\ell_i}{2}\frac{\sinh(\beta\ell_i)}{\beta\ell_i}\right)$$

Where i = 1, 2, 3, 4, and 5.

$\beta' = \frac{2\pi}{\lambda m}$ where λm is the microstrip wavelength

$N_i = e^{\delta\ell_i/2}$ where δ is the line taper

$$\delta_i = \ln\frac{Z_{Li}}{Z_{0i}}$$

$$\beta'\ell_i = \sqrt{\left(\frac{\delta\ell_i}{2}\right)^2 - (\beta'\ell_i)^2}$$

Where Z0i, ZLi, λ and ℓ are the input, output impedances, wavelength and thelength of the ith transmission line.

$$A_{2so} = \frac{1}{2_{2so}}\left(\cosh(\beta\ell_{2so}) + \frac{\delta\ell_{2so}}{2}\frac{\sinh(\beta\ell_{2so})}{\beta\ell_{2so}}\right)$$

$$B_{1ss} = jZ_{1ss} N_{1ss}\beta\ell_{1ss}\left(\frac{\sinh(\beta\ell_{1ss})}{\beta\ell_{1ss}}\right)$$

$$C_{2so} = j\frac{1}{Z_{2so}}\frac{1}{N_{2so}}\beta\ell_{2so}\left(\frac{\sinh(\beta\ell_{2so})}{\beta\ell_{2so}}\right)$$

$$D_{1ss} = N_{1ss}\left(\cosh(\beta\ell_{1ss}) - \frac{\delta\ell_{1ss}}{2}\frac{\sinh(\beta\ell_{1ss})}{\beta\ell_{1ss}}\right)$$

Where o is for open circuit and S is for stup.

The reflection and transmission coefficients of the even - odd mode can be calculated as:

$$\rho_{eo} = \frac{Z_L A_{Teo} + B_{Teo} - Z_L Z_S C_{Teo} - Z_S D_{Teo}}{Z_L A_{Teo} + B_{Teo} + Z_L Z_S C_{Teo} + Z_S D_{Teo}} \quad (11)$$

$$\tau_{eo} = \frac{2\sqrt{Z_S Z_L}}{Z_L A_{Teo} + B_{Teo} + Z_L Z_S C_{Teo} + Z_S D_{Teo}} \tag{12}$$

VI. Odd-Even Mode Analysis of Fig. 1

The Odd-Even mode equivalent of fig. 1 is shown in fig. 4, which consists of three-exponential lines of lengths $\ell 1$, $\ell 3$, and $\ell 5$ two stubs (open and short circuited) of lengths $\ell 2$ and $\ell 4$.

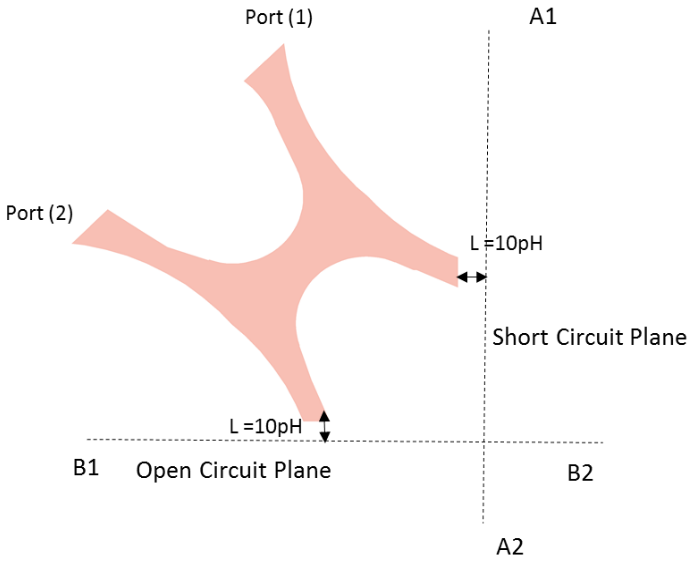

Figure 4 shows the odd-even mode equivalent circuit of figure 1.

