Design and Analysis of Two Port Matching Networks by Single Stub Transmission Lines Using RF Toolbox

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Abstract- Designing input and output matching networks is an important part of RF amplifier design. Reflection factors and the placement of a shunt stub in each matching network at a specified frequency place an the important role for designing the matching network .In this paper the author discuss about the procedure for designing the matching network under various RF frequencies and also analyse the performance like reflection coefficient, s-parameters and the stability Factor using RFTOOL box.

I. INTRODUCTION

A radio frequency amplifier, or RF amplifier, is a tunedamplifier that amplifies high-frequency signals used in radio communications. The frequency at which maximum gain occurs in an RF amplifier is made variable by changing the inductance or capacitance of the tuned circuit.

1.1 Stub matching

In microwave and radio-frequency engineering, a stub or resonant stub is a length of transmission line or waveguide that is connected at one end only. Stubs are used in antenna impedance matching circuits, frequency selective filters, and resonant circuits for UHF electronic oscillators and RF amplifiers. Comprising of one or two stubs are in common use , hence it maybe of two types , namely single stub and double stub . A section of a two wire transmission line of small length l connected in parallel to the line to be matched at a distance 'd' from the load as shown is known as a single stub. The load impedance is changed, one simply has to replace the stubs with another set of different length. The drawback of double stub tuning is that a certain range of load admittances cannot be matched, once the stub locations are fixed. Three stubs are necessary to guarantee that match is always is known as double matching.

1.2 Problem :

Designing of matching network by single stub transmission line is very much needed in all wireless devices.

It is critical , since the location of the stubs with reference to the amplifier interfaces is so challenging task.

1.3 Solution :

In this paper , we are going to discuss about the design procedure of two port matching networks by single stub transmission lines using RF tool box of MATLAB .

1.4 MATLAB RFtoolbox

RF Toolbox provides functions, objects and apps for designing, modelling, analyzing, and visualizing networks of radio frequency (RF) components, and also using RF Toolbox for wireless communications, radar, etc,. With RF Toolbox we can build networks of RF components such as filters, transmission lines, amplifiers, and mixers. Components can be specified using measurement data, network parameters, or physical properties. And also calculate S-parameters, convert among S, Y, Z, ABCD, h, g, and T network parameters, and visualize RF data using rectangular and polar plots and SmithCharts. RF Toolbox provides functions to manipulate and automate RF measurement data analysis, including de-embedding, enforcing passivity, and computing group delay. MATLABand Simulink provide the required tools for supporting all the RF system design tasks, from system exploration to algorithm development and lab prototyping. Modelling and simulating RF, Analog and digital systems together enables faster development and easier debugging.

II. DESIGN ASPECTS

2.1 Design :
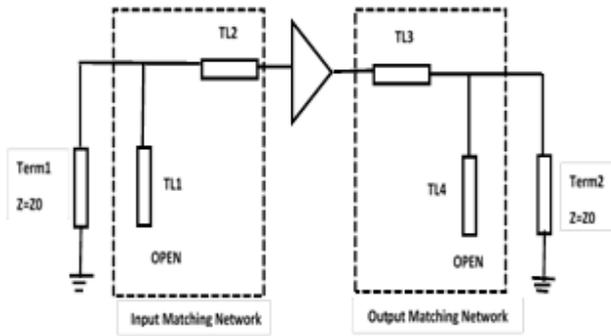
The proposed design model is shown in Fig:1

Fig:1. Design of proposed Model

In this design, the input and output matching networks by transforming the reflection coefficients for simultaneous conjugate match at the amplifier interfaces into the appropriate source and load admittance.

