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Lab 9 Report

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Background

In this week's lab, we design a patch antenna and its matching network. By using the analytical equations to calculate the dimensions of patch antenna, we can get a S11 deep point at center frequency. Then, we design and implement its matching network to improve its VSWR. The HFSS simulation model is a little bit different. It is a probe fed patch antenna. The input impedance along L direction on central line is different with electric field distribution for its operation mode.

Design

Task 1. Microstrip line fed patch antenna

By using the analytical equations in "ECEN 452 Lab 10 Activity", we get the dimensions of this patch antenna. By using the online microstrip line calculator, we can get all the information of width and lamda for the 50 ohm line we use in this matching network design. The design parameters are shown in the following table 1.

Design Parameter:		Microstrip line fed patch antenna at 3 GHz			
W_{patch}	31.3 mm	$L_{\triangle}$	0.739 mm	L	24.22 mm
ε_{eff}	3.774	$W_{feed\ line}$	3.11 mm		

Table. 1 Design Parameters for microstrip line fed patch antenna

Task 2. Probe fed patch antenna

Using the dimensions we get in Task 1. Then, adjusting the distance probe_fed_x to get a matching point for this design. By using the method mentioned in "***The Dependence of the Input Impedance on Feed Position of Probe and Microstrip Line-Fed Patch Antennas***" [1], I can estimate the feed point location for good impedance matching. By using their results and multiplying the normalized factor in figure 1, getting the estimate probe_fed_x is close to 5.8 mm. But the central frequency drift to a bit higher, I decrease the distance to 5.5 mm. Note that, it make sense that the impedance distribution in this figure is like the electric field distribution for the fundamental mode. The final design parameters are shown in the following table 2

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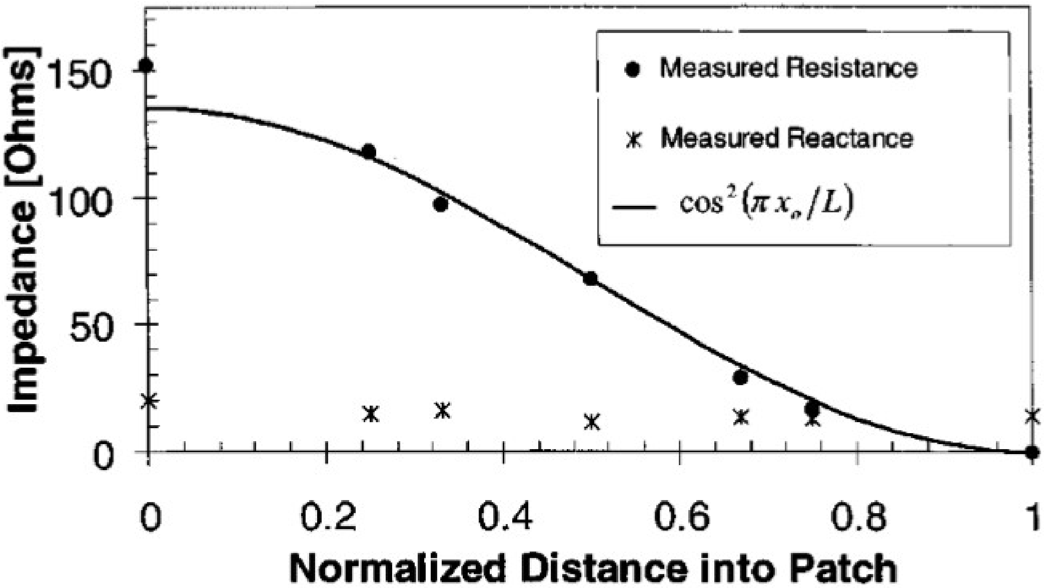

Fig. 1. Normalize probe fed patch antenna impedance via normalized distance

Design Parameter:		Probr fed patch antenna at 3 GHz			
W_{patch}	31.3 mm	L_{patch}	0.739 mm	$L_{probe\ feed}$	24.22 mm

Table. 2 Design Parameters for probe fed patch antenna

Procedure

Task 1. Microstrip line fed patch antenna

Implement this patch with a 50 Ω feed line using copper tape on FR4 substrate. The input impedance for our design is 100+30j ohm and the normalized input impedance (zin) is 2+0.6j ohm.

