5 GHz Bow-tie-shaped Meander Slot Antenna

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Abstract

In this paper, we propose a bow-tie-shaped meander slot antenna fed by a microstrip line to achieve compact size as well as wideband characteristic. While conventional bow-tie slot antennas exhibit wide band characteristic, they have relatively large size. On the other hand, the meander slot antennas are very small, but they reveal quite narrow bandwidth (typically less than 1 %). To realize miniaturized antennas having large bandwidth, combination of the bow-tie slot and the meander slot geometries is proposed in this paper. Theoretical results show that the proposed antenna with uniform slot width is 65.5 % smaller than that of the conventional bow-tie antenna in size, while the bandwidth is 3 times larger than that of the meander slot antenna. Moreover, the non-uniform slot width antenna shows 60 % smaller in size and about 3.5 times wider in bandwidth than the previous antennas. Measured antenna performance reveals excellent agreement with the predicted values.

Key words : bow-tie-shaped meander slot antenna, meander slot antenna, miniaturized antenna.

Ⅰ. Introduction

With the development of radio communication technologies, people are further interested in how to use the limited frequency resources more efficiently. For this reason, researches on 5 GHz Industrial/Scientific/Medical (ISM) band are in rapid progress. In the United states, 5 GHz frequency band is allocated to build up Unlicensed National Information Infrastructure (U-NII), and researches on the same frequency band are also conducted in Europe and Japan for Hyper Local Area Network (Hyper-LAN) system as well as data communication. In Korea, 5 GHz ISM band is utilized for small area network system, such as Wireless Local Area Network (WLAN) and Wireless Home Networking.

As microelectronic technology develops, there is a growing tendency for hardware of the system to be smaller in size. Therefore, antennas should be developed to meet this requirement such as smaller size, light-weight, and economical efficiency. Also, the required antenna must have a wide bandwidth characteristic to deal with the large bandwidth of data stream.

Many techniques have been proposed for size reduction and bandwidth enhancement. There are well-known techniques to reduce the size of antenna; (1) use of high dielectric substrate [1], (2) application of resistive/reactive loading between patch and ground, (3) shorted patch[2], (4) use of slow-wave structure [3] and so on. In addition, there are techniques to increase the bandwidth of antenna; (1) use of low dielectric substrate[4], (2) increase in substrate thickness[4], (3) use of impedance- matching techniques[5], (4) use of edge-coupled parasitic patches[6], (5) aperture-coupled stack[7] and so forth[8]. However, the improvement of the one characteristic normally results in the degradation of the other.

In this paper, the novel miniaturized broadband microstrip-fed slot antenna geometry is proposed on the basis of bow-tie shape. Microstrip-fed slot antennas have the advantage of the large bandwidth and good impedance matching[9]. The bow-tie slot antenna has broadband characteristic[10], but its dimension is quite large. Most meander slot antennas have small size[11],[12], while the bandwidth is relatively narrow. The geometrical advantages of both antennas are combined in the proposed design and as a result, wide operating bandwidth is achieved by a bow-tie-shaped outline of the slot and the size reduction is realized by meandered slot.

Ⅱ. Antenna Design

A microstrip-fed slot antenna consists of a slot cut in the ground plane and microstrip feed line on the other side [13]. Fig. 1 (a) and (b) show the top and side views of the generic microstrip-fed slot antenna geometry.

Four different antennas operating at 5.25 GHz are designed on Teflon substrate (dielectric constant = 2.3, thickness = 0.508 mm). The bow-tie slot antenna as well as the meander slot antenna are shown in Fig. 2 (a) and (b), respectively. The size

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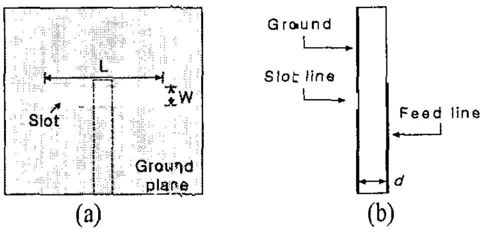


Fig. 1. Generic microstrip fed slot antenna geometry. (a) top view, (b) side view.

of the bow-tie slot antenna is H (13.82 mm)×V (9.08 mm), while the meander slot antenna is H (5.5 mm)×V (5.15 mm) with 0.5 mm slot width and total slot length is about 0.9 λ_g.

