A Microstrip Patch Antenna for a WLAN Receiver

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Abstract

A new microstrip patch antenna was designed and fabricated for a 2.45 GHz and 5.2-5.9 GHz WLAN receiver. The antenna covers a bandwidth of about 700 MHz for the 5.2-5.9 GHz WLAN band. In order to get a better response for the lower band at 2.45 GHz, a microstrip matching circuit was added. Electromagnetic simulations were used for the design and optimization process. In addition, antenna measurements were performed to validate the simulations. Some measurements will be presented during the conference.

1. Introduction

In this study, a receive-only patch antenna radiating in the 2.45 GHz and 5.2-5.9 GHz WLAN bands is presented. The antenna was designed as part of a WLAN receiver. Patch antennas have been studied in the literature extensively. The study in [1] has two dual-band microstrip-fed printed antennas having circular patch and hexagonal patch geometries. Their low bands are at 1.6 GHz, and their high bands are at 4 GHz and 3.8 GHz, respectively. Another study [2] which is different from traditional methods describes how to design a multiple-band antenna using transmission lines and metasurfaces. And in this way a wide band and a low profile 2.4/3.5-GHz dual-band operation has been obtained. Also different techniques of dual-polarized patch antennas have been examined in [3-6].

2. Designed and Fabricated Antenna

A basic microstrip patch antenna is composed of a metallic radiating patch above a dielectric substrate backed by a ground plane. For the presented antenna, about 1.5-mm thick FR4 substrate was used since FR4 performs well up to several GHz, and is a low cost material. The design was optimized using electromagnetic simulations. HFSS has been used as the simulation tool. The copper thickness for all conductive parts is 35 microns for all simulations. Fig. 1 shows the fabricated patch antenna. 100×100 mm^2 dimensions were chosen for the ground plane. The designed patch is a square, and each side is 28 mm. At right and left edges, non-symmetrical cuts were placed which help to reach a bandwidth of about 700 MHz at the upper band (5.2-5.9 GHz). An area of 12 by 2 mm^2 was cutted from the both sides of the patch for this purpose. The length of the 50-Ω microstrip between the SMA connector and the patch is 36 mm.

S11 response, gain, and radiation pattern measurements of the fabricated patch antenna at various frequencies were obtained at the Antenna Test and Research Laboratory at TÜBİTAK. Measured S11 response of the patch antenna is shown in Fig. 2. 2.45 GHz and 5.2-5.9 GHz WLAN bands can be seen clearly. Table 1 shows measured and calculated antenna gains at various frequency points. Radiation patterns in two dimensional planes will be presented at the conference.

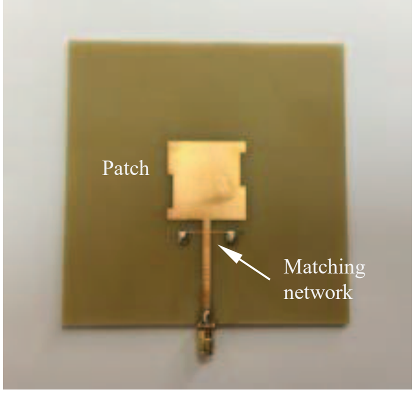


Fig. 1. A photograph of the patch antenna with the microstrip matching circuit.

