A Small Size Broadband MEMS Antenna for 5 GHz WLAN Applications

Ji-Hyuk Kim, Hyeon Cheol Kim, and Kukjin Chun

***Abstract*—A small size broadband microstrip patch antenna with small ground plane has been fabricated using MEMS. Multiple layer substrates are used to realize small size and broadband characteristics. The microstrip patch is divided into 3 pieces and each patch is connected to each other using a metal microstrip line. The fabrication process is simple and only one mask is needed. Two types of microtrip antennas are fabricated. Type A is the microstrip antenna with metal lines and type B is the microstrip antenna without metal lines. The size of proposed microstip antenna is 8*12*2 mm^3 and the experimental results show that the antenna type A and type B have the bandwidth of 420 MHz at 5.3 GHz and 480 MHz at 5.66 GHz, respectively.**

***Index Terms*—5 GHz, MEMS, microstrip antenna, broadband, compact**

I. INTRODUCTION

A microstrip antenna is a compact antenna that can be used in a mobile radio and wireless communication systems. A microstip antenna is widely used because of its simple fabrication process and its arbitrary shapes. Since microstrip antenna is low profile and conformable to planar surface, it can be integrated with packaging[1]. IEEE 802.11a is the standard for 5 GHz WLAN. Since 5 GHz WLAN is capable of transmitting and receiving up to 54 Mbps data, it is considered one of the candidates of next generation communication system. IEEE 802.11a has two frequency band at 5 GHz. Lower band is from 5.15~5.35 GHz and upper band is from 5.725 ~ 5.825 GHz. At 5 GHz the wavelength of electromagnetic wave is about 6 cm. Thus, the size of antenna has to be few cm by few cm. By making simple flat patch antenna, the antenna can be integrated with package to reduce total system size.

The problem with microstrip antenna is that it has a narrow bandwidth. Many works have been done to increase the bandwidth of the microstrip antennas. Some of the methods use E-patch[2], U slot[3], aperture coupling[4], and slits[5]. These approaches show broadband characteristics using air or low dielectric constant substrates, which results in large volume. They also require large ground plane. If we want to apply the microstip antenna to the packaging, not only the size of the antenna has to be small but also the ground plane has to be small and the substrate has to be thin.

In this paper, a compact microstrip antenna with small volume and limited ground plane is proposed. It has broadband characteristics at 5 ~ 6 GHz frequency band due to multiple layer substrates. There has been antenna with multiple layer substrates[6]. However, their antenna type, configuration, and applications are different from our work. To test the feasibility of the proposed microstrip antenna, we have investigated broadband characteristics of proposed antenna using multiple layer substrates. MEMS technology is used to fabricate the microstrip antenna.