The proposed design of bow-tie-shaped meander slot antenna is shown in Fig. 2 (c) and (d). This antenna geometry is a variation of the conventional meander slot antenna incorporating bow-tie shape. The total slot length of the conventional microstrip fed slot antenna is about 0.5 λ_g, however, the total slot length of the meander slot antenna and proposed antenna is about 1.0 λ_g due to corner effect and mutual coupling. The slot width of the proposed antenna is adjusted not to affect the antenna characteristics, such as resonant frequency, bandwidth and radiation pattern. In Fig. 2 (c), the antenna has uniform slot width, while the antenna shown in Fig. 2 (d) has non-uniform slot width to achieve the wider bandwidth than that of the uniform slot width one. As the slot width becomes wider, bandwidth becomes broader with increasing overall antenna size. Thus, the size and length of non-uniform slot width antenna are slightly larger than those of the uniform slot width antenna. In Fig. 2 (d), we use the small slot, which is bent a little inside to adjust the resonant frequency and keep the size small. The size of uniform slot width antenna is H (9.5 mm)×V (4.55 mm) and total length of the slot is about 0.9 λ_g. The slot width is equal to the width of a meander slot antenna (W=0.5 mm). However, for the non-uniform slot width antenna, the width of the center slot W_0 is 0.6 mm, while the width of the other parts W_1 and W_2 are fixed to 0.8 mm. The width of the gap G is 0.2 mm and resultant size of the overall antenna is H (9.8 mm)×V (5.25 mm). The length and width of the feed line are adjusted to achieve a good input match.

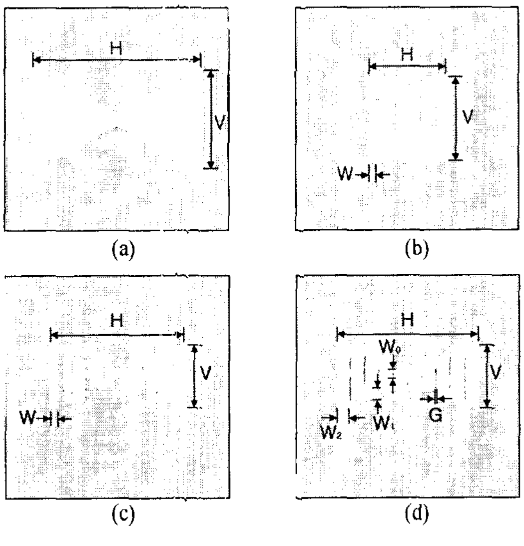


Fig. 2. Antenna geometries. (a) Bow-tie slot antenna, (b) Meander slot antenna, (c) Proposed antenna (uniform slot width), (d) Proposed antenna (non-uniform slot width).

Ⅲ. Numerical Results

The resonant properties of the antennas have been simulated using the method of moment(MOM) based commercial software. Simulated results of four different antennas are shown in Fig. 3 and Table 1 summarizes the bandwidth and corresponding antenna sizes. The bow-tie slot antenna is relatively large, even thought it has broad bandwidth about 407 MHz (7.75 %). The meander slot antenna is quite small compare to the other types of antennas (5.5 mm×5.15 mm), but its bandwidth is extremely narrow, typically about 40 MHz (0.76 %). The size of the proposed uniform slot width antenna is about 65.5 % smaller than that of the bow-tie slot antenna, while 10 dB bandwidth is about 3 times wider than that of the meander slot antenna. In addition, the bandwidth of the non-uniform slot width bow-tie-shaped meander slot antenna is about 25 MHz wider than that of the uniform slot width antenna. Moreover, the size is about 59 % smaller than that of the bow-tie slot antenna. However, its size is a little larger than that of the uniform slot width antenna, because the slot width is wider and slot length is increased. As the simulated results, the proposed antennas have been successfully implemented the size and bandwidth.

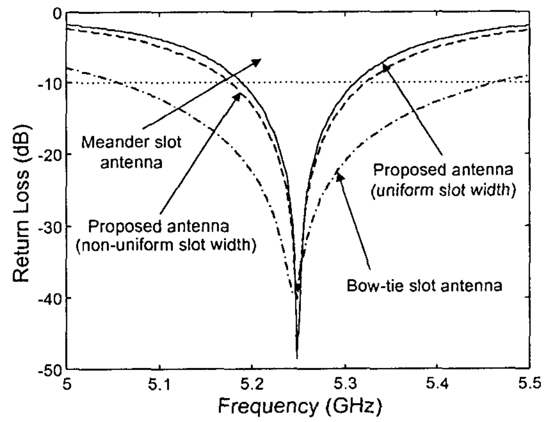


Fig. 3. Simulated results of each antenna.

Table 1. Antenna size and simulated bandwidth characteristics.

	Size (mm)	Bandwidth (MHz)
Bow-tie antenna	13.82×9.08 [100 %]	407 [7.75 %]
Meander slot antenna	5.5 ×5.15 [22.5 %]	40 [0.76 %]
Uniform slot width antenna	9.5 ×4.55 [34.5 %]	118 [2.25 %]
Non-uniform slot width antenna	9.8 ×5.25 [41 %]	143 [2.72 %]

Ⅳ. Experimental Results

Based on the simulated results, antennas are fabricated on the Teflon substrate (dielectric constant = 2.3, thickness = 0.508 mm) and the simulated and measured data of the antennas are presented in Fig. 4, Fig. 5, Fig. 6, Fig. 7 and Fig. 8. The size of the ground plane is chosen large enough not to affect the antenna performance (greater than $\lambda_g/4$).As shown in Fig. 4, fabricated antennas reveal almost identical resonant frequencies with the simulation data and have wider bandwidth than the simulated ones.