The following step by step procedures are shown in figure 2.

Step 1. By rotating lamda/4 to get the normalized input susceptance (yin).

Step 2. The distance “d” is the length from yin to the reactance circle 1. The distance is 0.129 guided wavelength.

Step 3. The distance “Lstub” is the length to compensate the imaginary part. The distance is 0.11 guided wavelength.

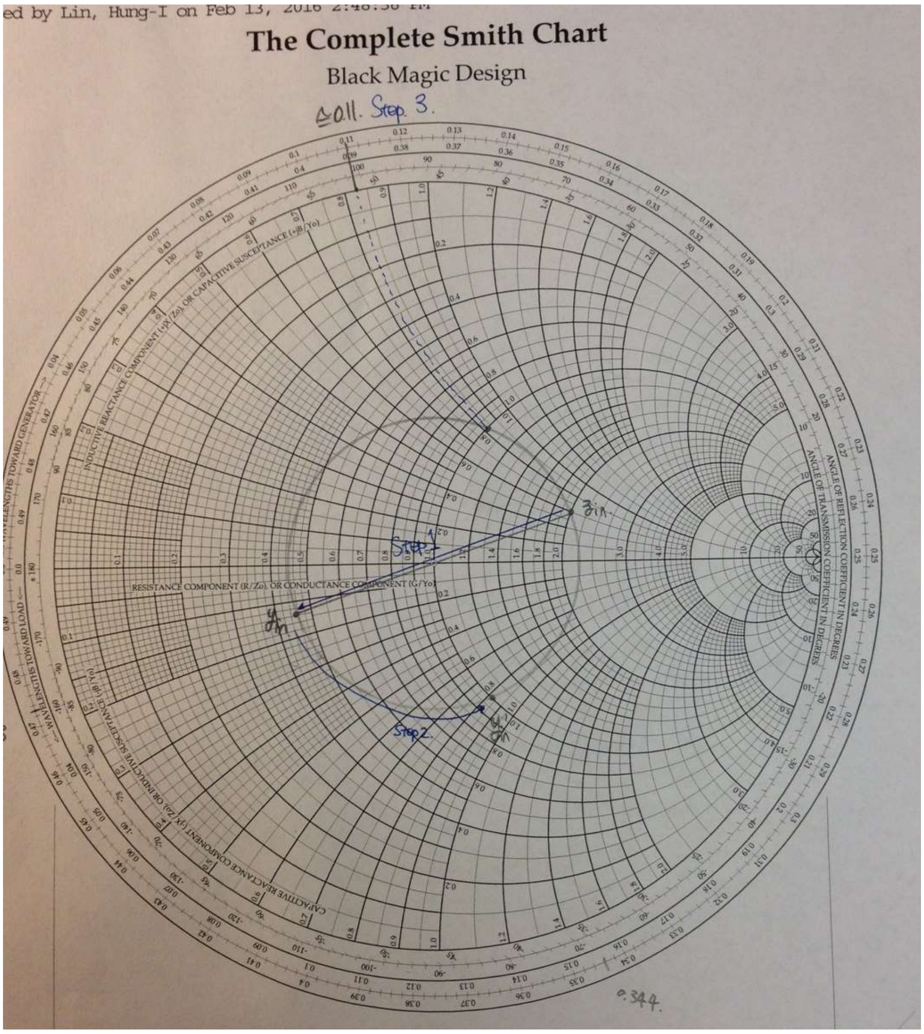

Fig 2. Smith Chart for stub design

Task 2. Probe fed patch antenna

Using the method in [a] and tuning.

Results and Discussion

Task 1. Microstrip line fed patch antenna

The measurement results are shown in figure 2. For the unmatched patch antenna, we still can get a good VSWR (close to 2) result. It means this structure is not just an “open-low-impedance line” which just reflect power but it is an antenna radiate the signal out to free space. After adding the matching network, we can see a significant improvement on this design.