2.2 Flow diagram for the proposed design:

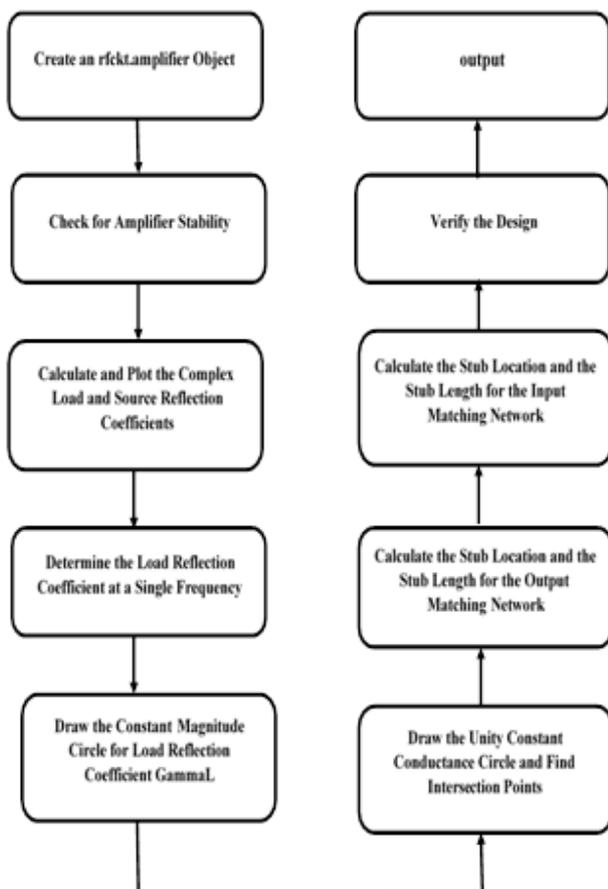The flow diagram of proposed design is shown in Fig: 2

Fig: 2. Flow diagram of proposed design

2.3 Design procedure:

Here for example , we are going to design the matching network for the frequency 1.9 GHz .

Step:1 Check for Amplifier Stability

Before proceeding with the design, determine the measured frequencies at which the amplifier is unconditionally stable. Use the stability must ability mu function to calculate mu and mu prime at each frequency. Then, check that the returned values for mu are greater than one. This criteria is a necessary and sufficient condition for unconditional stability. If the amplifier is not unconditionally stable, print out the corresponding frequency value (Fig : 3).
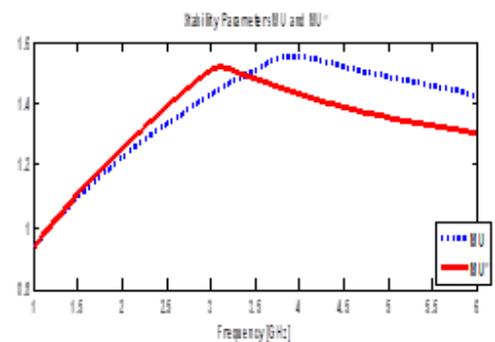

Fig 3 : Stability parameter mu and mu prime

After executing the program , from the above Fig : 3 , the Stability parameter mu and mu prime. As per the criteria , in between the Frequency = 1.0e+09 to 1.1e+09, the amplifier is not unconditionally stable.

Step2: Calculate and Plot the Complex Load and Source Reflection Co-efficient

Calculate and plot all complex load and source reflection coefficients for simultaneous conjugate match at all measured frequency data points that are unconditionally stable. These reflection coefficients are measured at the amplifier interfaces. This is shown in Fig :4
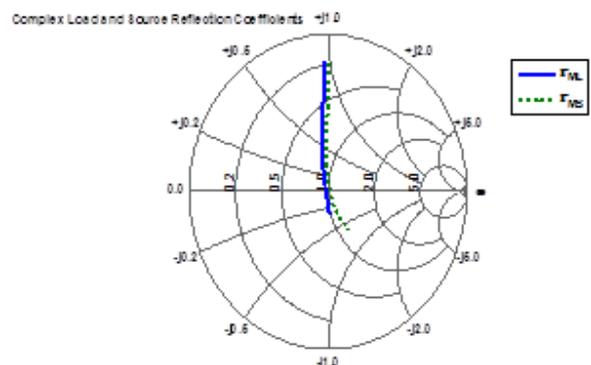
Fig 4 : Complex Load and   Source Reflection Co-efficient

Step:3 Determine the Load Reflection Coefficient   at a Single Frequency

Find the load reflection coefficient, Gamma L, for the output matching network at the design frequency 1.9 GHz. This is shown in Fig:5
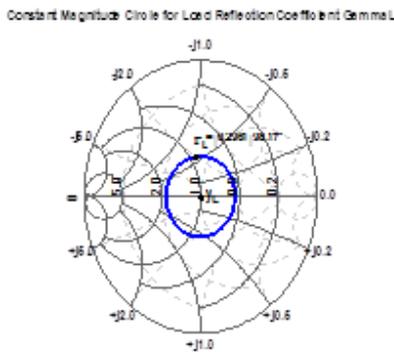