The ABCD matrix for Odd - Even mode equivalent circuit is:

$$\begin{bmatrix} A_{Toe} & B_{Toe} \\ C_{Toe} & D_{Toe} \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix} \begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix} \begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix} \begin{bmatrix} A_5 & B_5 \\ C_5 & D_5 \end{bmatrix} \begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix} \tag{13}$$

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

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ C_{1so}/A_{1so} & 1 \end{bmatrix}$$

$$\begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ D_{2ss}/B_{2ss} & 1 \end{bmatrix}$$

Where $A_i = \frac{1}{N_i}(\cosh(\beta \ell i) + \frac{\delta \ell i}{2} \frac{\sinh(\beta \ell i)}{\beta \ell i})$

$$B_i = j Z_i N_i \beta \ell i (\frac{\sinh(\beta \ell i)}{\beta \ell i})$$

$$C_i = j \frac{1}{Z_i} \frac{1}{N_i} \beta \ell i (\frac{\sinh(\beta \ell i)}{\beta \ell i})$$

$$D_i = N_i(\cosh(\beta \ell i) - \frac{\delta \ell i}{2} \frac{\sinh(\beta \ell i)}{\beta \ell i})$$

Where i = 1, 2, 3, 4, and 5.

$\beta' = \frac{2\pi}{\lambda m}$ where λm is the microstrip wavelength

$N_i = e^{\delta \ell i/2}$ where δ is the line taper

$$\delta i = \ln \frac{Z_{Li}}{Z_{0i}}$$

$$\beta'\ell i = \sqrt{(\frac{\delta\ell i}{2})^2 - (\beta'\ell i)^2}$$

Where Z0i, ZLi, λ and ℓ are the input, output impedances, wavelength and the length of the ith transmission line.

$$A1so = \frac{1}{Z1so}(\cosh(\beta\ell1so) + \frac{\delta\ell1so}{2}\frac{\sinh(\beta\ell1so)}{\beta\ell1so})$$

$$B2ss = jZ2ss\,N2ss\,\beta\ell2ss(\frac{\sinh(\beta\ell2ss)}{\beta\ell2ss})$$

$$C1so = j\frac{1}{Z1so}\frac{1}{N1so}\beta\ell1so(\frac{\sinh(\beta\ell1so)}{\beta\ell1so})$$

$$D2ss = N2ss(\cosh(\beta\ell2ss) - \frac{\delta\ell2ss}{2}\frac{\sinh(\beta\ell2ss)}{\beta\ell2ss})$$

Where o is for open circuit and S is for stup.

The reflection and transmission coefficients of the odd - even mode can be calculated as:

$$\rho_{oe} = \frac{Z_LA_{Toe} + B_{Toe} - Z_LZ_SC_{Toe} - Z_SD_{Toe}}{Z_LA_{Toe} + B_{Toe} + Z_LZ_SC_{Toe} + Z_SD_{Toe}} \qquad (14)$$

$$\tau_{oe} = \frac{2\sqrt{Z_SZ_L}}{Z_LA_{Toe} + B_{Toe} + Z_LZ_SC_{Toe} + Z_SD_{Toe}} \qquad (15)$$

VII. Odd - Odd Mode Analysis of Fig. 1

The Odd-Odd mode equivalent of fig. 1 is shown in fig.5, which consists of three-exponential lines of lengths $\ell1$, $\ell3$, and $\ell5$ two short stubs of lengths $\ell2$ and $\ell4$.