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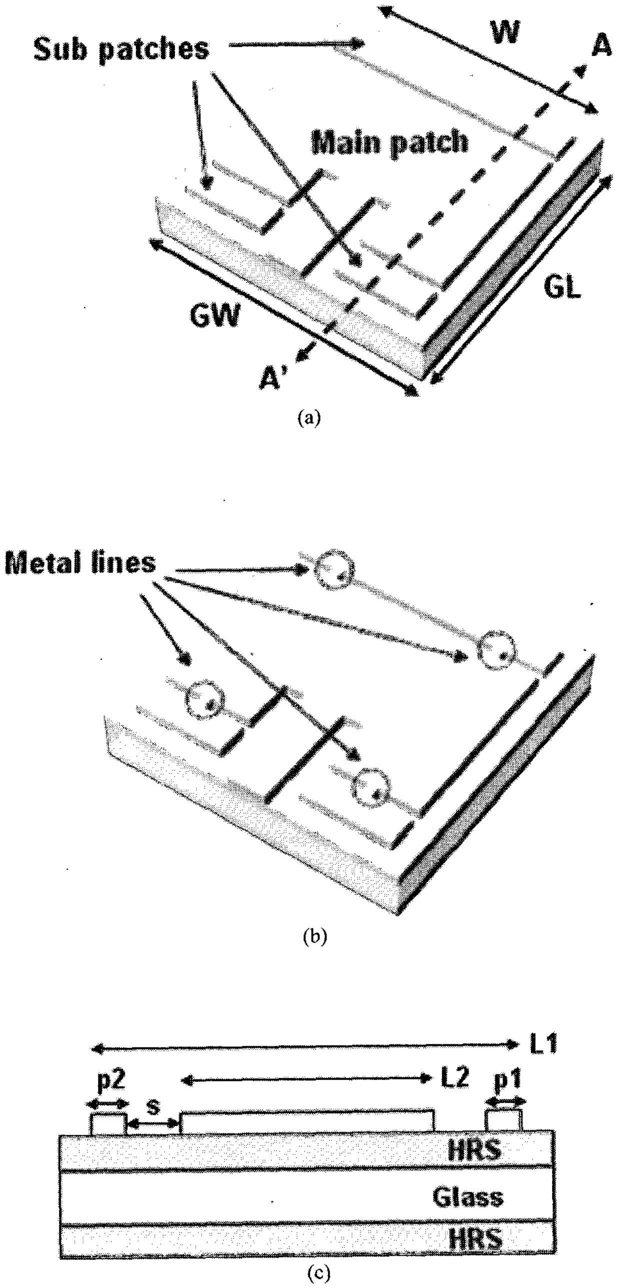
II. MICROSTRIP ANTENNA WITH MULTIPLE LAYER SUBSTRATES

1. Design

A microstip antenna that can be integrated on packaging should have small volume and ground plane. Unfortunately, the bandwidth is closely related to the ground size[7]. Small ground size lowers the bandwidth of the microstrip antenna. The design constraints of the dimensions of the micrstrip antenna are the microstrip antenna size (< 1cm^2), substrate height (< 2mm), and ground size (~ 1.5*1.5 cm^2). The ground size is about 0.25λ. In general, this is a very small value.

The frequency band of 802.11a WLAN is 5.15 ~ 5.35 GHz and 5.725 ~ 5.825 GHz. Two types of antennas are proposed to satisfy lower and upper frequency bands of WLAN. Figure 1 shows the schematic of proposed microstrip antenna. Type A (Fig. 1(a)) is the microstrip antenna with patches divided into four patches with no connection line between patches. Type B (Fig. 1(b)) is the microstrip antenna with patches connected with metal lines. Type A is for the upper band of WLAN and type B is for the lower band of WLAN. An inset feed is used for input impedance matching. The patch is divided into one main and three sub-patches. According to the simulation results, dividing patch into two patches caused the problem of input impedance mismatch, because the relative length of the inset feed is changed as the patch length is changed. This phenomenon is observed in other paper[8]. By making four patches, the input impedance matching at 5 GHz is ensured. The patches are designed to operate at 5 GHz. The length of main patch (L2) is for upper 5 GHz (5.7 GHz) and the length of the total patch (L1) is for lower 5 GHz (5.2 GHz).



(a)

(b)

(c)

Fig. 1. Schematics of proposed microstrip antenna. (a) top view of type A (b) top view of type B (b) cross-section (A-A') of type A.

Multiple layer substrates of high and low dielectric constant materials are chosen to enhance broadband characteristics. HRS (High Resistivity Silicon) with the resistivity of 10000 ohm*cm is selected as high dielectric constant substrate and BOROFLOAT® 33 glass is selected as low dielectric constant substrate. The dielectric constant of HRS and glass is 11.9 and 4.6, respectively. The glass substrate is located at the middle of two HRS substrate forming a 'sandwich' like structure. HRS substrates under the patch and above the ground plane enable small patch size while glass substrate lowers the effective dielectric constant of the substrate.

