3-dB Quadrature (90°) Hybrid Coupler-Design, Fabrication and Measurement

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Abstract- **Micro-strip 3-db Quadrature Hybrid coupler was fabricated that operates at a frequency of 1.63 GHz. This report briefly describes the working of the 3-dB hybrid coupler, the design and simulation of the coupler in CST followed by the comparison of measured results and simulated results.**

THEORY

Hybrid Coupler is a type of directional coupler where power is to be equally divided between the coupled and through port at the operating frequency. There are two types of Hybrid couplers, 90 degree and 180 degree coupler [1], angle signifying phase difference between coupled and through port. 90 degree quadrature hybrid coupler has been implemented in this project. Quadrature coupler is a symmetric passive device that provides a phase difference of 90 degrees between the coupled and through port. The fields travel in quasi TE-TM mode on the micro-strip line [3]. The scattering matrix of quadrature coupler has been presented in the Figure.1.

$$[S] = \frac{-1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}$$

Figure.1 Scattering matrix

The scattering matrix can be derived by use of odd mode, even mode analysis [2] [3]. Figure.2 [4] shows the hybrid coupler. This design has been used to implement the micro-strip quadrature hybrid coupler (Zo=50Ω).

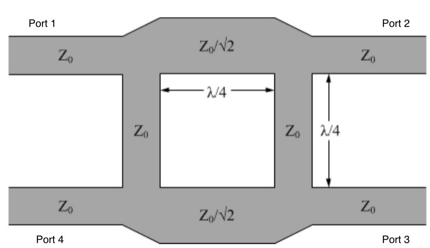

Figure.2 Hybrid Coupler

Quadrature hybrid coupler can be used as a power divider, phase shifter, in signal samplers[5], power summer[6] and a variable attenuator (with the use of PIN diodes) [7].

DESIGN AND SIMULATION

Coupler was designed in CST STUDIO SUITE. The width and quarter wavelengths of the micro-strip traces were calculated using the 'Impedance Calculation' and 'Calculate Wavelength' under 'Macros' for 1.8GHz. Figure.2 and Figure.3 [8] were used for reference to calculate lengths and widths of traces. 'Rogers RO4533(lossy)' PCB was used as the substrate.

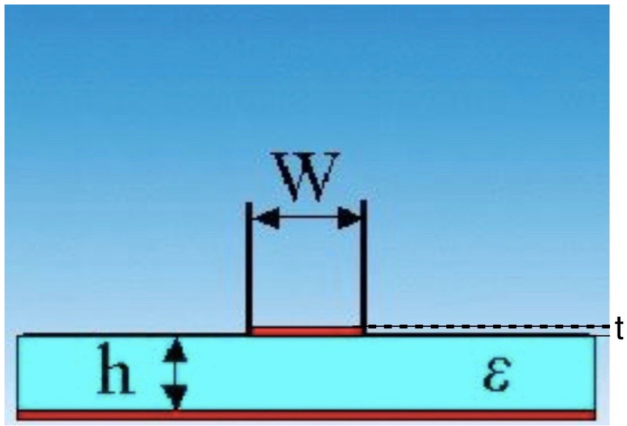

Figure.3 Cross-section view of trace

The parameters that were used in the design are summarized in the table.1 below.

Parameters	Value
Dielectric Constant (ε)	3.3
Substrate thickness (h)	1.524 mm
Trace thickness (t)	0.0347mm
Length of 50Ω quarter wavelength line	25.78mm
Length of 35.36Ω quarter wavelength line	25.22mm
Width of 50Ω quarter wavelength line	3.62mm
Width of 35.3Ω quarter wavelength line	6.02mm

Table.1 List of Parameters used for design

The following graphs (Figures.4.1-4.8) describe the result of CST simulations, both phase and magnitude have been presented. The operating frequency has shifted to 1.65 GHz approximately (device was designed to operate at 1.8GHz) and the desired phase difference between through and coupled ports was obtained at the shifted frequency.