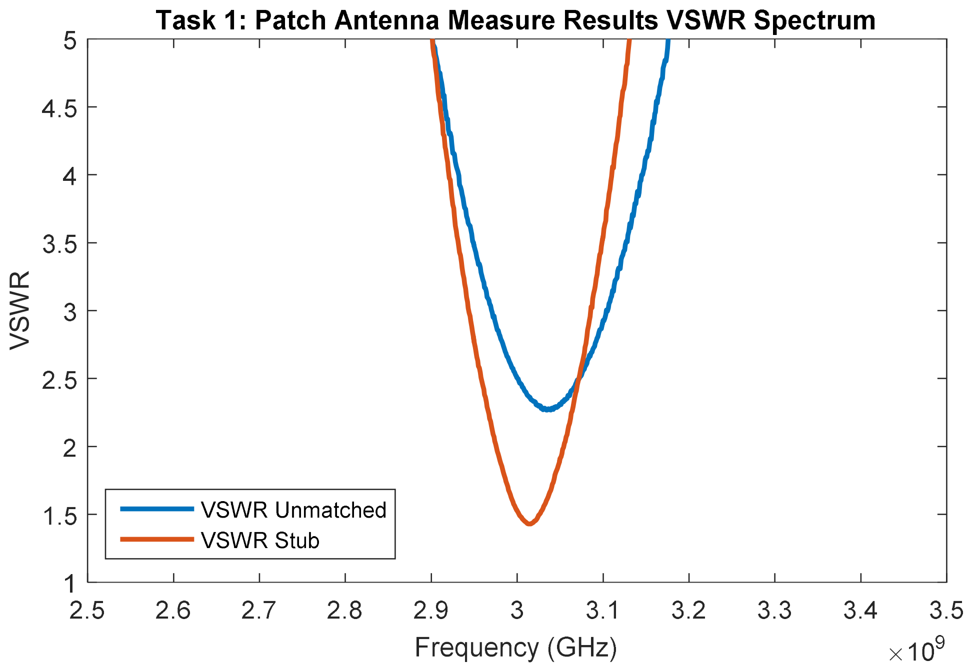

Fig. 2 Microstrip line fed patch antenna measure results

Task 2. Probe fed patch antenna

After some tuning jobs, I get the simulation results shown in figure 3 and 4. In figure 3, we can see the VSWR minimum is below 1.2 at 3 GHz. The 3 GHz point in Smith chart (figure 4) is close to the center. We can also see the second high order mode for this patch is at 4.7 GHz. From figure 5, I believe this higher order mode is TM02 mode caused by antenna's width which is a full wave length resonance. Then, why there is no place for TM01 mode in this structure? The reason is that our feed point is on the center line of width. The electric field distribution for TM01 mode is a null point which will cause full reflection. This phenomenon can also explain why we set the distance probe_fed_x is 0 mm and there is no minimum point on VSWR at 3GHz. By the way, the radiate efficiency for this higher order mode (TM02) should be very terrible. The reason is the equivalent magnetic current cancel out each other in far field.

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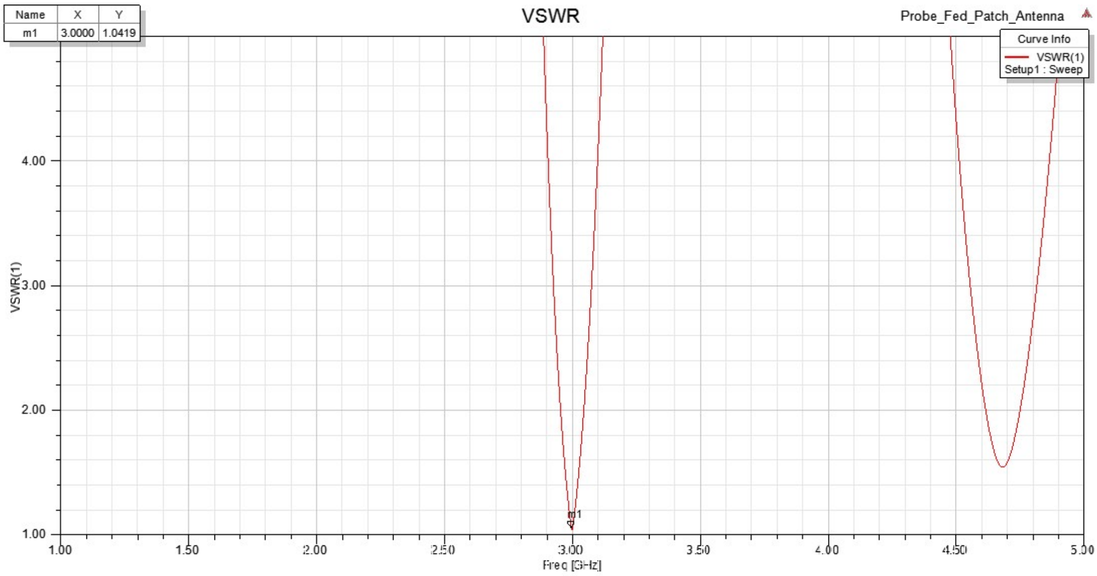