HFSS simulator tool was used to simulate and verify the operation and characteristics of proposed microstrip antenna. The dimensions of the microstrip antenna are as follows. The length of the total patch (L1) is 8 mm and the width (W) is 12 mm. The spacing between the patches (s) is 0.2 mm and the sub patch length p1 and p2 is 0.3 mm and 0.5 mm, respectively. The thickness of HRS is 0.5 mm and

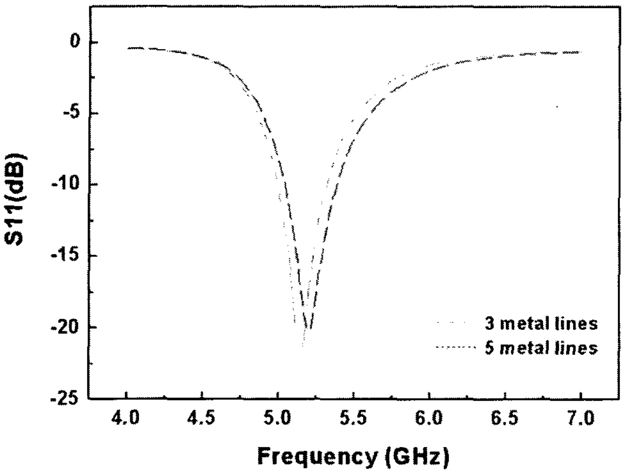


Fig. 2. The simulation results of type B antenna with three and five metal lines.

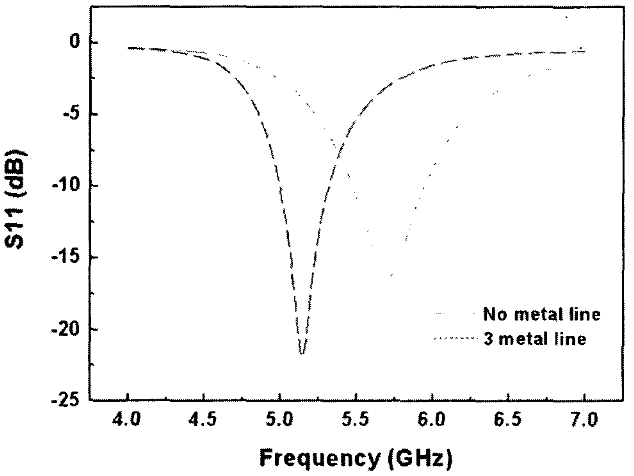
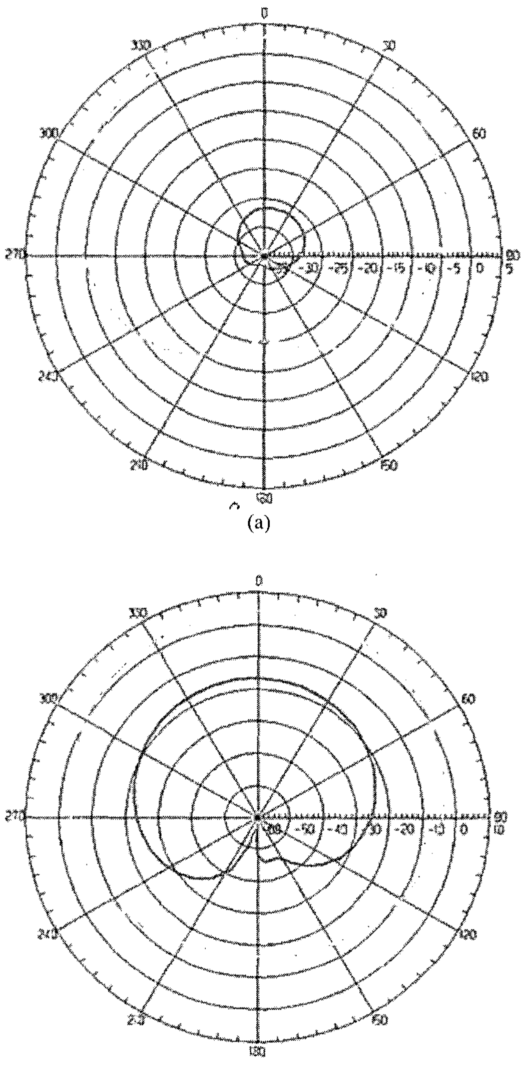


Fig. 3. The s11 simulation results of type A and type B antennas.

the glass is 1 mm. Thus the total thickness is 2 mm. The size of the ground (GL*GW) is 15*15 mm^2.