Fig:5 Load Reflection Coefficient at a Single Frequency (1.9 GHz)

Step:4 Draw the Constant Magnitude Circle for Load Reflection Coefficient GammaL . This is shown in Fig:6

Draw a circle that is centred at the normalized admittance Smith chart origin and whose radius equals the magnitude of Gamma L. A point on this circle represents the reflection coefficient at a particular location on the transmission line. The reflection coefficient for the transmission line at the amplifier interface is Gamma L, while the centre of the chart represents the normalized load admittance, y_L. The example uses the circle method to draw all appropriate circles on a Smith chart. Using analytical equations for this circuit we get:

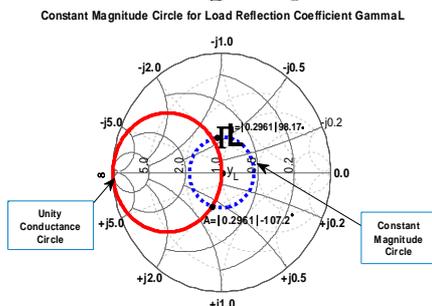$$t = \frac{X_L + - \sqrt{R_L[(Z_0 - R_L)^2 + X_L^2]/Z_0}}{R_L - Z_0}$$

Fig:6 Constant Magnitude Circle for Load Reflection Coefficient GammaL

Step:5 Draw the Unity Constant Conductance Circle and Find Intersection Points

To determine the stub wavelength (susceptance) and its location with respect to the amplifier load matching interface, plot the normalized unity conductance circle and the constant magnitude circle and figure out where the two circles intersect. Find the points of intersection interactively using the data cursor or analytically using the helper function, 'find_circle_intersections_helper'. This example uses the helper function. The circles intersect at two points. The example uses the third-quadrant point, which is labelled "A". The unity conductance circle is centred at (-.5,0) with radius .5. The constant magnitude circle is centred at (0,0) with radius equal to the magnitude of Gamma L. This is shown in Fig :6

Step:6 Calculate the Stub Location and the Stub Length for the Output Matching Network

The open-circuit stub location in wavelengths from the amplifier load interface is a function of the clockwise angular difference between point "A" and Gamma L. When point "A" appears in the third quadrant and Gamma L falls in the second quadrant. This is shown in Fig :6

Step: 7 Calculate the Stub Location and the Stub Length for the Input Matching Network

Calculated the required lengths and placements, in wavelengths, for the output matching transmission network. Following the same approach, the line lengths for the input matching network are calculated. This is shown in Fig : 7, Fig : 8 and Fig : 9
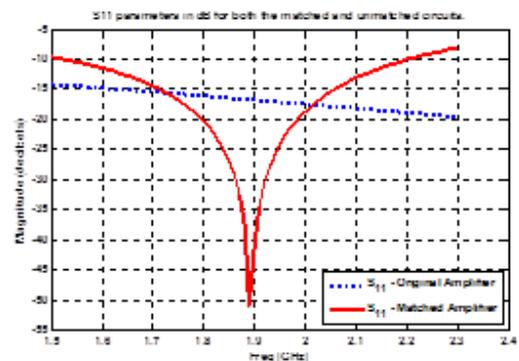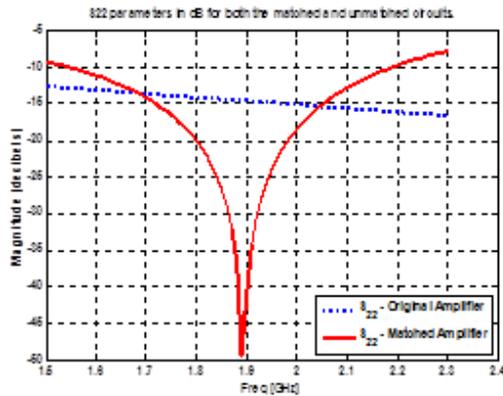

