Compact Size Wideband Microstrip Antenna Element for Repeater and Base Stations at 2 GHz

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Abstract

A compact size microstrip antenna element using FR-4 substrate is proposed for use in repeater and base stations. Two stacked patches are aperture-coupled by two split feedlines. Rectangular stubs on the split feedlines are laid under the aperture and have the effect of considerably lowing the magnitude of S_{11} [dB] and broadening impedance bandwidth. The designed structure has been fabricated and measured. Based on 20 dB, the return loss bandwidth is about 16.8 % (1.86 GHz~2.20 GHz), which covers the frequency range assigned for IMT-2000 with a large margin. The overall dimension of the proposed antenna structure is 37 mm×41 mm×19 mm (very compact). The antenna gain is more than 7.5 dBi over the required frequency range.

Ⅰ. INTRODUCTION

Recently, many design techniques for wideband microstrip antennas have been introduced. The aperture-coupled microstrip antenna using stacked patches can provide bandwidths on the order of 30~40 %[1]. Recent papers[2]~[3] show that wide bandwidth more than 50 % can be achieved using capacitively coupled feeds or some slits on the patch using coaxial feeds. The impedance bandwidth of these antennas is usually based on 10 dB return loss. Based on 20 dB return loss, it becomes much narrower, typically 30 % of that based on 10 dB return loss. To obtain large bandwidth based on 20 dB return loss with a modest volume is considered to be a difficult job. In this paper, we propose a compact size aperture-coupled microstrip antenna which uses rectangular stubs on the split feedlines. Instead of expensive Teflon substrate, we use the FR-4 substrate, which can be purchased at a much lower price. Although the use of a high relative permittivity (ε_r = 4.7) substrate usually restricts the operation bandwidth, the 20 dB return loss bandwidth is obtained safely over the frequency range assigned for IMT-2000 (1.92 GHz~2.17 GHz), modifying the feeding structure proposed in[4]. The feedline for the near-resonant size aperture is split into two and has rectangular stubs below the aperture for broadband operation. In section Ⅱ, the promising effects of these rectangular stubs are analysed by a parameter study varying their width and length. The designed microstrip antenna has been fabricated and measured. The measured impedance matching is compared with simulation over the frequency range of interest. The measured radiation pattern is also compared with the simulated one.

Ⅱ. SIMULATED AND MEASURED RESULTS

Fig. 1(a) and (b) show the antenna geometry proposed for use in IMT-2000 repeaters and base stations. The stacked patches are etched on FR-4 substrate with relative permittivity of 4.7 and thickness of 1 mm, which is available everywhere and usually very cheap. We also use the same material for the feedline. The overall size is about 37 mm×41 mm×19 mm (very compact). The dimensions of the stacked patches are shown in Table 1. The foams (ε_r = 1.07) are used to keep the height of two patches. The relative permittivities and their thickness are summarized in Table 2. The optimized dimensions of the proposed split feedlines are calculated by the Ensemble 5.1.

The split feedlines have been reported in [4] to be better than a single feedline for broadband operation. We found that the impedance bandwidth is increased even wider by using rectangular stubs on the split feedlines. To see this affect, we have simulated the structures with a single feedline and split feedlines, respectively. The results of simulation are summarized in the following paragraphs. Fig. 2(a) shows the optimized dimensions of a single feedline and split feedlines (with fixed P_{W1} = 39.2 mm, P_{L1} = 43.2 mm, P_{W2} = 35.8 mm, P_{L2} = 39.8 mm). The relative permittivities and thickness of the substrates are the same as in Table 2. Fig. 2(b) shows the simulated return loss using a single feedline and split feedlines. Good impedance matching is obtained by optimizing the width, and length of the stub, and the aperture length(L_a) (with fixed W_a = 3.2 mm). Based on 20 dB, the bandwidth of split feedlines are shown to be (about 100 % increased) broader than that