The width of metal lines connecting main and sub patches is 100um. Three and five metal lines are used to connect patches. Figure 2 shows the simulation results of comparing the difference of s11of three and five metal lines. The center frequency and bandwidth of the antenna with three metal lines is 5.15 GHz and 320 MHz, respectively. The center frequency and bandwidth of the antenna with five metal lines is 5.2 GHz and 330 MHz, respectively. The bandwidth of two antennas is almost the same. The center frequency of the antenna with three metal lines is lower than the antenna with five metal lines because its electrical length is slightly longer.



(a)

(b)

Fig. 4. E-field simulation results of antennas.(a) type B antenna at 5.15 GHz (b) type A antenna at 5.7 GHz.

Figure 3 shows the simulation results of type A and type B antennas. The solid line represents s11 data of type A and the dotted line represents s11 data of type B with three metal lines. The center frequency and the bandwidth of the antenna type B with three metal lines is 5.15 GHz and 320 MHz. The center frequency and the bandwidth of the antenna type A is 5.7 GHz and 460 MHz. The simulation results show that the antenna type A satisfies the upper band of 802.11a and the antenna type B satisfies the lower band of 802.11a. Figure 4 shows the simulation results of E-field pattern of the proposed microstrip antenna. Figure 4(a) shows E-field pattern for type B antenna at 5.15 GHz. Figure 4(b) shows E-field pattern for type A antenna at 5.7 GHz. According to Figure 4, the microstrip antenna is linearly polarized and the E-filed pattern shows typical shape of microstrip patch antenna.

2. Fabrication

The microstrip antenna was fabricated using the designed dimensions from previous subsection. Figure 5 shows the fabrication process. The substrate is prepared by anodic bonding of glass and HRS wafer. Anodic bonding is performed two times to fabricate HRS/glass/HRS substrate (Fig. 5(a)). Ti/Au seed layer of 300 Å/1000 Å is deposited using thermal evaporator (Fig. 5(b)). PR mold are patterned using AZ4620 at a height of 6um (Fig. 5(c)). Au electroplating of 3um is performed to fabricate microstrip antenna (Fig. 5(d)). PR mold and seed metal are removed by wet etchants (Fig. 5(e)). Ti/Cu of 300 Å/5000 Å are deposited at the backside of the substrate to form a ground plane (Fig. 5(f)). Finally the wafer is diced and SMA connector is soldered with antenna's feeding line for the measurements. Figure 6 shows the photograph of the fabricated microstrip antenna.

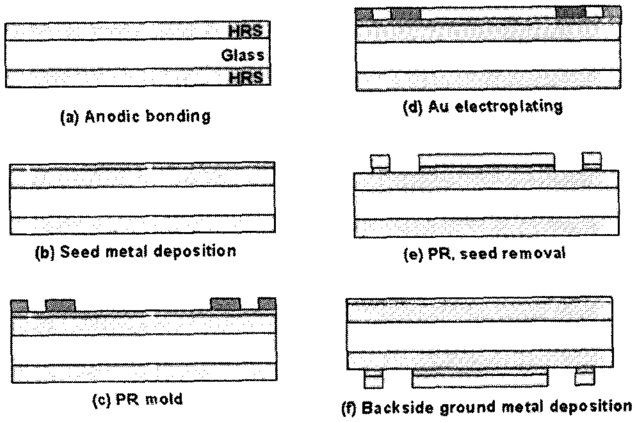


Fig. 5. Fabrication process of microstrip patch antenna.