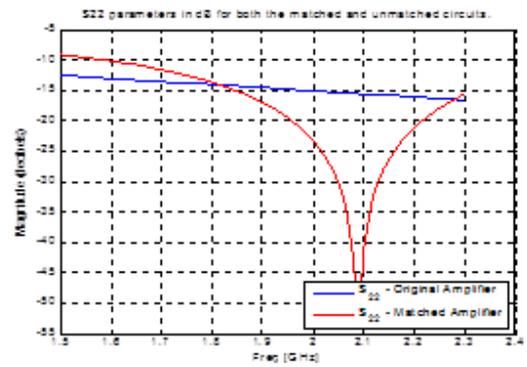Fig :7   S11 parameters at 1.9 GHz

Fig :8   S22   parameters at 1.9 GHz

Step:8 Verify the Design

To verify the design, assemble a circuit using 50-Ohm micro strip transmission lines for the matching networks. First, determine if the micro strip line is a suitable choice by analyzing the default micro strip transmission line at a design frequency of 1.9 GHz. This is shown in Fig : 9
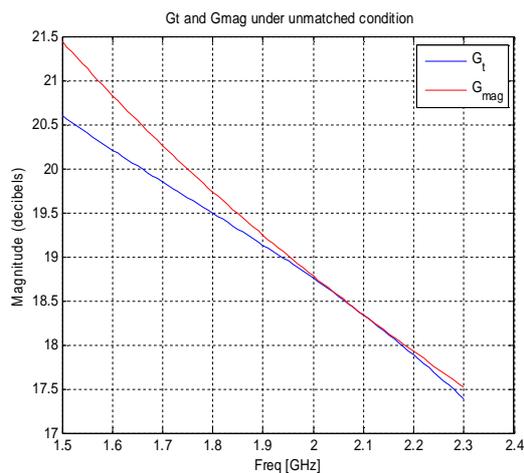

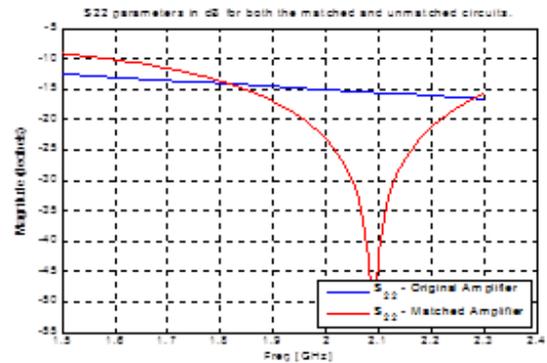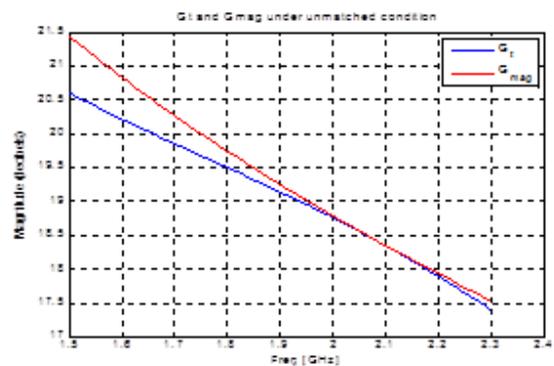Fig : 9 Gt & Gmag are matched at 1.9 GHz.

III. RESULT AND DISCUSSION

For practical verification , the same above procedure is repeated in the designed matching network for different frequencies like 2.1 GHz, 3 GHz, 4 GHz, and 5 GHz, and the results are verified and tabulated in Table :1

For the frequency 2.1   GHz, the S11 and S22 parameters under matching and un-matching conditions are shown in Fig : 10 & Fig : 11. Similarly the Fig 12. Shows that the Gt and Gmag are matched at 2.1 GHz.