Manuscript received March 23, 2001; revised May 10, 2001.
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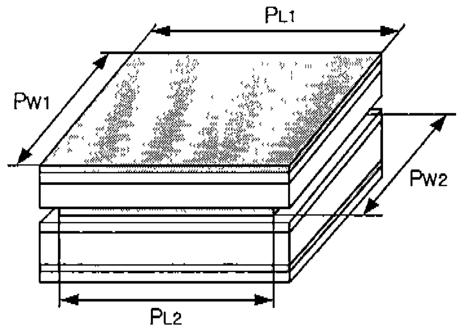
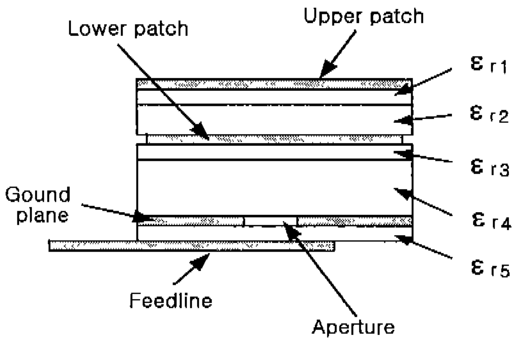


(a)



(b)

Fig. 1. Geometry of the proposed antenna.

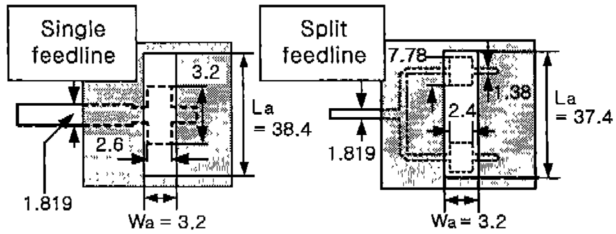
Table 1. Dimensions of the stacked patches

Upper patch length (P_{L1})	41.2 mm
Upper patch width (P_{W1})	37.2 mm
Lower patch length (P_{L2})	38.8 mm
Lower patch width (P_{W2})	34.8 mm

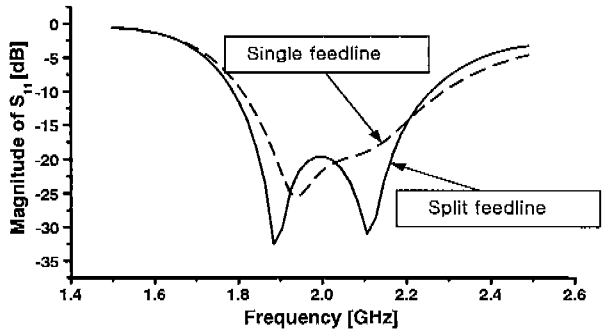
Table 2. Relative permittivity and thickness of the substrates

Description	Relative permittivity	Thickness(mm)
ε_{r1}	4.7	1
ε_{r2}	1.07	5.5
ε_{r3}	4.7	1
ε_{r4}	1.07	11
ε_{r5}	4.7	1

of a single feedline. The split feedlines does not suffer from the increased Cross-pol introduced by a single feedline[4].



(a) Dimensions of the feedlines (Unit : mm)



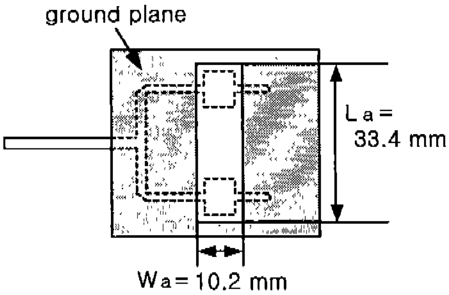
(b) Return loss

Fig. 2. Simulated return losses of a single feedline and split feedlines.