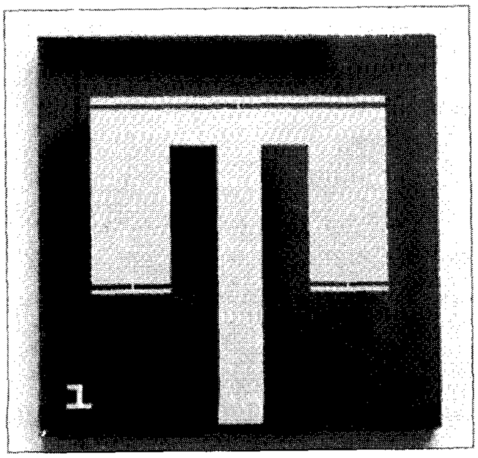


Fig. 6. Photograph of fabricated microstrip antenna with metal line connecting main patch with sub patches.

3. Measurements

The S11 parameter of the fabricated microstrip antenna was measured using HP8410C network analyzer. Figure 7 and figure 8 show the graphs of experimental data of S11. As mentioned in previous subsections, two types of antennas were measured. The microstrip antenna for upper 5 GHz band (Type A antenna) showed the bandwidth of 480 MHz with the resonant frequency of 5.66 GHz, and the microstrip antenna for lower 5 GHz band (Type B antenna) showed the bandwidth of 420 MHz with the resonant

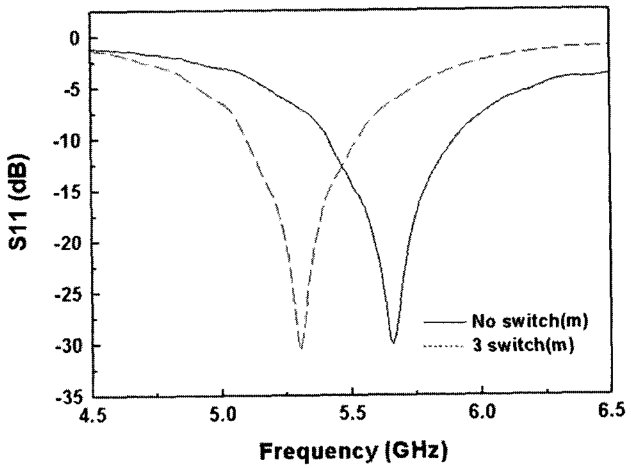


Fig. 7. Measured S11 data of the microstrip antenna of type A and type B.

