4-Channel Patch Array Antennas for Home Network System

Kyeong-Sik Min · Dong-Jin Kim

Abstract

This paper describes a design of a miniature patch antenna and its 4-channle array for 5.25 GHz wireless LAN band. Each patch element is designed for the low mutual coupling between each element and for the small size of the array antenna. The size of the each element is 7 mm × 14.5 mm × 5.6 mm and it satisfy IEEE 802.11a frequency band. It is arrayed for independent 4-channel operation. The total size of the array antenna is 35.6 mm × 52.5 mm × 5.6 mm. The measured reflection coefficients and the radiation patterns of the fabricated antennas show the reasonable agreements with prediction.

Key words : Miniature Patch Antenna, 4-Channel, Low Mutual Coupling, Broad Bandwidth.

Ⅰ. Introduction

Recently, the RFID(Radio Frequency-Identification), the UWB(Ultra Wide Band) and the MIMO(Multi-Input Multi-Output) system have emerged as the application fields which will be applied in the 4th generation mobile communication. Especially, the advance of the Home-Networking technique which includes the W-LAN proposed from IEEE 802.11a is developing very fast, because the IEEE 802.11a band supports very high speed(54 Mbps) for W-LAN[1].

Many attempts have been made by using the new transmission technique with the multiple antenna system and the new signal processing technique for the 4th generation mobile communication. There are many methods, for example the Tx diversity, the MIMO system and the Beam forming technique in the MASP(Multi Antenna Signal Processing) technique which has many antenna elements for mobile communication environment are studied. Especially, the MIMO technique is a good candidate for the recent mobile communication environment. However, the MASP techniques like MIMO system have some serious problems such a signal interference caused by the strong mutual coupling between each antenna element, and the correlation coefficients in free space. Because the mutual coupling between antenna elements is difficult to solve using baseband algorithm and signal processing, its embodiment is difficult[2]. Therefore, we propose a small and broad bandwith antenna which is satisfy recent trends and has low mutual coupling. The design conditions of the proposed antenna are assumed that it will be able to operate for independent channel in MIMO system and it satisfy 5 GHz frequency band proposed from IEEE 802.11 and the antenna gain is above 6 dBi. The patch array antenna is designed for the minimized mutual coupling with consideration for independent channel operation in 4-channel MIMO antenna system. So, the key point of this paper is the independent 4-channel MIMO antenna design for minimized mutual coupling among the each antenna element for the wireless home network system.

Ⅱ. Single Element Design

The miniature patch antenna proposed in this paper is employed an air substrate and coupled gap feed for miniature size of the antenna and broad bandwidth[3]~[5]. Commercial tools such as Ensemble V6 and HFSS V9

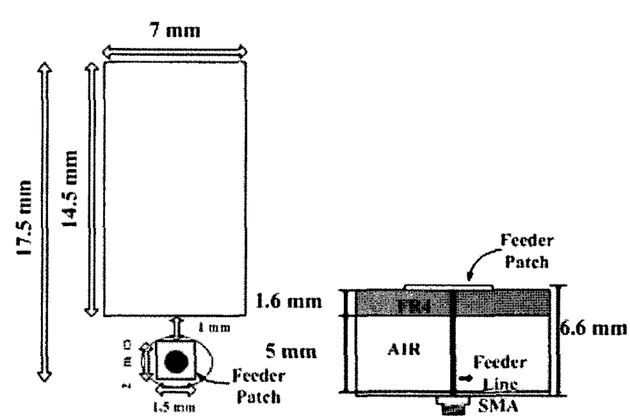

Fig. 1. Design structure and specification of a miniature patch antenna.

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are used for antenna design. Fig. 1 shows the design specification of a proposed miniature patch antenna[6]. The dielectric substrate used for antenna design is FR4 (ε_r=4.4) which has thickness of 1.6 mm. The size of a patch antenna at 5.25 GHz is 7 mm width, 13.8 mm length and 5.6 mm thickness. The proposed patch antenna employs a coupled feeding method with 1 mm gap between feed and patch.