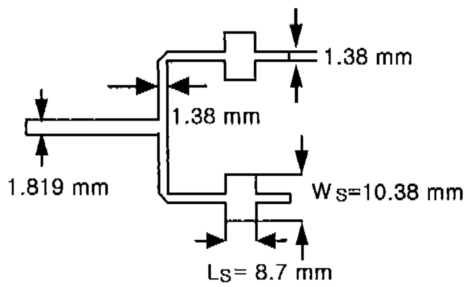
Fig. 3(a) shows the optimized dimensions of the aperture (W_a : aperture width, L_a : aperture length). Fig. 3(b) shows the optimized dimension of split feedline and rectangular stubs (W_s : stub width, L_s : stub length). In Fig. 4(a), the simulated return loss is plotted as a function of frequency with W_s being changed from 0 mm to 12.38 mm (with fixed L_s = 8.7 mm). As W_s increases up to 10.38 mm, the magnitude of S_{11} [dB] is considerably decreased down to about 30 dB and its bandwidth based on 20 dB becomes larger. But beyond W_s = 10.38 mm, the per- formance is deteriorated.

In Fig. 4(b), the simulated return loss is plotted as a function of frequency with L_s being changed from 0 mm to 11.2 mm (with fixed W_s = 10.38 mm). In this case, similar trends as in Fig. 3(a) are obtained. Optimized size of L_a and W_a are 8.7 mm and 10.38 mm, respectively.

In Fig. 5(a), the simulated return loss is plotted as a function of frequency with W_a being changed from 6.2 mm to 12.2 mm (with fixed L_a = 33.4 mm). Based on 20 dB, the bandwidth



(a) Dimension of the aperture

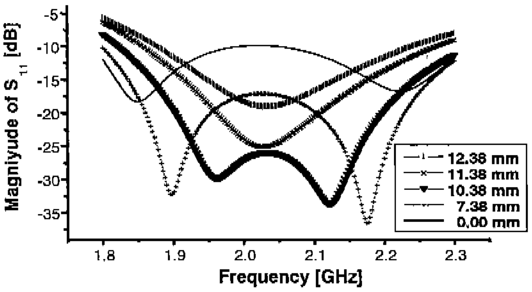


(b) Dimensions of the feedlines

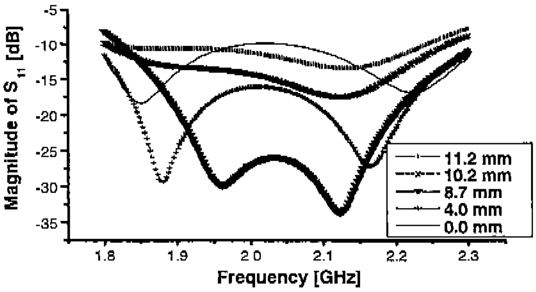
Fig. 3. Optimized dimensions of the feedline.

is largest when W_a = 10.2 mm. In Fig. 5(b), the return loss is plotted as a function of frequency with L_a being changed from 30.4 mm to 34.8 mm (with fixed W_a = 10.2 mm). Based on 20 dB, the bandwidth is largest when L_a = 33.4 mm. The optimum of aperture is W_a = 10.2 mm and L_a = 33.4 mm provided that all other dimensions remain unchanged. The designed antenna has been fabricated and measured. In Fig.6, the simulation and measurement magnitudes of S_{11} [dB] are compared with each other. They are shown to be in good agreement. Based on 20 dB, the simulated bandwidth is about 14.2% (1.9 GHz~2.19 GHz) and the measured one is about 16.8% (1.86 GHz~2.195 GHz). Based on 10 dB, the simulated bandwidth is about 24% (1.82 GHz~2.31 GHz) and the measured one is about 33.8% (1.78 GHz~ 2.48 GHz). The comparison between the simulated and measured bandwidth is summarized in Table 3.