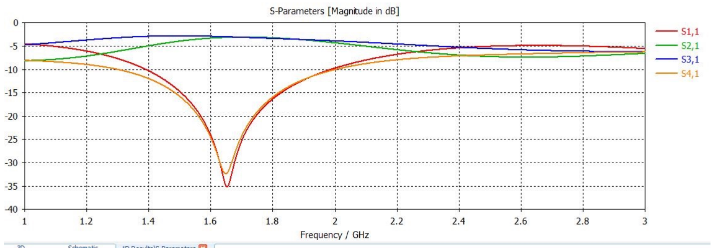

Figure.4.1 S-parameters for Input at Port 1

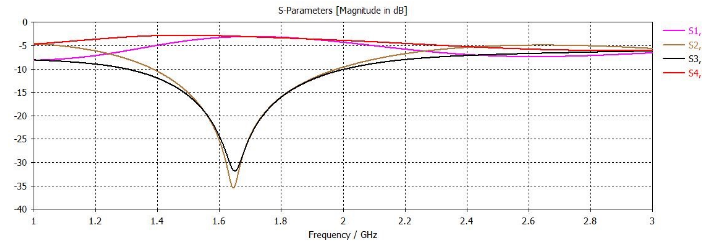

Figure.4.2 S-parameters for Input at Port 2

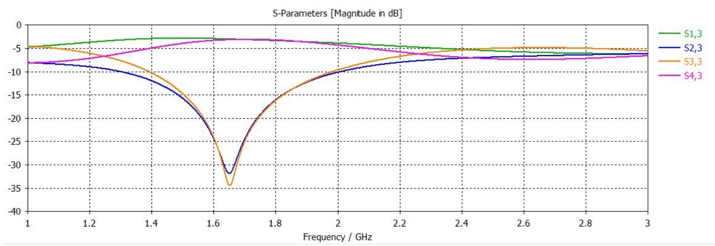

Figure.4.3 S-parameters for Input at Port 3

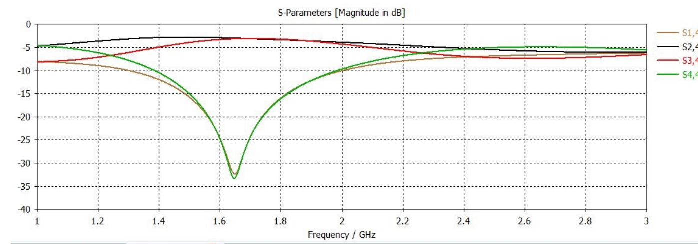

Figure.4.4 S-parameters for Input at Port 4

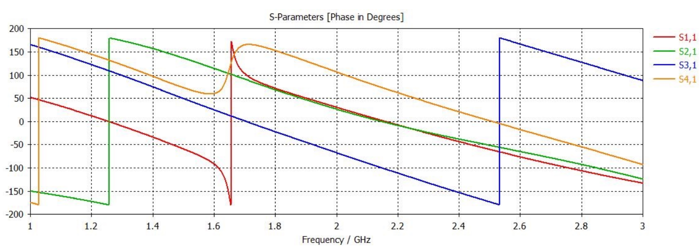

Figure.4.5 S-parameters (phase) for Input at Port 1

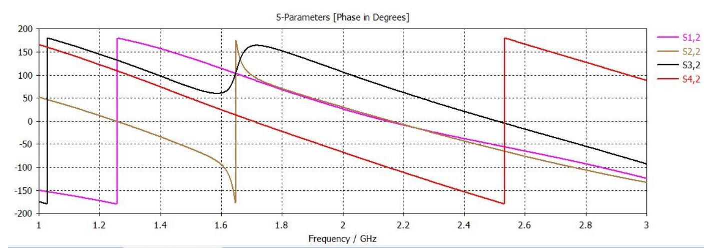

Figure.4.6 S-parameters (phase) for Input at Port 2

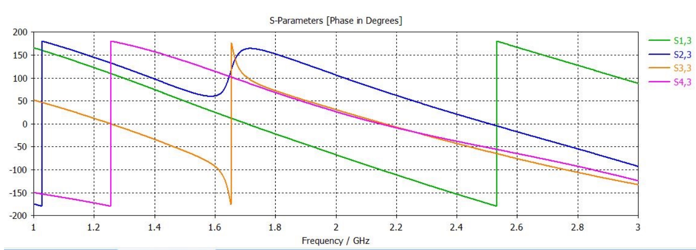

Figure.4.7 S-parameters (phase) for Input at Port 3

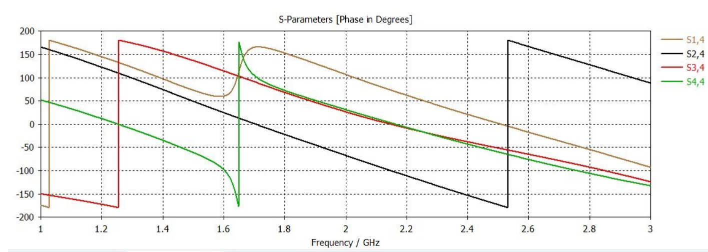

Figure.4.8 S-parameters (phase) for Input at Port 4

FABRICATION

The simulated design was transferred onto the PCB with the help of a PCB transfer film. Placing the PCB in etchant solution the desired trace was obtained. Connectors (50Ω) were soldered onto the PCB. Photograph of the coupler is in Figure.5.

RESULTS

The S-parameters, both magnitude and phase were measured with the help of VNA. The results were plotted in MATLAB and compared with the simulated S-parameters.