Fig. 3 Probe fed patch antenna VSWR simulation result

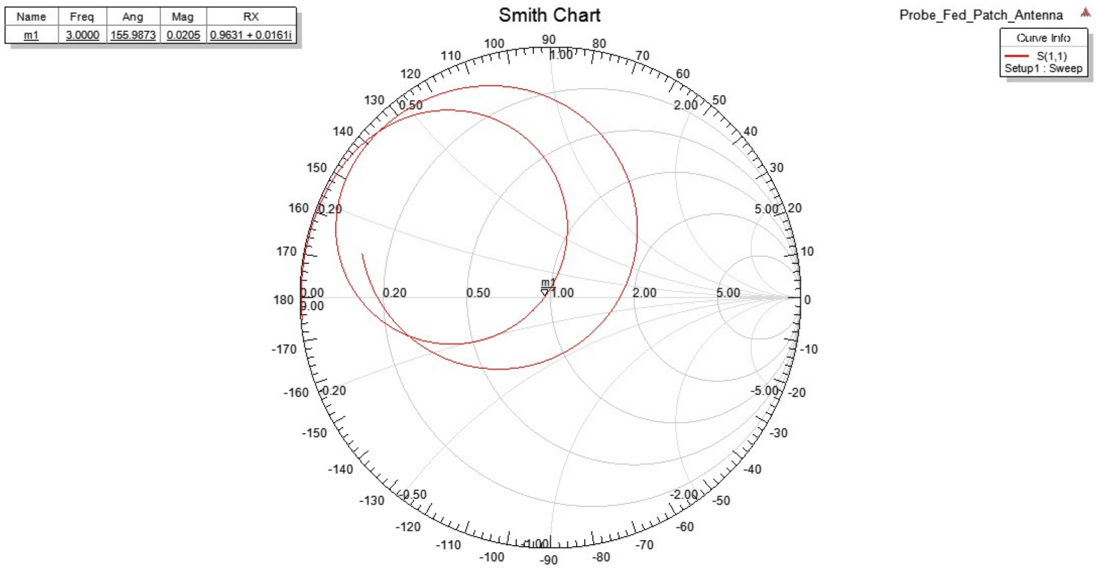

Fig. 4 Probe fed patch antenna Smith Chart simulation result

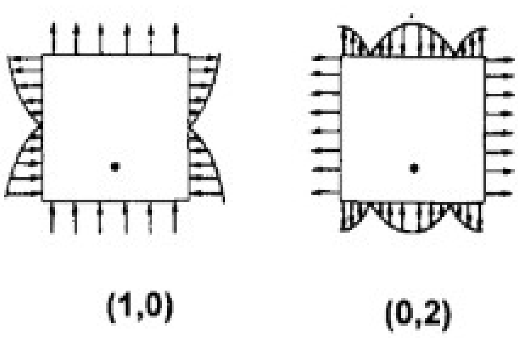

Fig. 5 Patch antenna field distribution for TM10 and TM02 mode.

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Conclusion

- For probe fed patch antenna, input point location is important. It would disappear the resonant point because the impedance mismatch.
- The length and width can be the radiate element when they are close to the resonant length. We can see the s11 deep point on S parameter spectrum due to the resonance. But, the minimum point cannot promise a good radiation efficiency at the frequency.