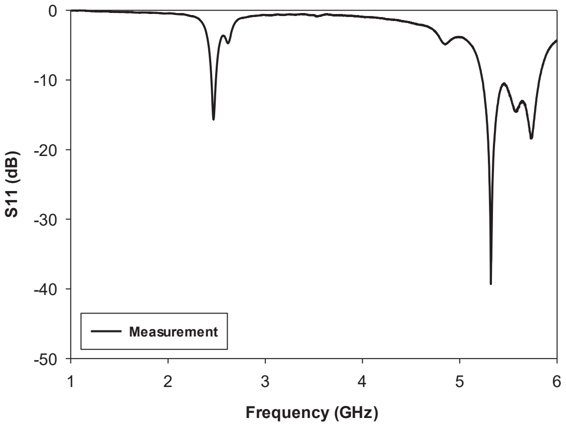


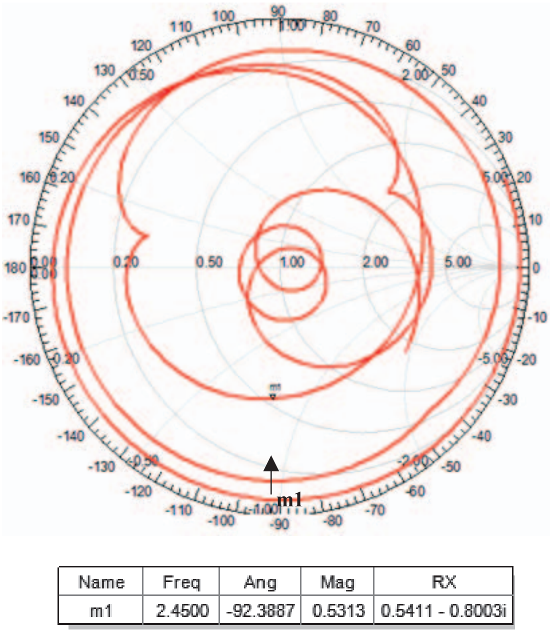
Fig. 2. Antenna S11 measurement.

Table 1. Comparison of simulated and measured antenna gains at different frequencies.

Frequency (GHz)	Measured Gain (dBi)	Simulated Gain (dBi)	Measured S11 (dB)	Simulated S11 (dB)
2.4	-2.98	-1.97	-3.77	-4.03
2.5	-0.174	0.98	-8.31	-9.36
5.4	2.98	1.04	-12.53	-14.07
5.6	0.454	0.03	-13.97	-13.04
5.8	2.259	-0.25	-11.55	-8.36

3. Design Procedure

Antenna input impedance is required for the design of the matching circuit. Without the matching circuit, the low-band response is not at an acceptable level. Fig. 3 shows the S11 on Smith chart as seen from the SMA connector port without the matching network. The location of the normalized input impedance ($\overline{Z_{in}}$) at 2.45 GHz as seen from the feed port is indicated by marker m1 in Fig. 3. The corresponding normalized and denormalized impedance values are $\overline{Z_{in}} = 0.5411 - j0.8003$ and $Z_{in} = 27.055 - j40.015\ \Omega$ at 2.45 GHz. The matching circuit is implemented just 2 mm before the antenna, so the antenna input impedance Z_A has to be calculated by subtracting a length of 34 mm. The electrical length βl of the 34-mm long microstrip line is calculated as 183.3º. Antenna impedance is treated as the load impedance and then a move of 2βl towards the load on the Smith Chart (in the counter clockwise direction, CCW) yields the value of the antenna impedance.



Name	Freq	Ang	Mag	RX
m1	2.4500	-92.3887	0.5313	0.5411 - 0.8003i

Fig. 3. The location of the normalized input impedance on the Smith plot.

The antenna is considered as a load and since $2\beta l$ is about 367°, 360° is subtracted from 367° and 7° (or 0.0097λ) is obtained. This is the offset distance between source and destination points. The position of the normalized antenna impedance Z_A is found by moving 0.0097 λ CCW. Smith chart calculations were performed using the Smith Software [7], and the antenna impedance Z_A was calculated after removing the effect of the 34-mm long microstrip. A matching network is required at 2.45 GHz to transform Z_A to 50 Ω without distorting the 5.2-5.9 GHz band. Z_A is shown as point 1 in Fig. 4. Series and shunt inductors can be used for the matching. It can be seen that a shunt inductor is more suitable for the matching network since it will have minimum effect on the upper band. Points 2 and 3 are on the VSWR circle 2:1 which corresponds to about -10 dB S11 value. It is possible to get close to the VSWR 2:1 circle for some values of the shunt inductor as seen from Fig. 4. Adding a shunt inductor would move the impedance from point 1 to point 2, and even to point 3 depending on the inductance value. The moves from point 1 to point 2, and from point 1 to point 3 correspond to about 6 nH and 3 nH shunt inductors, respectively. A grounded and narrow microstrip line was used to achieve the required shunt inductance. However, for the practical design, two grounded and narrow microstrips have been used. The length of each microstrip is 4 mm. Both are 3-mm wide and terminated by a shorted load (RF grounded).

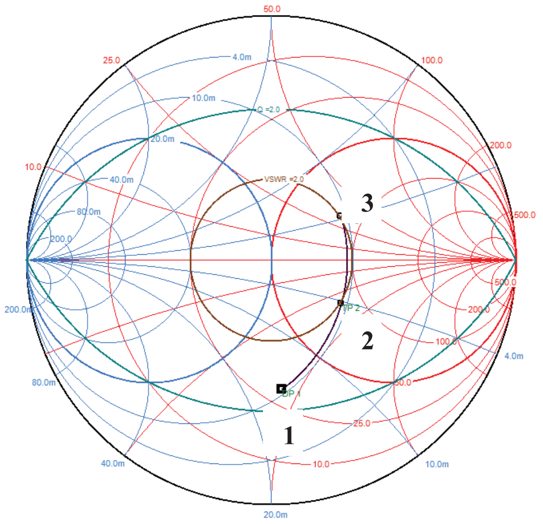


Fig. 4. Matching with a parallel inductor of 6 nH at point 2 and matching with a parallel inductor of 3 nH at point 3.