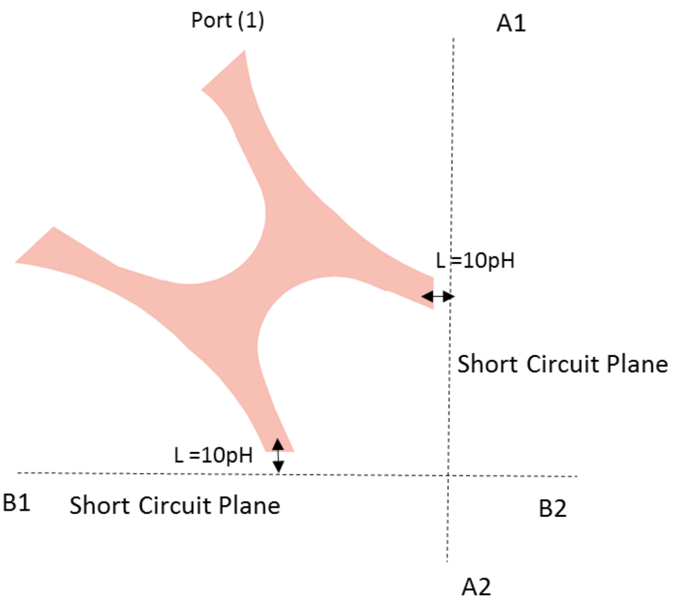

Figure 5 shows the odd-odd mode equivalent circuit of figure 1.

The ABCD matrix for Odd - Odd equivalent as:

$$\begin{bmatrix} A_{Too} & B_{Too} \\ C_{Too} & D_{Too} \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix}\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}\begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix}\begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix}\begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix}\begin{bmatrix} A_5 & B_5 \\ C_5 & D_5 \end{bmatrix}\begin{bmatrix} 1.0 & j\omega L \\ 0.0 & 1.0 \end{bmatrix} \qquad (4.16)$$

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

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ D_{1ss}/B_{1ss} & 1 \end{bmatrix} \qquad (4.16a)$$

$$\begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ D_{2ss}/B_{2ss} & 1 \end{bmatrix} \quad (4.16b)$$

Where $A_i = \frac{1}{N_i}(\cosh(\beta\ell_i) + \frac{\delta\ell_i}{2}\frac{\sinh(\beta\ell_i)}{\beta\ell_i})$

$$B_i = jZ_i N_i \beta\ell_i(\frac{\sinh(\beta\ell_i)}{\beta\ell_i})$$

$$C_i = j\frac{1}{Z_i}\frac{1}{N_i}\beta\ell_i(\frac{\sinh(\beta\ell_i)}{\beta\ell_i})$$

$$D_i = N_i(\cosh(\beta\ell_i) - \frac{\delta\ell_i}{2}\frac{\sinh(\beta\ell_i)}{\beta\ell_i})$$

Where i = 1, 2, 3, 4, and 5.

$\beta' = \frac{2\pi}{\lambda m}$ Where λm is the microstrip wavelength

$N_i = e^{\delta\ell_i/2}$ where δ is the line taper

$$\delta_i = \ln\frac{Z_{Li}}{Z_{0i}}$$

$$\beta'\ell_i = \sqrt{(\frac{\delta\ell_i}{2})^2 - (\beta'\ell_i)^2}$$

Where Z0i, ZLi, λ and ℓ are the input, output impedances, wavelength and the length of the ith transmission line.

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

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

Where nss = 1 and 2 and o is for open circuit and S is for stup.
The reflection and transmission coefficients of the even - odd mode can be calculated as:

$$\rho_{oo} = \frac{Z_L A_{Too} + B_{Too} - Z_L Z_S C_{Too} - Z_S D_{TOO}}{Z_L A_{Too} + B_{Too} + Z_L Z_S C_{Too} + Z_S D_{oo}} \quad (17)$$

$$\tau_{oo} = \frac{2\sqrt{Z_S Z_L}}{Z_L A_{Too} + B_{Too} + Z_L Z_S C_{Too} + Z_S D_{Too}} \quad (18)$$