Fig. 7(a) and (b) show the comparison between the simulated and measured Co-pol radiation patterns in E-plane and H-plane at the frequency of 1.92 GHz and Fig. 7(c) and (d) show those at the frequency of 1.98 GHz. Simulation and measurement are in reasonably good agreement. The difference of beam width in the H-plane comes from the fact that simulation has been performed based on the infinite ground plane but the fabricated

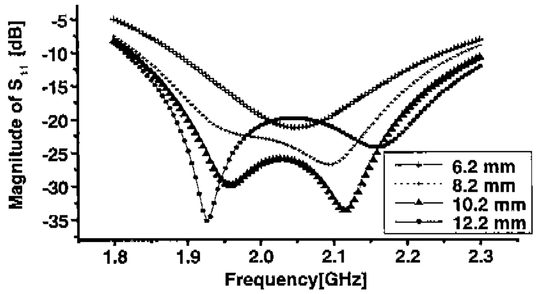


(a) L_s = 8.7 mm

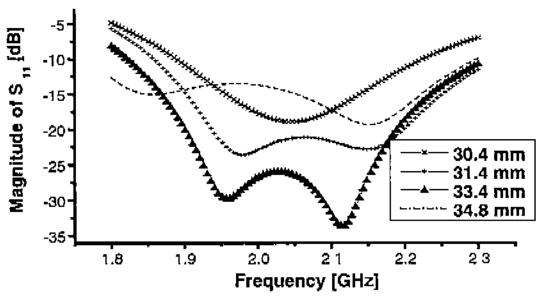


(b) W_s = 10.38 mm

Fig. 4. Simulated return loss as a function of frequency with varying W_s and L_s.



(a) L_a = 33.4 mm



(b) W_a= 10.2 mm

Fig. 5. Simulated return loss as a function of frequency with varying W_a and L_a.

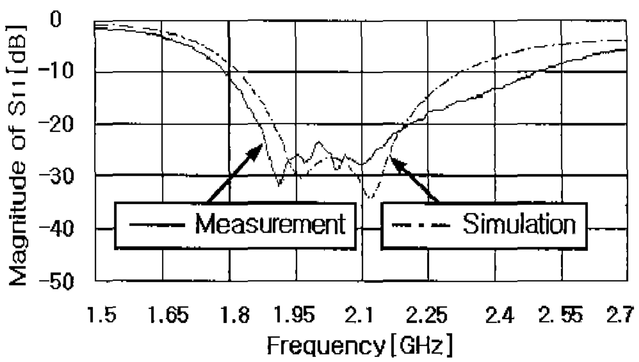


Fig. 6. Simulated and measured magnitude of S_{11} [dB].

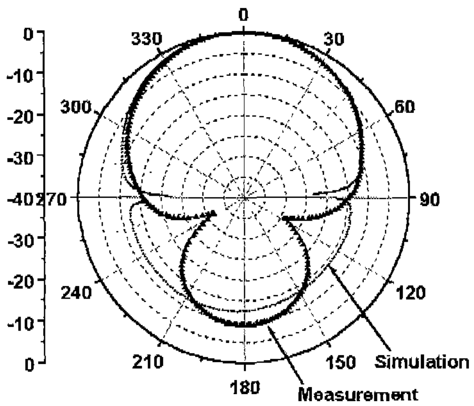
antenna has a finite ground plane. The relatively large FBR (Front to Back Ratio) is due to the near-resonant aperture size. Thus, use of a reflector is recommend. The Cross-pol level is below 30 dB in the two main planes and is not shown in Fig. 7. Fig. 8(a) and (b) show the photographs of radiating part and feeding part of the proposed antenna, respectively.