Fig. 2 shows a photograph of the fabricated miniature patch antenna. Figs. 3 and 4 show a measured reflection coefficients and radiation patterns at 5.25 GHz, respectively. As shown in Figs. 1 and 2, since the proposed antenna has a separated structure between resonance patch and feeder patch, the electric fields are generated two direction; along the vertical direction and horizontal direction by coupling. Thus, the proposed antenna shows dual resonance. The measured return loss of the fabricated antenna is satisfied the IEEE 802.11a frequency band, and it is observed reasonable agreement with prediction. The measured radiation patterns of the fabricated antenna are almost same comparing with simulation results at 5.25 GHz. Back lobes in measured patterns depend on the finite ground plane size.

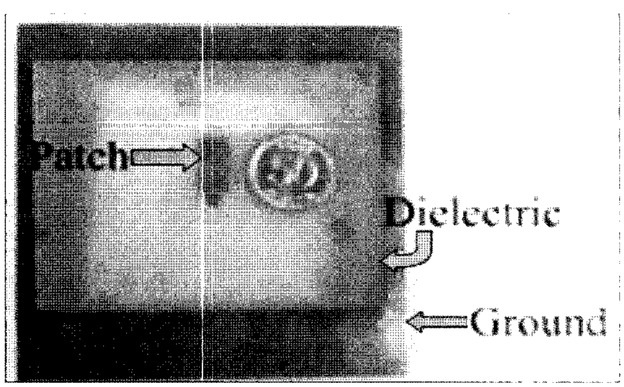


Fig. 2. Photograph of the fabricated antenna.

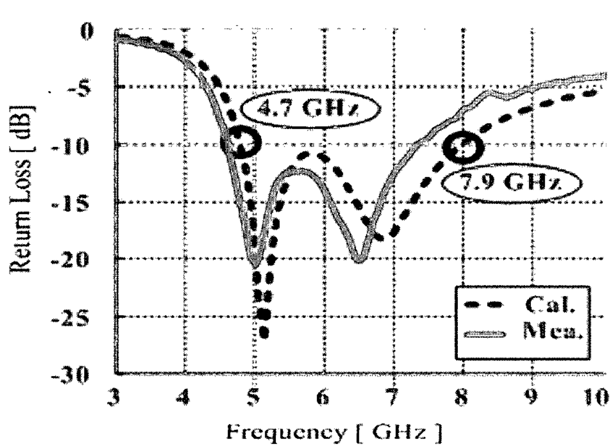
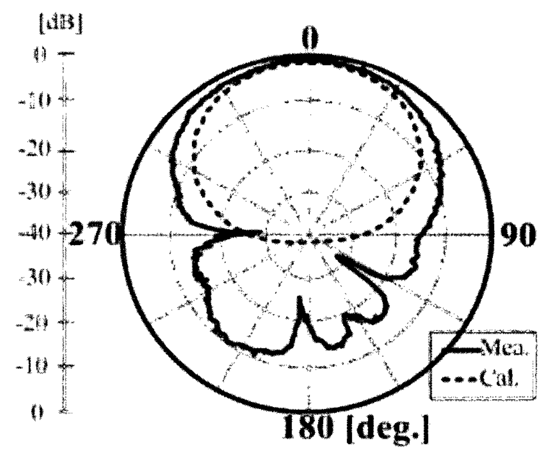
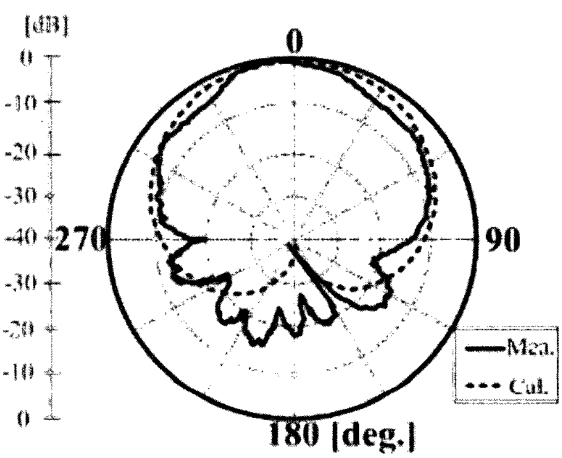


Fig. 3. Measured reflection coefficient of the fabricated antenna.



(a) E-pie



(b) E-theta

Fig. 4. Measured radiation patterns of the fabricated antenna at 5.25 GHz.