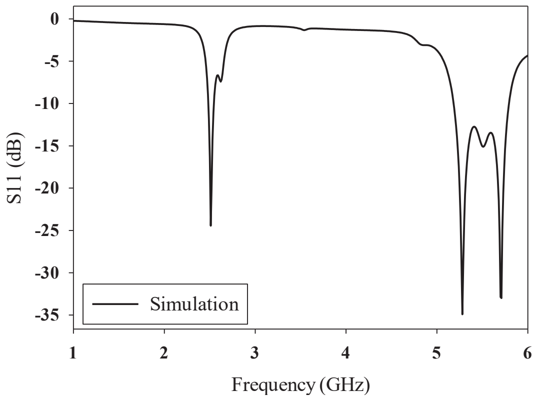


Fig. 5. S11simulation of the proposed patch antenna with the parallel inductors at d=34 mm distance from feeding.

S11 of the antenna with the matching network is shown in Fig. 5. It can be seen that the low-band is at 2.51 GHz, and the high-band starts at 5.2 GHz, ends at 5.9 GHz. Now the question is what is the value of the shunt inductance due to the shorted microstriplines? To answer this question, the geometry in Fig. 6 was analyzed. The patch antenna was removed and only one side of the shorted microstrip was left for the calculation of the impedance of the shorted microstrip line section.

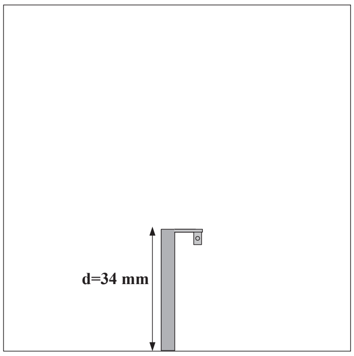
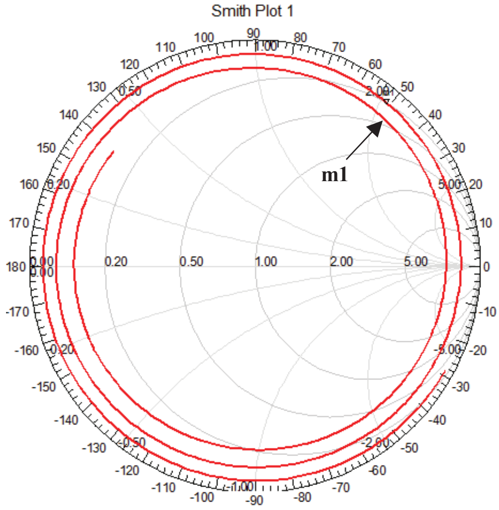


Fig. 6. Geometry of the shunt inductor at 34 mm distance from feeding.

At 2.45 GHz, input impedance of the structure is found as $(\overline{Z_{in2}})= 0.1977 + j2.0895$ from the m1 data point in Fig. 7. After denormalization, $Z_{in2} = 9.89 + j104.475\ \Omega$ is obtained. Since the length of the 50-Ω line up to the parallel strip is 34 mm, after removing the effect of this line length, impedance of the parallel strip is read as Z_(parallel inductance)=7.8 +j89.8 Ω. Since $j89.8\Omega = 2\pi f L$ at 2.45 GHz, inductance value is found as about 6 nH. Since two parallel inductors are used in the actual design, total inductance is half of this value, that is about 3 nH. This is very close to the low-end of the 3 and 6 nH inductance range which corresponds to the inside of the VSWR 2:1 circle, shown in Fig. 4.



Name	Freq	Ang	Mag	RX
m1	2.4500	50.8266	0.9293	0.1977 + 2.0895i

Fig. 7. Normalized input impedance of the shunt inductors at 34 mm distance from the feed point.

6. Conclusions

A new microstrip patch antenna is proposed in this study for a 2.45 GHz and 5.2-5.9 GHz WLAN receiver. Antenna has an extensive bandwidth at the high band due to non-symmetrical cuts on the radiating patch, and a microstrip matching network to obtain an better response for 2.45-GHz low-band. These two are the main approaches of the presented antenna. Antenna measurements were observed and compared with the simulations.

7. References

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