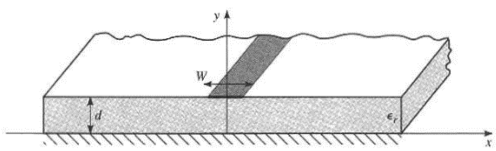
ELCT 564: RF Circuit design for Wireless Application

***Abstract*—In this report we investigate two problems in RF circuit literature using Advanced Design System (ADS) and giving optimized solutions with theoretical calculations. Then we check feasibility of these solutions and conclude at the end. During all parts we assume circuits fabricated using FR-4 Copper clad PC board, εr=4.7, tanδ=0.02, h=711.2 µm and t=25.4 µm.**

Problem 1

1. Find Normalized impedance: $\tilde{Z} = \frac{150}{50} = 3;$
2. Find location in smith chart and move $\frac{\lambda}{4}$ *toward generator*
3. $\lambda = \frac{c}{f} = \frac{3\times10^8}{5.8\times10^9} = 5.17cm$
   $l = \frac{\lambda}{4} = 1.2931cm$
4. Now we calculate w theoretically:



$$A = \frac{Z_0}{60}\sqrt{\frac{\epsilon_r + 1}{2}} + \frac{\epsilon_r - 1}{\epsilon_r + 1}\left(0.23 + \frac{0.11}{\epsilon_r}\right)$$

After calculations: A = 1.571

$$B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}}$$

And B =5.463. Now we can find $\frac{w}{d}$

$$\frac{W}{d} = \begin{cases} \frac{8e^A}{e^{2A}-2} & \text{for } W/d < 2 \\ \frac{2}{\pi}\left[B - 1 - \ln(2B-1) + \frac{\epsilon_r - 1}{2\epsilon_r}\left\{\ln(B-1) + 0.39 - \frac{0.61}{\epsilon_r}\right\}\right] & \text{for } W/d > 2 \end{cases}$$

Since project mentioned $\frac{w}{d} < 10$ we will consider first equation therefore, $\frac{w}{d} = 1.8199$ ➔ $w = d(or\ h) \times 1.8199 = 711.2um \times 1.8199 = 1.294mm$

Now we check this result with ADS:

In ADS software we have a useful tool so called "LineCalc" we will run this to find $Z_0 = 50\ ohm\ and\ l = \frac{\lambda}{4} = 1.2931cm$

As it is obvious in the Fig.1:

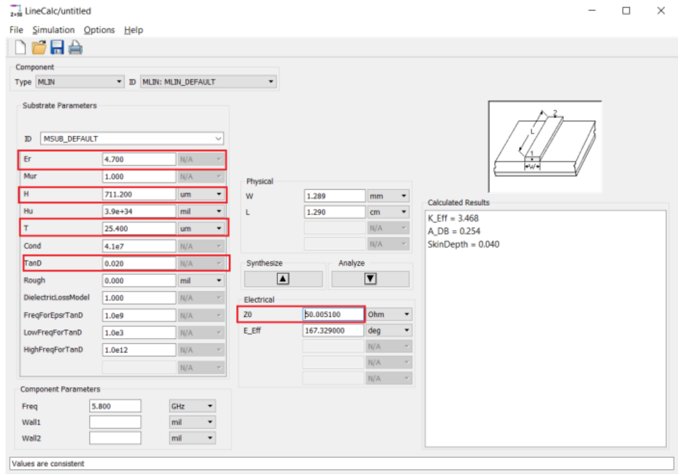


Fig.1 Line calculation in ADS

Corresponding W is 1.289mm which is very close to theoretical calculation came with 1.29mm. All requirements defined by project is satisfied with this number. [W/h<10] The corresponding designed schematic showed in Fig.2:

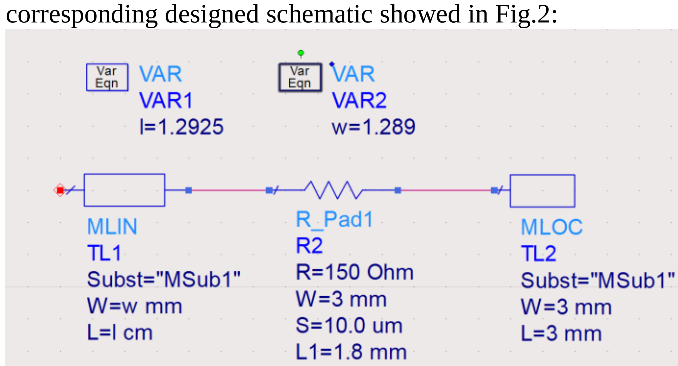


Fig.2 Proposed schematic in ADS

By clicking on generate/update layout we can get Fig.3.

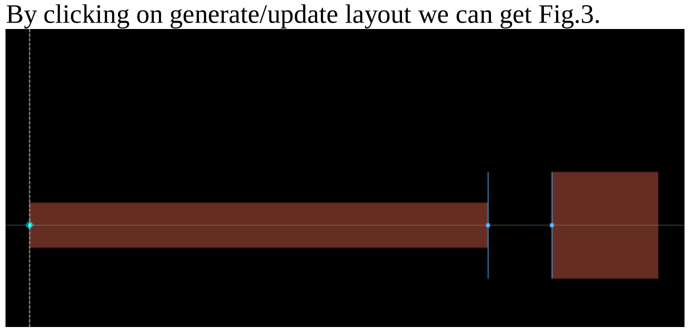


Fig.3 Proposed Layout in ADS

For better insight to layout we plotted it in 3D mode in Fig.4:

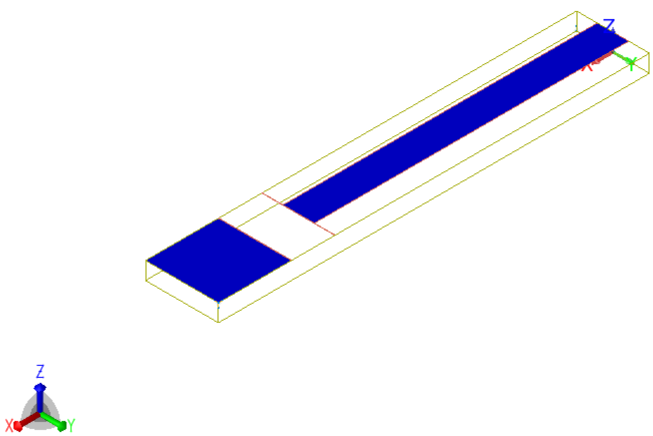


Fig.4 Proposed Layout in 3D mode

Problem2

Normalized impedance: $\tilde{Z}_L = \frac{150+j150\Omega}{50} = 3 + 3j\Omega$ With corresponding $\tilde{Y}_L = \frac{1}{\tilde{Z}_L} = 0.33 + 0.33j\Omega$

First we assume a predefined length for closest stub to the load and find equivalent inductance and then solve two stub problem to find other stub lengths(l) and check if we satisfy requirements. At the end, this theoretical point will be our start point for optimization in ADS, we will check results with ADS software to optimize lengths for the best matching point.

First attempt: stub with length: $l = \frac{\lambda}{8} = \frac{c}{f\times 8} = \frac{3\times10^8}{20\times10^9 * 8} = 1.875mm$ and open stub.

We rotate from open left side of smith chart for $\frac{\lambda}{8}$ and find the point in 1+jb circle and find Y_1 and then rotate $d = \frac{\lambda}{8}$ to the load to find Y_L as plotted in the Fig.5 and 6.