Table 3. Comparison between the simulated and measured return loss bandwidth

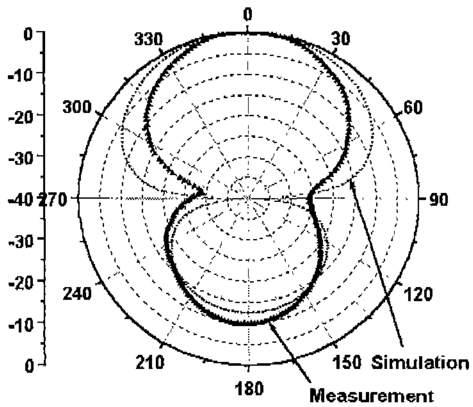
Description	Return loss bandwidth	
	Based on 20 dB	Based on 10 dB
Simulation	14.2 % 1.90~2.19 GHz	24 % 1.82~2.31 GHz
Measurement	16.8 % 1.86~2.2 GHz	33.8 % 1.78~2.48 GHz

Ⅲ. CONCLUSION

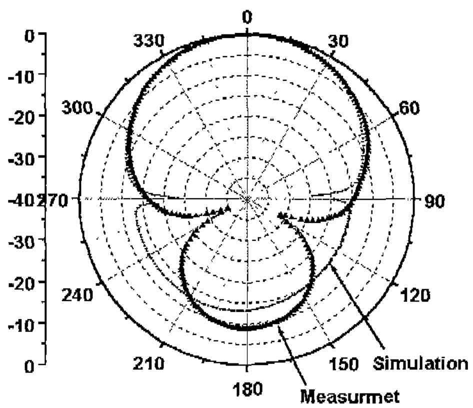
In this paper, a compact size microstrip antenna using the split feedlines with rectangular stubs is proposed for use in



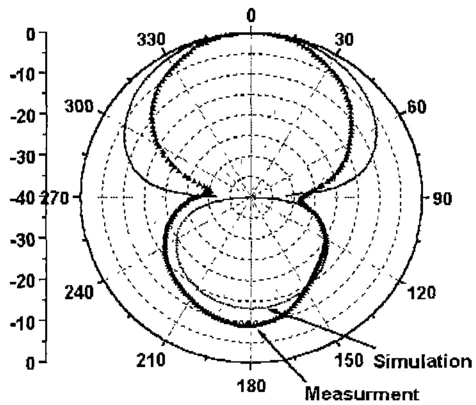
(a) E-plane at 1.92 GHz



(b) H-plane at 1.92 GHz

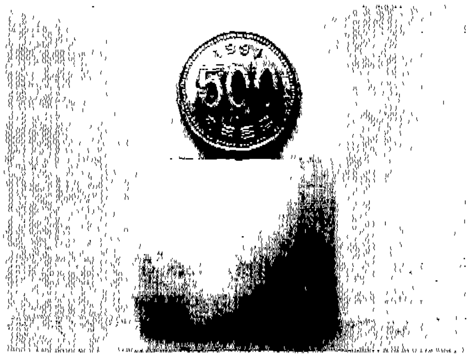


(c) E-plane at 1.98 GHz

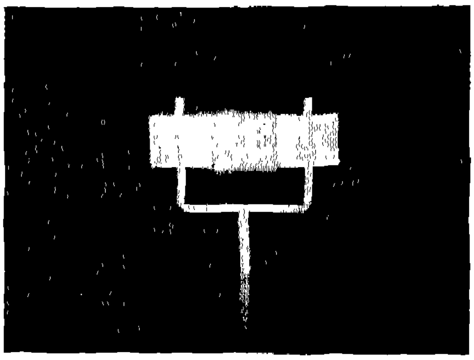


(d) H-plane at 1.98 GHz

Fig. 7. Simulated and measured radiation pattern.



(a) Radiating part



(b) Feeding part

Fig. 8. Photographs of the proposed antenna.

IMT-2000 repeater and base stations. The FR-4 substrates are used to decrease the production cost. The measured 20 dB return loss bandwidth is 16.8 % and the antenna gain is about 7.5 dBi~8.1 dBi. The promising effects of rectangular stubs on the split feedlines for wideband operation has been shown. The Cross-pol level is very low and the antenna size is 37 mm × 41 mm × 19 mm (very compact). The simulated return loss and radiation pattern are in good agreement with the measured ones.

This work was financially supported by Kyunghee University.

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