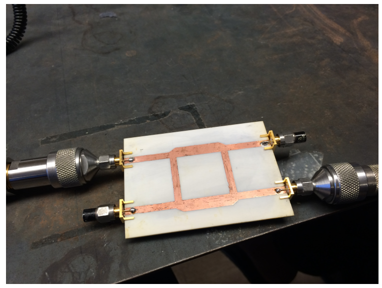

Figure.5 Photograph of Hybrid Coupler

OBSERVATIONS

The measured S-parameters were roughly the same as the results of CST simulation. Figures. 5.1-5.4 show the measured S-parameters (magnitude) plotted against the CST simulations. Figures.5.5-5.8 show the phase of measured s-parameters.

The following observations were made from the measured s-parameters:

- The bandwidth of coupler is about 17% (1.66-1.95GHz) for a phase error of +/- 10 degrees.
- Maximum coupling (~ -3.5dB) and isolation (≤ -30dB) occurred at frequencies between 1.62GHz and 1.63GHz resulting in a shift of about 0.02GHz from the simulated design.
- At the second harmonic nearly all the power is coupled to the coupled port. (port 3 for an input at port 1).

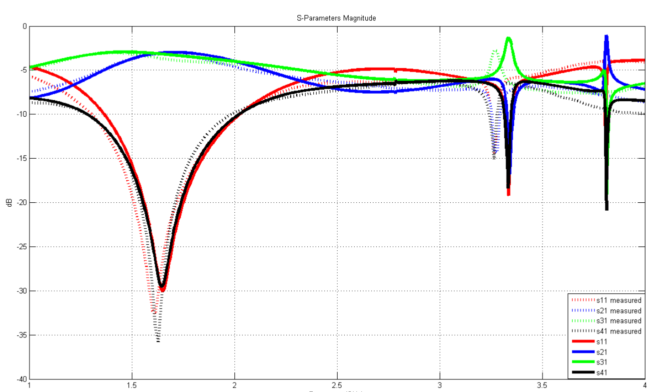

Figure.5.1 Measured vs simulated S-parameters for Input at Port 1

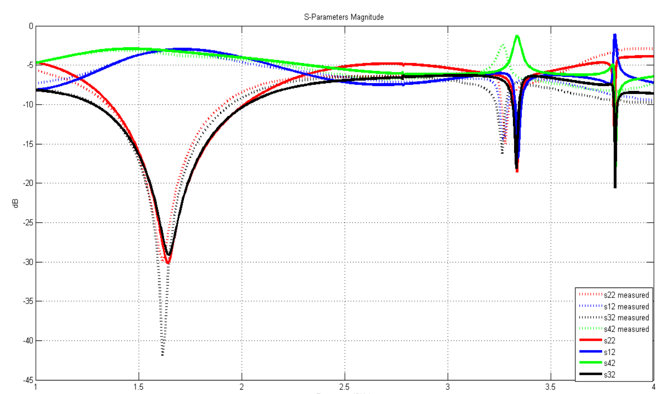

Figure.5.2 Measured vs simulated S-parameters for Input at Port 2

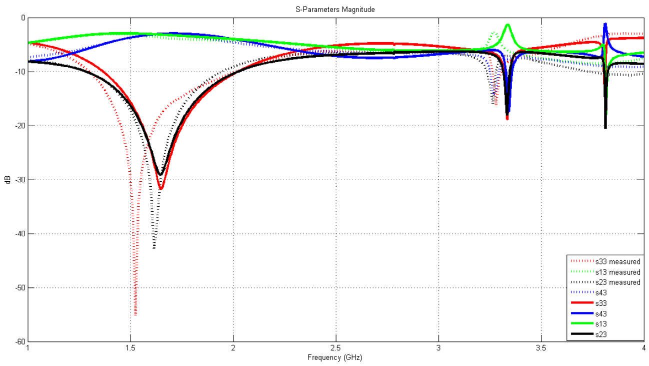

Figure.5.3 Measured vs simulated S-parameters for Input at Port 3