Fig : 10   S11 parameters at 2.1 GHz

Fig : 11   S22 parameters at 2.1 GHz

Fig : 12   Gt & Gmag are matched at 2.1 GHz

For the frequency 3   GHz, the S11 and S22 parameters under matching and un-matching conditions are shown in Fig : 13 & Fig : 14. Similarly the Fig 15. Shows that the Gt and Gmag are matched at 3 GHz.
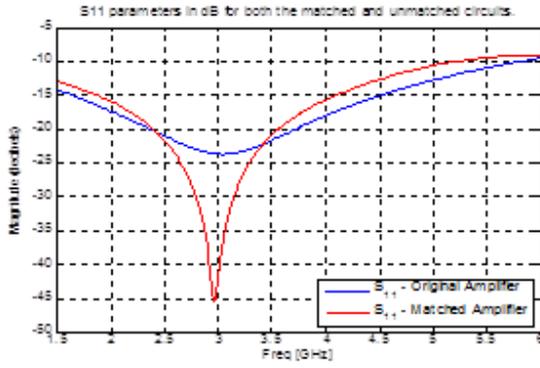
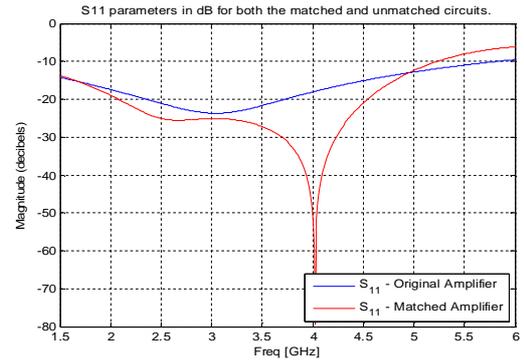Fig : 13   S11 parameters at 3 GHz

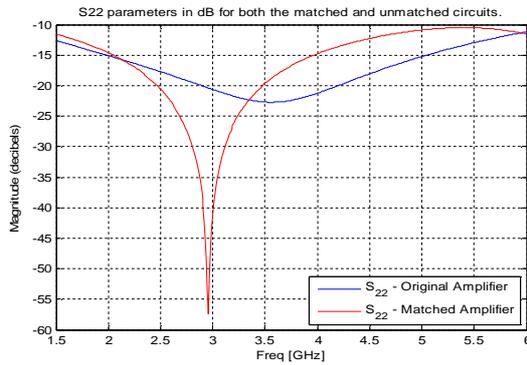Fig : 16   S11 parameters at 4 GHz

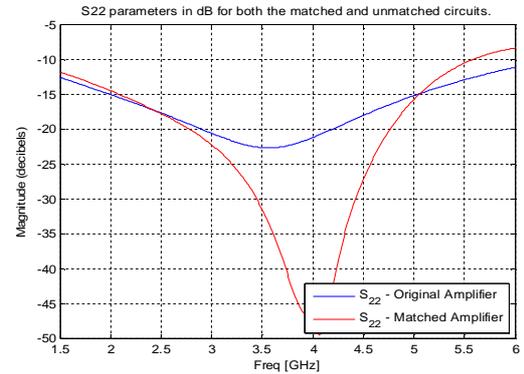Fig : 14   S11 parameters at 3 GHz
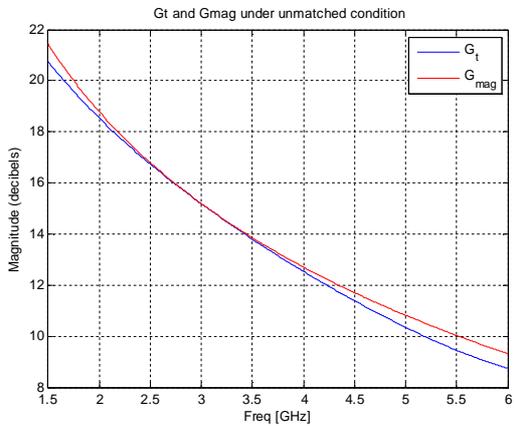

Fig : 17   S11 parameters at 4 GHz

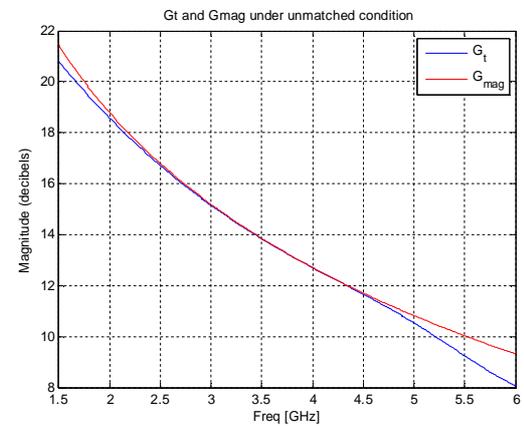Fig : 15   Gt & Gmag are matched at 3 GHz

Fig : 18   Gt & Gmag are matched at 4 GHz

For the frequency 4   GHz, the S11 and S22 parameters under matching and un-matching conditions are shown in Fig : 16 & Fig : 17. Similarly the Fig 18. Shows that the Gt and Gmag are matched at 4 GHz.

