Development of One-Sided Directional Thin Planar Antenna for 5GHz Wireless Communication Applications

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Introduction

Antennas are considered to be the largest components of a wireless device so that it is necessary to miniaturize small size and low profile antennas. Planar printed antennas such as slot antenna and microstrip antenna are attractive for their use in mobile and wireless communication systems due to their low profile compact size [1], [2]. However, for size reduction, another problem occurs. Namely, omni directional antennas such as the performance of the slot antennas are remarkably deteriorated if metal blocks like a ground plane of MMIC (Microwave Monolithic IC), RFIC (radio frequency integrated circuit) or body of a car approaches on the back of the antenna because of the electro-magnetic interference. Patch antenna, which has large ground plane, is one of the solutions to overcome these problems [2], [3]. However, radiation efficiency and bandwidth of a patch antenna decreases rapidly as the thickness of the substrate decreases; therefore, miniaturization of the patch antenna is usually carried out at the cost of the substrate thickness. Therefore, miniaturized antennas on thinner substrate are necessary for future 3-dimension packaging techniques in integrating with RF-chips. Slot antennas with ground plane are suitable for CPW-fed configuration for this purpose and the possibility is studied in this paper.

In this paper, first we design the broadband one-sided directional slot antennas with floating metal layer on the bottom side, for broadband 5GHz-band (4.9 GHz – 5.725 GHz) applications. By exploiting two resonances appeared from the slot and top metal, we realize the wide band and one-sided directional radiation without any external matching circuits that presented for narrow band applications (@2.4GHz in Ref. [4] by the authors. We designed and simulated the proposed antenna by using the commercial electro-magnetic (EM) field simulator (Ansoft; HFSS, ver.10). Furthermore, comparison of the simulated results with that of experimental using the Friis transmission formula shows the good agreement, which verifies the concept employed in this paper.

Design of Proposed One-Sided Directional Slot Antenna

Fig. 1 shows the layout of the CPW-fed slot antenna on FR4 substrate with one-wavelength center feed line which has a conductor-backed configuration. At first, *L*-type slot antenna is designed whose parallel resonant frequency is around 5 GHz. Next, the length of the top layer (L_{F1}) is chosen to be a λ/2 at 5 GHz-resonance. Namely, both slot section and another edge is an open ended,

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respectively. Next, in order to suppress the resonance of the bottom floating metal layer and obtain the 10dBi peak gain, L_{F2} is selected so that bottom layer does not resonate at around 5 GHz. Finally, length of the CPW feed line (F) is optimized in such as way that Z_{in} in Fig.1 is approximately to be 50Ω at 5GHz. The size of L_1, L_2, L_{F1}, L_{F2}, and F are 10mm, 8.5mm, 12 mm, 5 mm and 11 mm, respectively. The total antenna size is 29 mm x 22 mm, which is 48% smaller than that of patch antenna [3].

To illustrate the performance deterioration due to the thinner substrate, Table 1 shows the comparison between the simulated performance by HFSS between a patch antenna and the proposed antenna. This clearly shows that the simulated gain of the patch antenna degraded rapidly than that of the proposed antenna. Fig. 2 shows the EM simulated electric field distribution of top and bottom floating metal layer, respectively where the top layer resonates whereas the bottom layer doesn't, and this suppresses the radiation in the backward direction.

Comparison with Experimental Results

Fig. 3 shows the comparison of normalized radiation pattern of the antenna at different frequencies. The directivity for forward direction is larger than that of backward direction in simulated (Fig. 3(a)) and measured (Fig. 3(b)). Both results are in good agreement verifying the developed antenna has the directivity only in one direction. Fig. 4 shows the comparison of the return loss $|S_{11}|$ of the antenna where measured $|S_{11}|$ is obtained less than –20dB which is better than the simulation.

Discussion on Measured Results

In this section, we discuss the gain measurement of the antenna using the Friis' transmission formula by using the measured S-parameters. The relations of two antennas, which has transmitted power P_t and received power P_r is given by,

$$P_r = |S_{21}|^2 P_t = \left(\frac{\lambda}{4\pi d}\right)^2 G_t G_r P_t \qquad (1)$$

where G_t and G_r are the antenna gain of the transmitted and received antennas, respectively, λ is the wavelength, and d is the distance. In this situation, our two slot antennas are connected to the VNA, where the transmitted antenna is fixed for the forward direction, namely G_t is constant. The received antenna is connected both forward and backward direction, and measure $|S_{21}|$, respectively. From Eq. (1), the frequency dependency of G_r is calculated as shown in Fig. 6 where estimated gain is in fair agreement with the measured results in high frequency range. Because the raw data of $|S_{21}|$ of backward direction is very small values, some experimental errors may be encountered especially in low frequency range. However, the EM simulated gain is consistent of the measured gain irrespective of the frequency. In the simulation, the Forward/Backward (F/B) ratio of the antenna is almost 10 dBi in the 5 GHz band and this tendency is well reproduced by the measurement in the figure.

Conclusion

In this paper, the one-sided directional slot dipole antenna with for 5 GHz-band application have been designed and experimentally verified. The antenna size is 22 mm x 29 mm, which is smaller than a patch antenna at the same frequency. The measured radiation patterns are in the good agreement with the simulation which shows the effectiveness of the presented technique to realize on-sided directional antenna. Such antennas are very advantageous than that of a patch antenna for mounting 3-dimensional packages or layer structures in miniaturized RF-front end in thinner substrate.