Ⅲ. Array Design

To compose 4-channel MIMO antenna, it is considered a reasonable distance between each antenna element for lower mutual coupling, nice gain and total size of arrayed 4-channel MIMO antenna[7]. Distances of each antenna element are changed form 0.4 λ to 0.6 λ. The mutual coupling coefficient is evaluated as the S_{21} which is easy to find on simulation tool. The mutual coupling coefficient is lower than −18 dB in entitle distance, but the gain is changed according to the distance between two elements as shown in Fig. 5.

Fig. 5 shows the simulation results for gain and S_{21} according to the distance between two elements. Finally, it is arranged 0.6 λ and 0.5 λ for horizontal array(D1) and vertical array(D2) by using the consideration of gain and S_{21}, respectively. Fig. 6 shows the photograph of fabricated array patch antenna.

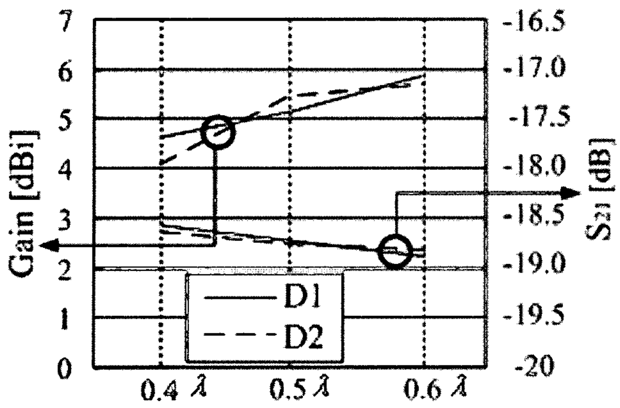


Fig. 5. Variation of the gain and S_{21} according to the distance between two elements.

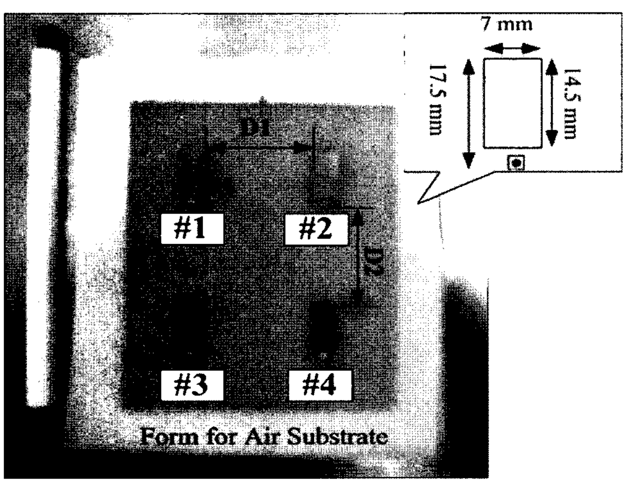


Fig. 6. Photograph of the fabricated array antenna.

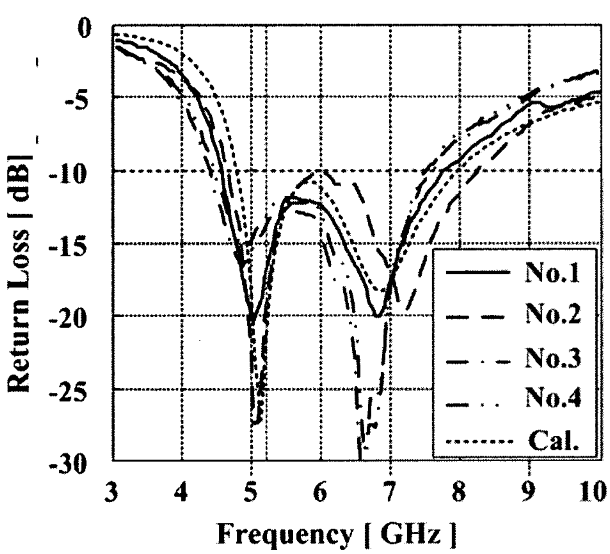
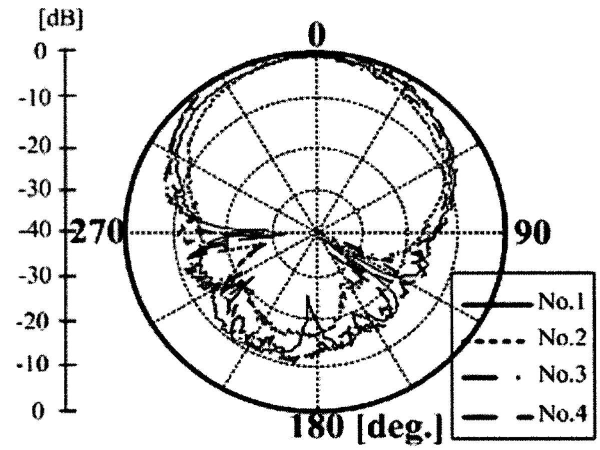
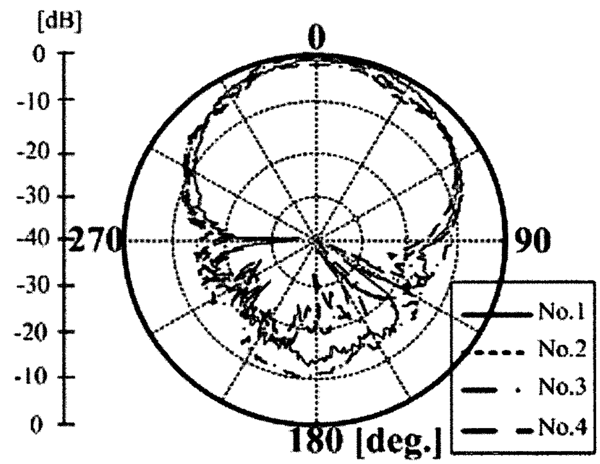