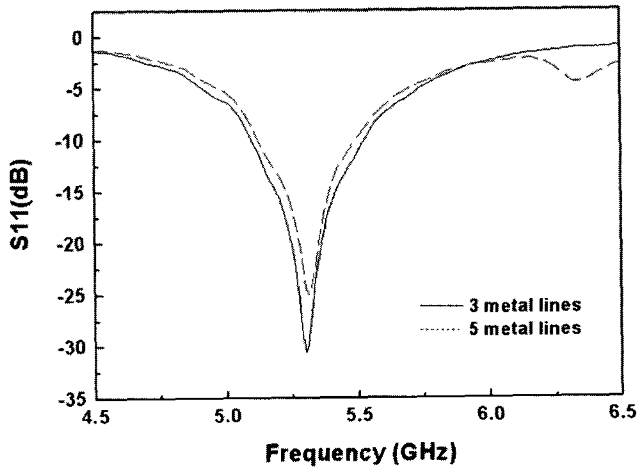
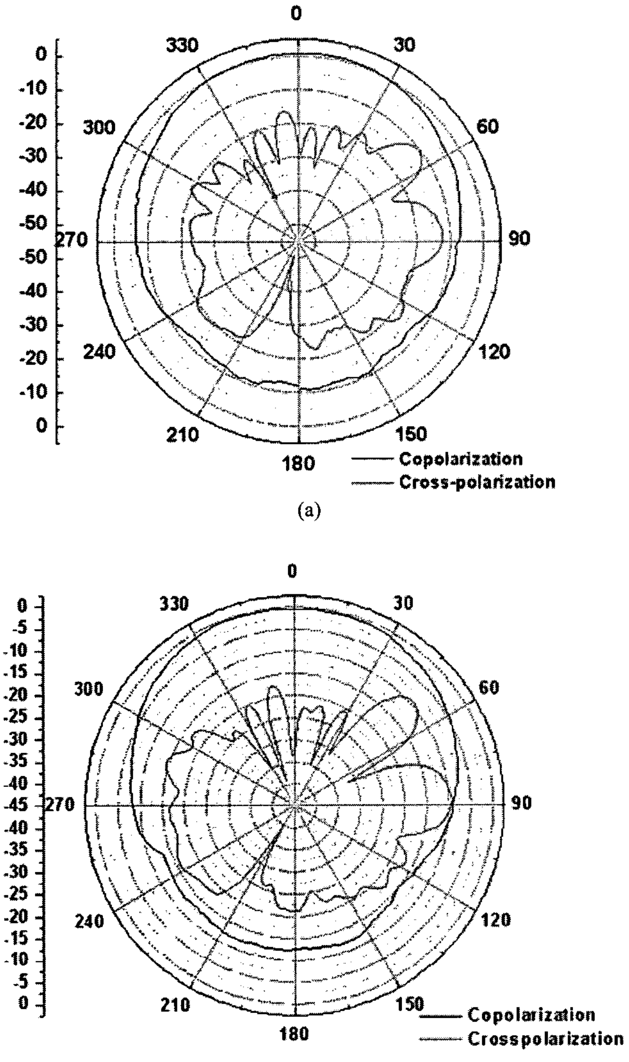


Fig. 8. Measured S11 data of the microstrip antenna of type B with three and five metal lines.



(a)

(b)

Fig. 9. Measured E-field pattern of microstrip antenna (a) 5.3 GHz (b) 5.66 GHz.

freuquency of 5.3 GHz. The bandwidth is about 8%, which is a large value considering the size of the microstrip antenna and the ground plane. Figure 8 shows the measured s11 data of type B antenna. Type B antennas with three and five metal lines have been compared. Type A antenna satisfies the upper band of 802.11a and type B antenna satisfies the lower band of 802.11a.

The E-field patterns of the fabricated antennas have been measured in an anechoic chamber. Figure 9 shows the E-field pattern of the fabricated microstrip antenna. Figure 9(a) is the measured E-field pattern of type B microstrip antenna with 3 metal lines at 5.3 GHz. Figure 9(b) is the measured E-field pattern of type A microstrip antenna at 5.66 GHz. The gain of the type A microstrip antenna and type B microstrip antenna is 0 dBi and 1 dBi, respectively. The gain is small because of small ground plane and lossy HRS and glass substrates. If we use HRS with higher resistivity or use larger ground plane, the gain will be increased at the cost of decreased bandwidth. The cross-polarization was also measured for type A and type B antennas. The level of cross-polarization for both antennas was suppressed below -15 dBi within the HPBW (Half Power Bandwidth). The value of back lobe was quite large due to small ground planes.

III. CONCLUSIONS

We have designed and proposed a small size compact broadband microstrip antenna. Narrow bandwidth caused by small ground planes was overcome by multiple layer substrates. Two types of antennas were suggested to satisfy lower and upper band of 802.11a. Simple one mask process using MEMS technology has been suggested and successfully fabricated proposed microstrip antenna. If we can replace metal lines with switches, we can make a reconfigurable antenna that satisfies both lower and upper band of 802.11a which is 5.15 ~ 5.35 GHz, 5.725 ~ 5.825 GHz.

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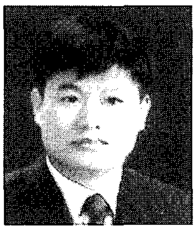

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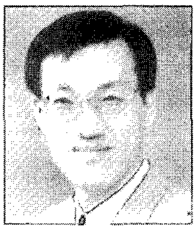

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