Acknowledgement

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Table 1: Influence of the simulated antenna gain by HFSS due to the thickness of the substrate.

Thickness of substrate, *d* [mm]	0.4	0.8	1.6
Antenna Gain of proposed antenna (dBi)	2.86	4.35	5.25
Antenna Gain of patch antenna (dBi)	-0.51	3.89	4.29

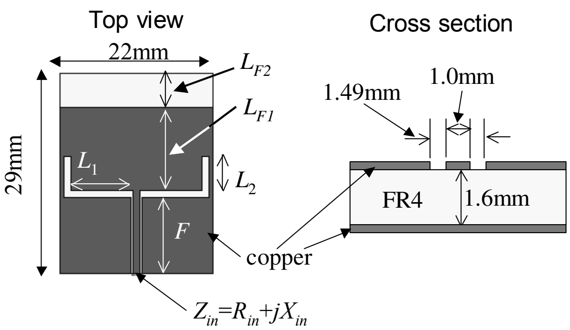


Fig. 1. Layout of the one-sided directional antenna with floating metal plane.

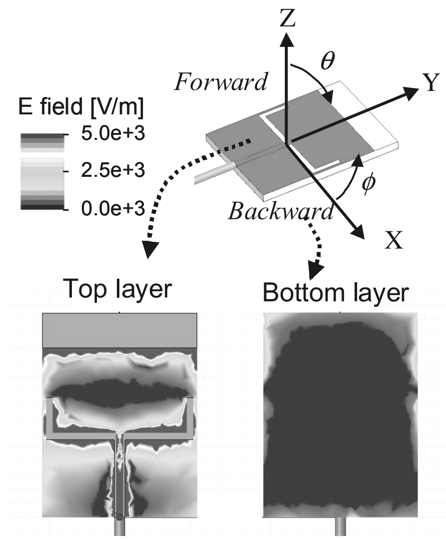
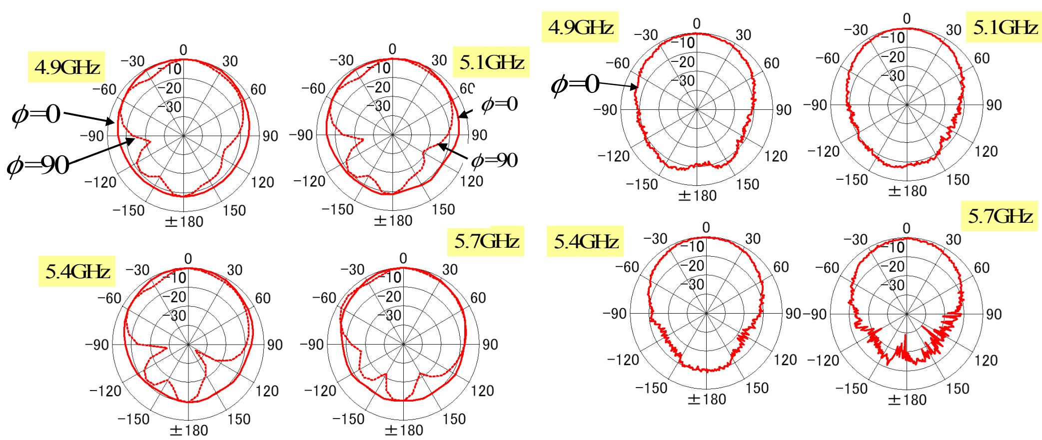


Fig. 2. EM simulated electric field distribution of top and bottom floating metal layer, respectively.



(a) Simulation by HFSS

(b) Measured in anechoic chamber

Fig. 3. Normalized radiation pattern of the one-sided directional proposed antenna.

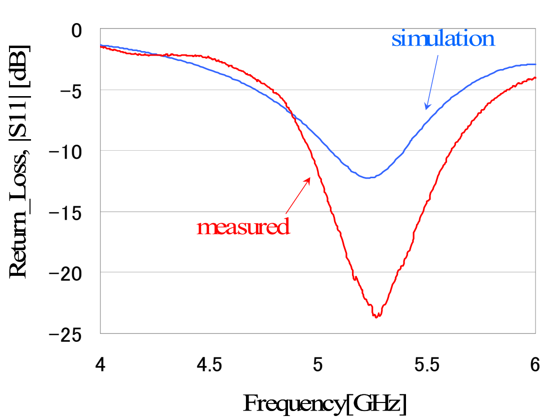


Fig. 4. Return loss ($|S_{11}|$) of the one-sided directional antenna.

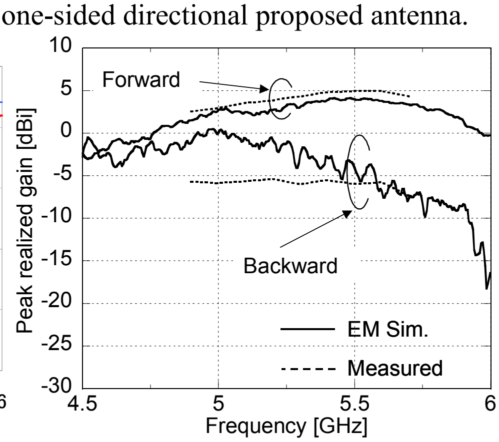


Fig. 5. Comparison of the measured and calculated peak realized gain of forward and backward radiation, respectively.