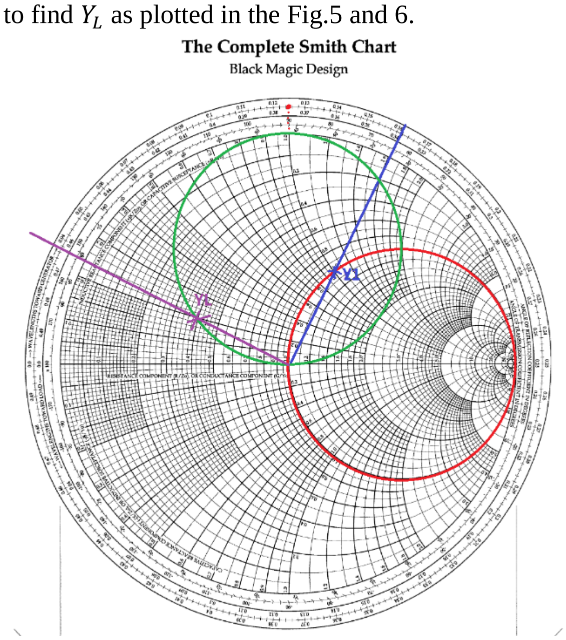


Fig.5 Smith chart for finding stub lengths

Next step is to find lengths for two other stubs, therefore, after findingY_L, we plot rotated 1+jb $(\frac{\lambda}{8})$, find Y_1 and Y_2 and rotate $d = \frac{\lambda}{8}$ toward generator and then incident it to original 1+jb circle and find distance to left side of smith chart for open stub and right for short stub and determine b values. For calculate final length we can use this formula:

$$l = \frac{\lambda}{2\pi}\tan^{-1} b$$

As we can see in the following plot b values are:

b1 = 0.335 → l_1 =0.507 $\lambda = 0.507 \times \frac{c}{f} = 0.507 * 0.015 = 7.6mm$

b2 = 0.2 → l_2 =0.310 $\lambda = 0.310 \times \frac{c}{f} = 0.310 * 0.015 = 4.65mm$

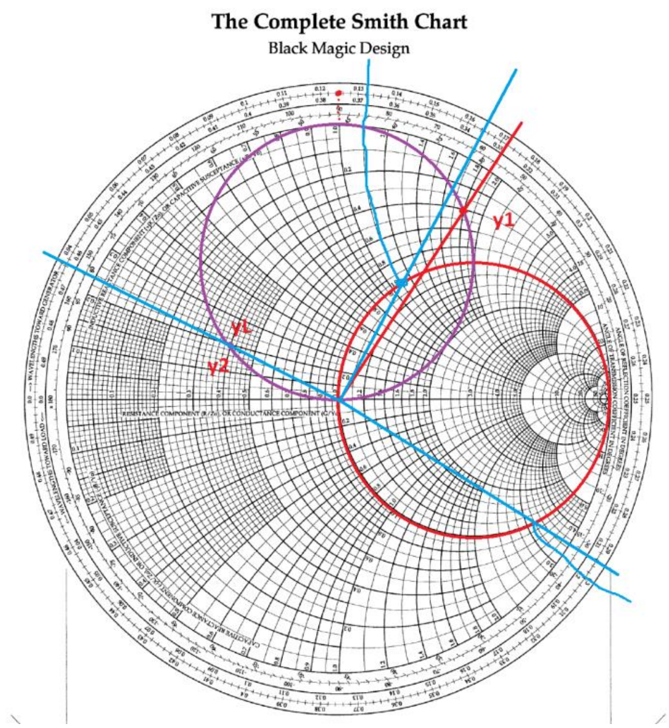


Fig.6 Smith chart for finding stub lengths

Now we with this configuration we will implement this in ADS, as we can see we have to start linecalc tool again to find value of "w". in this frequency will be 1.401 mm. as depicted in Fig.7:

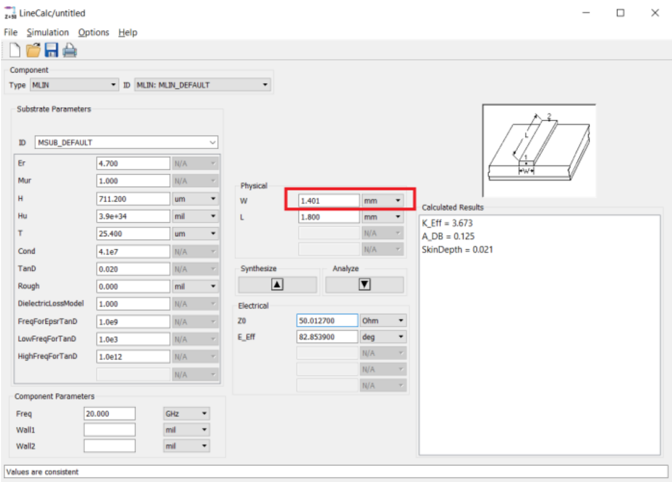


Fig.7 Find width value of micro strip line

At this step we implement schematics for the proposed layout and see S analysis as depicted in Fig.8.

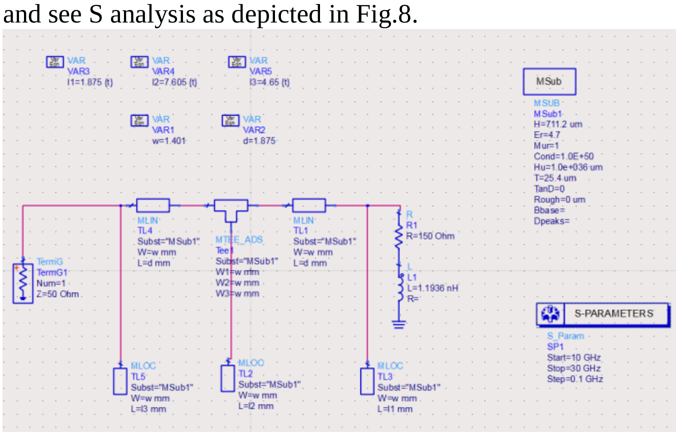


Fig.8 Overall schematic of proposed layout

Fig.9 shows S analysis of our starting point, with predefined length for stub 1:

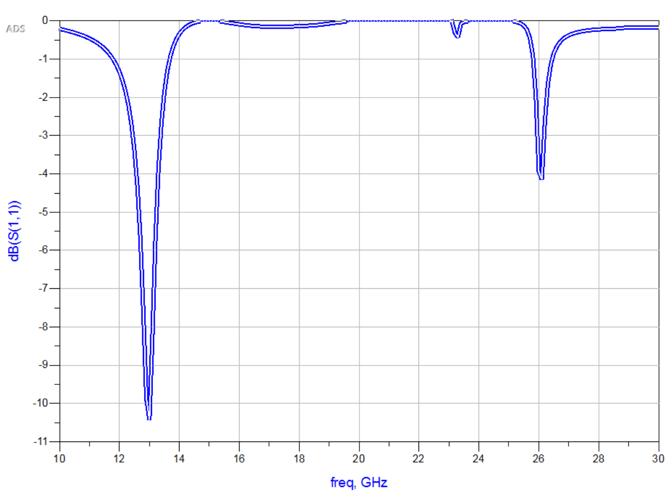


Fig.9 S analysis of initial starting point

As Fig.9 depicted, pre assumed length for stub 1 is not optimized for matching goal, therefore, we have to perform optimization step in order to find the best values for three stub length. We use “Tuning” tool to optimize our design in ADS.