Fig. 7. Measured reflection coefficients of the fabricated array antenna.



(a) E-pie



(b) E-theta

Fig. 8. Measured radiation patterns of the fabricated 4-channel MIMO antenna at 5.25 GHz.

Ⅳ. Experimental Results

The total size of the fabricated patch array antenna is 35.6 mm×52.5 mm×5.6 mm which is considered the gain and the mutual coupling. Figs. 7 and 8 show the measured return loss and the radiation pattern of the fabricated antennas, respectively. Each element has the broad bandwidth above 62 % at below VSWR 2. The measured radiation patterns of the fabricated antennas are observed reasonable agreement with the calculated patterns. As shown in Fig. 9, the measured mutual coupling is −20 below at entitle frequency band. The proposed 4-channel MIMO antenna has not only lower coupling but also small size of the antenna. It can apply the W-LAN for home network system and MIMO system, etc.

Ⅴ. Conclusion

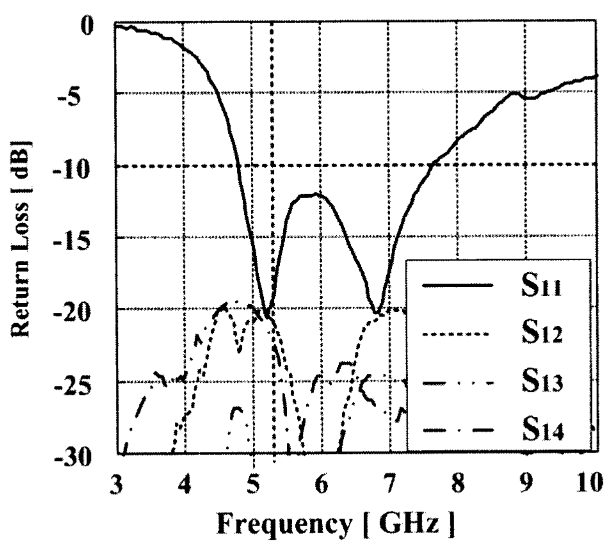


Fig. 9. Measured S-parameters of the fabricated 4-channel MIMO antenna.

In this paper, a single miniature patch antenna and its 4-channel MIMO antenna designed for the W-LAN band, respectively. The proposed single patch antenna employs probe feeding method and it is considered its current distribution for minimization antenna size. In order to obtain broad bandwidth, the stack structure with two different dielectric constants is adopted for antenna design. In measurement, it is observed a nice bandwidth at VSWR 2 for IEEE 802.11a frequency band. In array design, it is also considered relation between the gain and the mutual coupling coefficient in the case of thehorizontal array and the vertical array, respectively. Although the total size of the patch array antenna is small, it shows broad bandwidth, and its calculated antenna gain of each element is observed 5.61 dBi when four antenna elements operate for independent channel, respectively. The proposed antenna will be able to apply many application fields for MIMO and W-LAN.

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