VIII. The scattering matrix Parameters of The Novel Ultra Broad-BandExponential Taper 8-Port network

The overall scattering matrix parameters ofthe proposed ETL 8-Port hybrid can be calculated by applying the superposition theory [1-2] as:

$$S_{11} = \frac{\rho_{ee} + \rho_{eo} + \rho_{oe} + \rho_{oo}}{4} \quad (19)$$

$$S_{21} = \frac{\tau_{ee} + 2\tau_{eo} + \tau_{oo}}{4} \quad (20)$$

$$S_{31} = \frac{\tau_{ee} - \tau_{oo}}{4} \quad (21)$$

$$S_{41} = \frac{\rho_{ee} + \rho_{eo} - \rho_{oe} - \rho_{oo}}{4} \quad (22)$$

$$S_{51} = \frac{\rho_{ee} - \rho_{eo} - \rho_{oe} + \rho_{oo}}{4} \quad (23)$$

$$S61 = \frac{\tau_{ee} - 2\tau_{eo} + \tau_{oo}}{4} \quad (24)$$

$$S71 = S31 \quad (25)$$

$$S81 = \frac{\rho_{ee} - \rho_{eo} + \rho_{oe} - \rho_{oo}}{4} \quad (26)$$

IX. The Frequency Responses of The Novel Ultra Broad-BandExponential Taper 8-Port network (Figure 1)

Fig. 6 shows the frequency responses of the scattering matrix parameters of the Ultra Broad-Bandexponential taper 8-port network. By taking -20 dB as reference for both the return losses and the isolations among the ports, While taking 0.125dB as reference for the insertion loss. This shows the frequency response indicated that the proposed network provides the optimized proposed network enjoyanultra-broad-band operation capabilityand good performance.

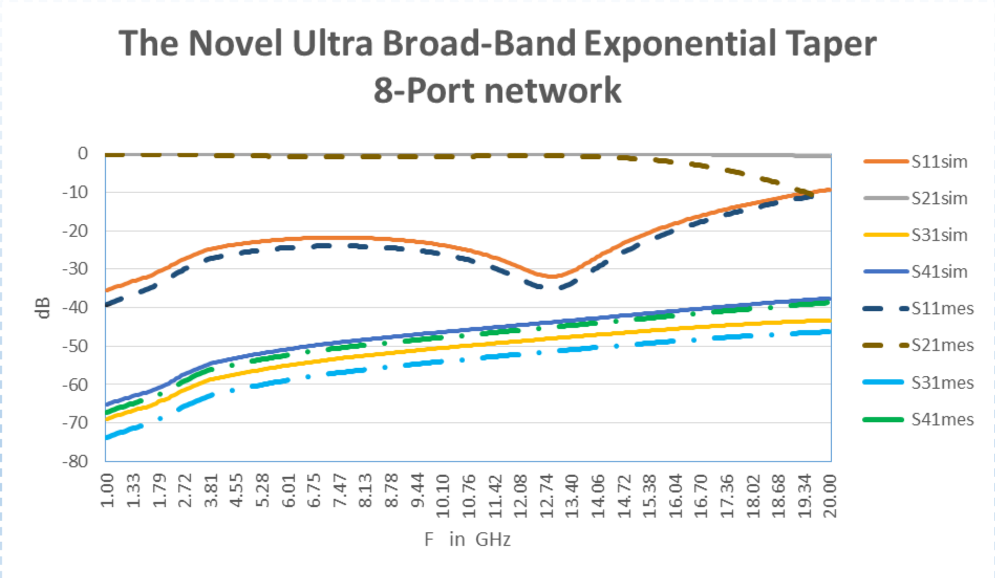

Figure 6a. The frequency responses of the Novel Ultra Broad-Band Exponential Taper 8-Port network