After moving around different lengths showed in Fig.10, we found the following lengths for best performance:

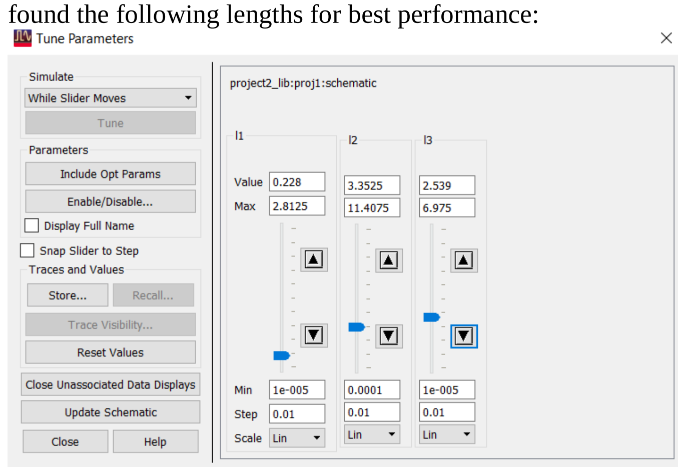


Fig.10 Tuning stub lengths to achieve desired performance

With these lengths we can see the performance of Fig.11 and 12. As it is obvious in plot S(1,1) in our working frequency of 20 GHz is around -45dB.

$$l_1 = 0.228mm$$
$$l_2 = 3.3525mm$$
$$l_3 = 2.539\ mm$$

And corresponding results will be:

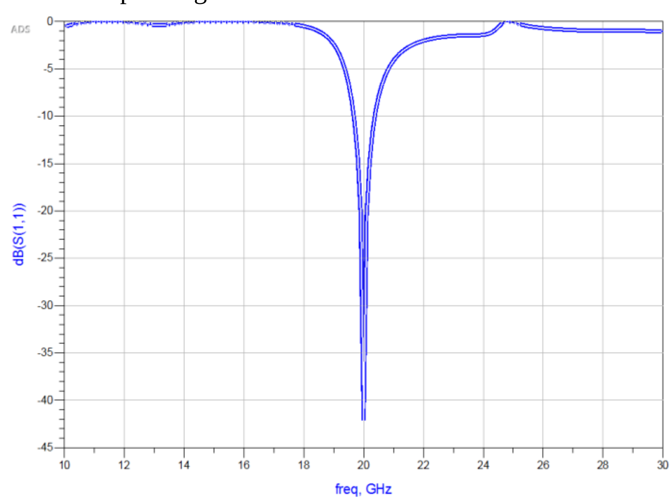


Fig.11 S analysis of tuned lengths

With smith chart as:

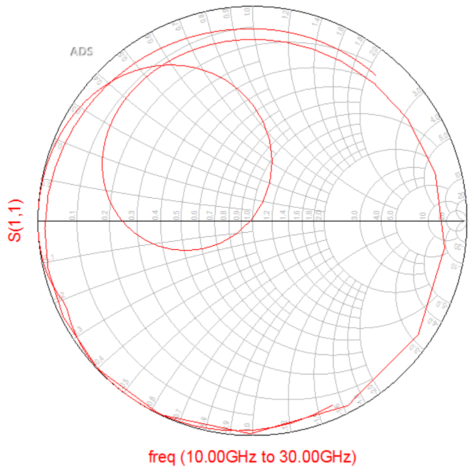


Fig.12 Smith chart of tuned lengths

If we repeat same procedure for radial stubs in Fig.13

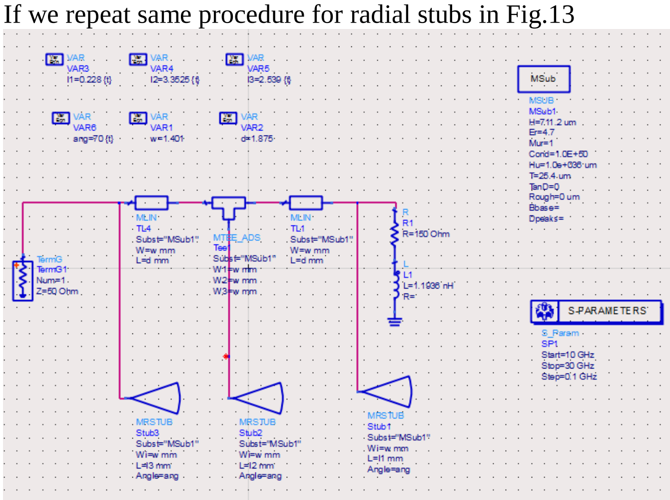


Fig.13 Overall schematic for radial stubs

We start optimizing again this time with additional variable which is angle of stub in Fig.14:

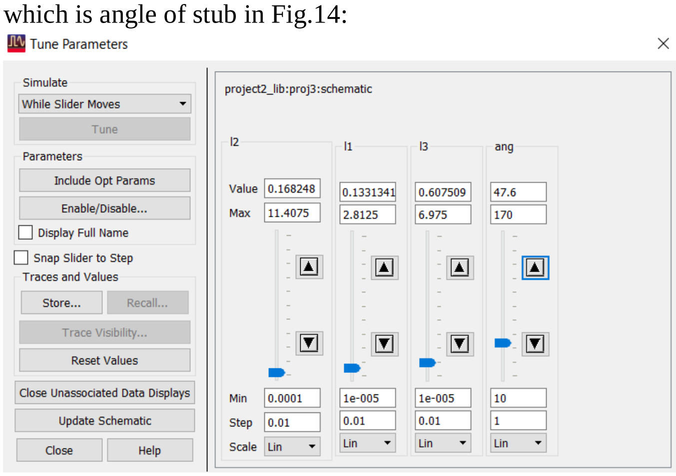


Fig.14 Tuning for radial stubs

With the best optimization we got these values:

$$l_1 = 0.168248mm$$
$$l_2 = 0.133134mm$$
$$l_3 = 0.6075\ mm$$
$$angle = 47.6\ degree$$

The performance depicted in Fig.15 and 16:

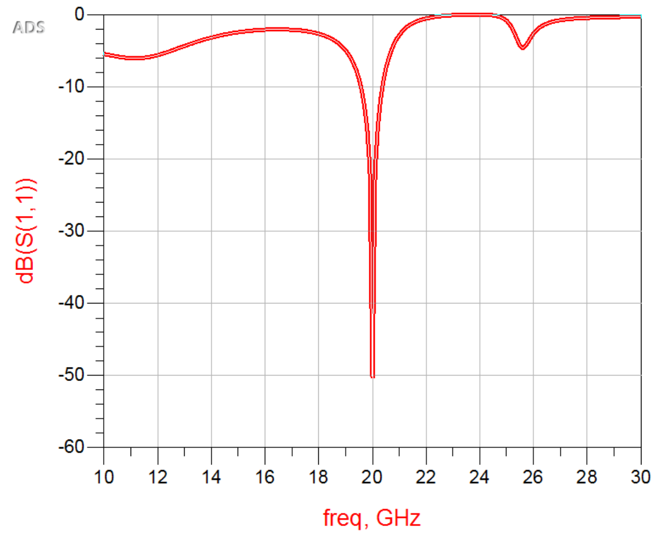


Fig.15 S analysis for tuned radial stubs

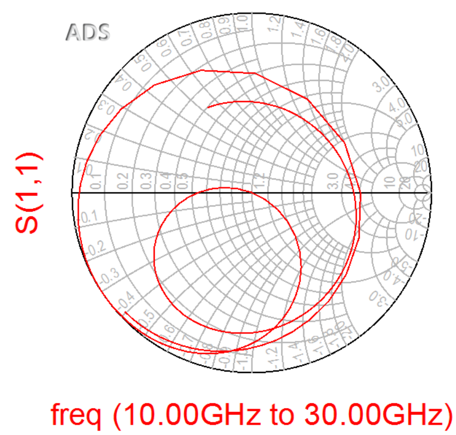


Fig.16 Smith chart for tuned radial stubs