For the frequency 5   GHz, the S11 and S22 parameters under matching and un-matching conditions are shown in Fig : 19 & Fig : 20. Similarly the Fig 21. Shows that the Gt and Gmag are matched at 5 GHz.
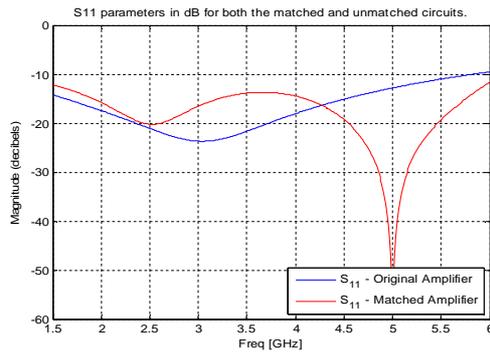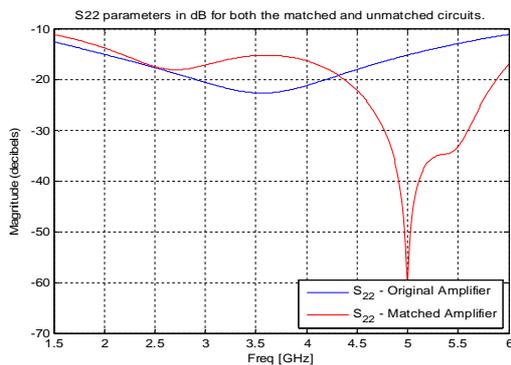
Fig : 19 S11 parameters at 5 GHz
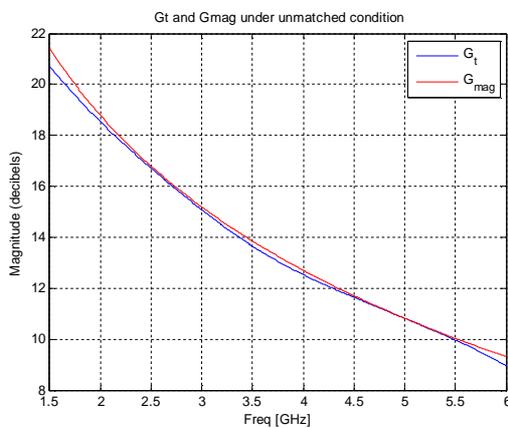

Fig : 20 S11 parameters at 5 GHz

Fig : 21 Gt & Gmag are matched at 5 GHz

Table: 1 Location of the stubs and the stub length

Unmatched condition	Matched Freq(GHz)	StubPosition		Gamma		Stub Length		Z0
		In	Out	S	L	Out	In	
Frequency = 1.0e+09 - 1.1e+09	1.9	0.2267	0.2147	-0.0099 + 0.2501i	-0.0421 + .2931i	0.0883	0.0759	50.2561
	2.1	0.2314	0.2171	-0.0081 + 0.1899i	-0.0408 +0.2380i	0.0735	0.0588	50.2780
	3	0.3141	0.2177	0.0132 + 0.0122i	-0.0277 + 0.0843i	0.0281	0.0057	50.3894
	4	0.4548	0.5611	0.0513 - 0.1065i	-0.0128 - 0.0127i	0.0057	0.0372	50.5342
	5	0.4448	0.4943	0.0974 - 0.1860i	-0.0009 - 0.0827i	0.0262	0.0646	50.6969

IV. CONCLUSION

In this paper the author discussed about the procedure for designing the matching network under various RF frequencies and also analysed the performance like reflection coefficient, s-parameters and the stability Factor using RFtoolbox. Designing input and output matching networks is an important part of RF amplifier design. Here we can analyzed the Reflection factors and the placement of a shunt stub in each matching network at a specified frequency . The Matlab RFtoolbox is an efficient tool for effective designing and analyzing the matching network. In the future work the author introduces the designing procedure for double stub matching network .

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