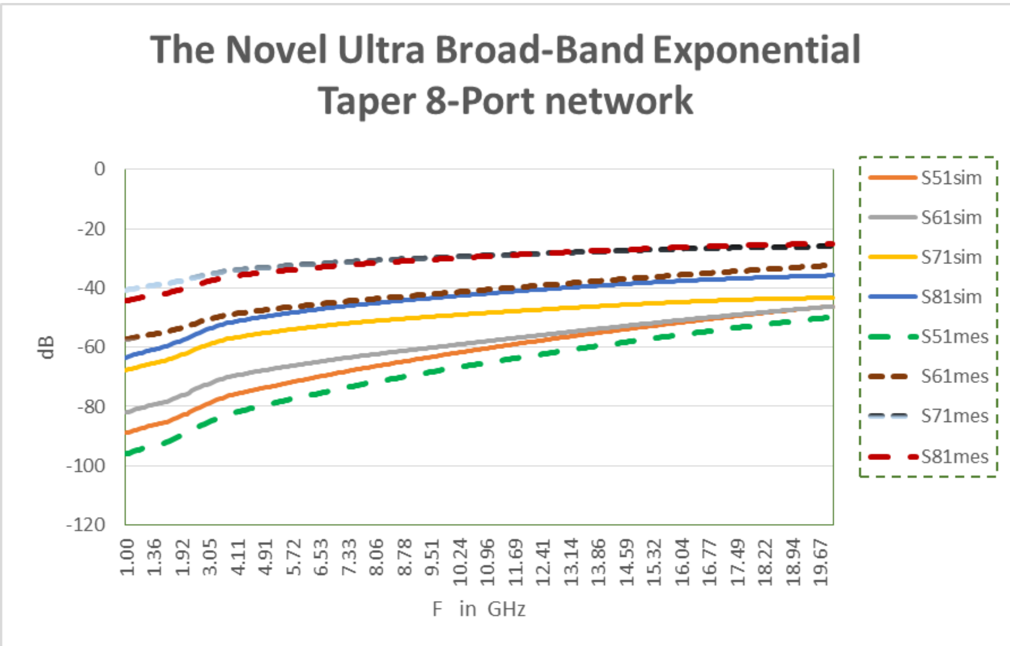

Figure 6b. The frequency responses of the Novel Ultra Broad-Band Exponential Taper 8-Port network

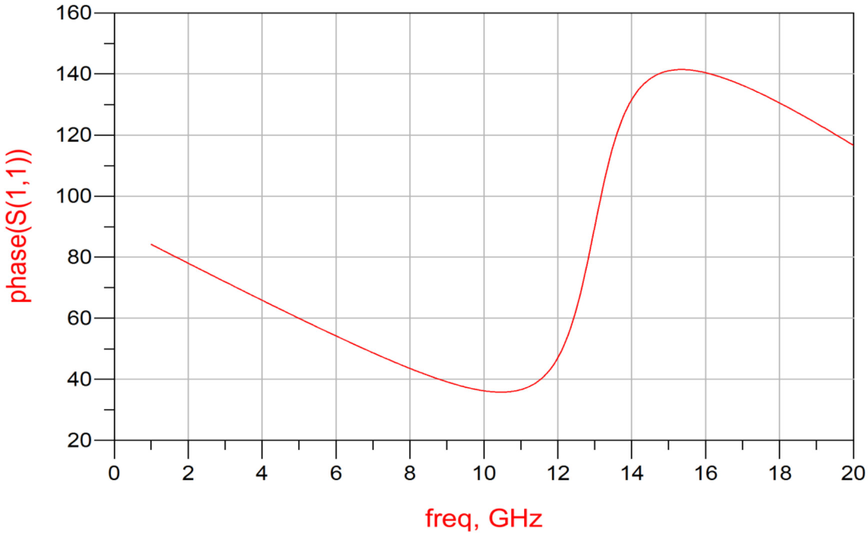

Figure 6c. The frequency responses of the Novel Ultra Broad-Band Exponential Taper 8-Port network in phase

X. Conclusion

The developed 8-port exponential network provides both ultra-broad-band operation and high performance. There is agreement between the simulation and measurement performances of these developed exponential 8-port network. This developed 8-port exponential network can find several applications in both microwave and millimeter wave field.

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