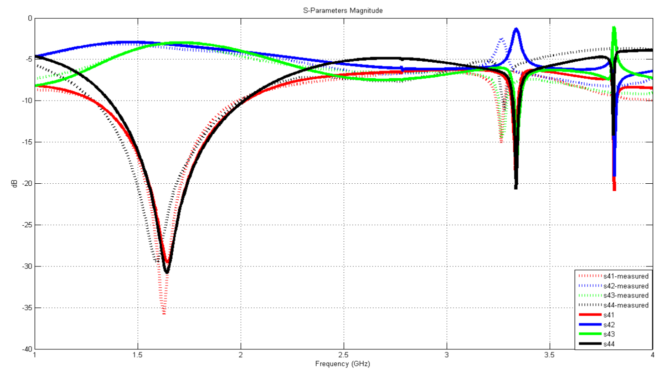

Figure.5.4 Measured vs simulated S-parameters for Input at Port 4

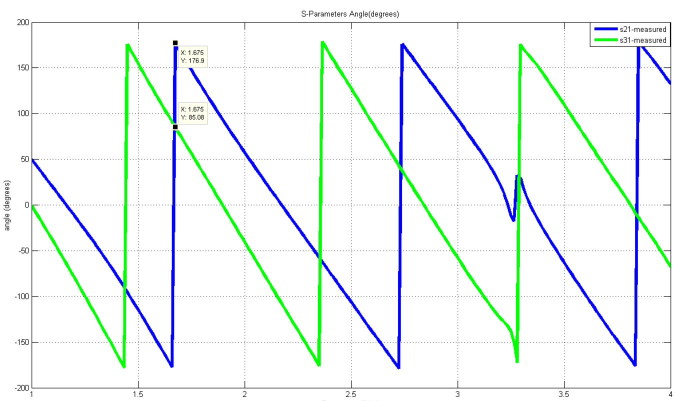

Figure.5.5 Measured phase of s21 and s31

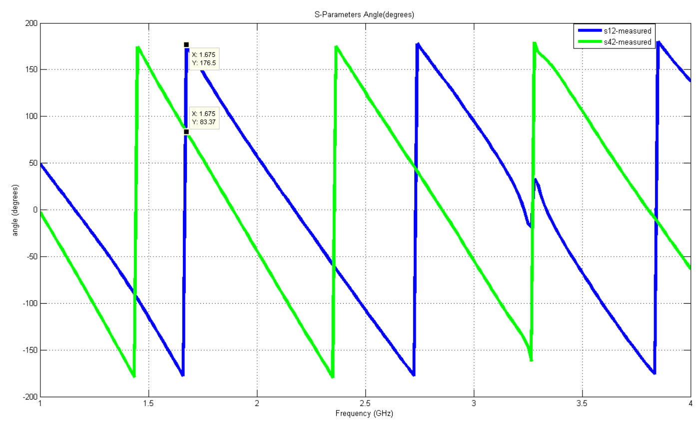

Figure.5.6 Measured phase of s12 and s13

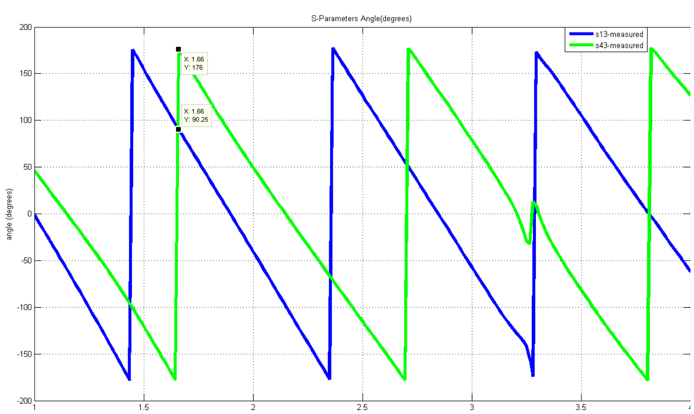

Figure.5.7 Measured phase of s13 and s43

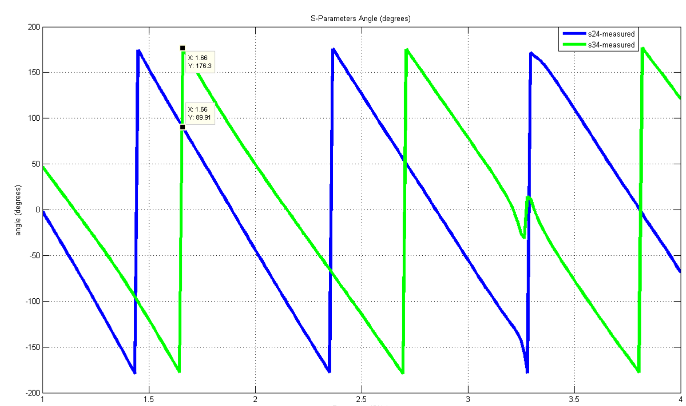

Figure.5.8 Measured phase of s24 and s34

Difference between the measured and simulated parameters could be caused by the defects of the fabricated device and the environment in which the measurements were made. The trace was found to non-uniform in certain regions and the presence of floating metallic objects could have also contributed to this difference in measured s-parameters.

REFERENCES

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[2] J.Reed and J. Wheeler, “A method of Analysis of Symmetrical Four-Port Networks”, Microwave Theory and Techniques, IRE Transactions on (Volume:4, Issue:4), Oct 1956, pp-246-252.
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