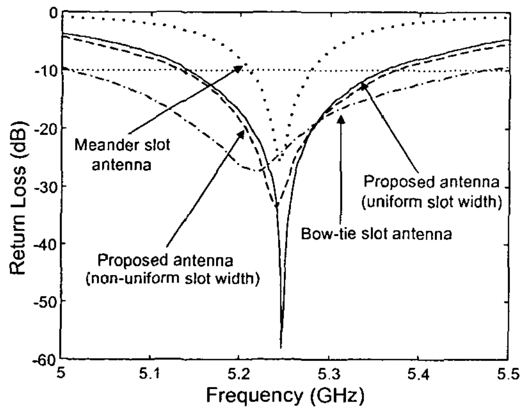


Fig. 4. Measured return loss of the fabricated antennas.

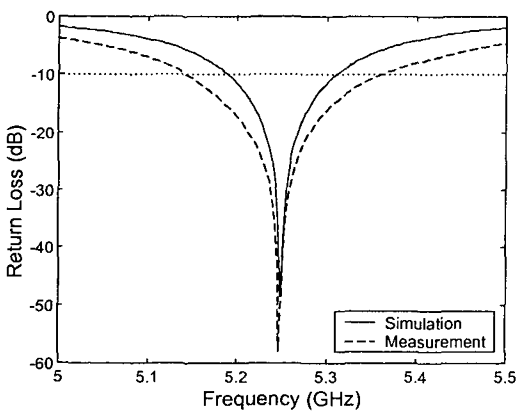


Fig. 5. Simulated and measured return loss of the uniform slot width antenna.

Table 2. Simulated and measured results of the uniform slot width antenna.

	Resonant frequency (GHz)	Bandwidth (MHz)
Simulation	5.25	118 (5191~5309)[2.25 %]
Measurement	5.25	218 (5142~5360)[4.13 %]

Simulated and measured return losses of the uniform slot width bow-tie-shaped meander slot antenna are presented in Fig. 5, and reveal excellent agreement, even though the measured return loss has broader bandwidth (100 MHz) due to various losses, such as dielectric and conductor losses. Table 2 summarizes the simulated and measured results.

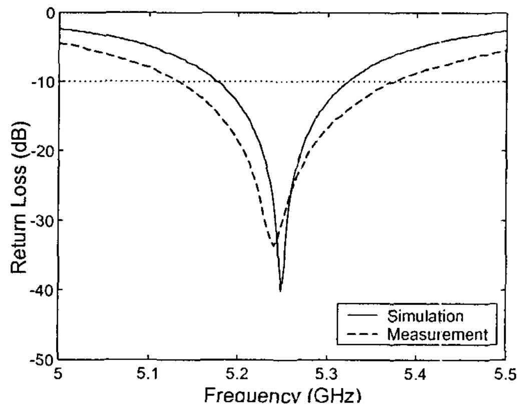


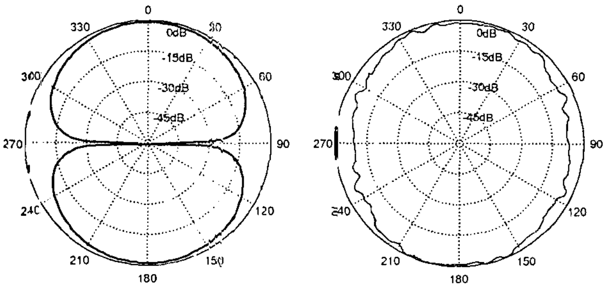
Fig. 6. Simulated and measured return loss of the non-uniform slot width antenna.

Table 3. Simulated and measured characteristics of the non-uniform slot width antenna.

	Resonant frequency (GHz)	Bandwidth (MHz)
Simulation	5.25	143 (5178~5321)[2.72 %]
Measurement	5.24	235 (5135~5370)[4.48 %]

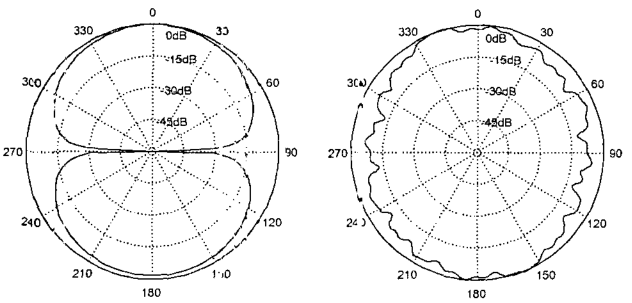
Fig. 6 depicts the return loss characteristics of the bow-tie-shaped meander slot antenna with non-uniform slot width. The measured and simulated data agree very well, even through the measured bandwidth is slightly broader as summarized in table 3. The measured bandwidth is about 92 MHz wider than that of the simulated one due to the same reason for the previous case. In addition, the bandwidth of the non-uniform slot width antenna is about 17 MHz wider than that of the uniform slot width one.

The radiation patterns of the proposed antenna are measured and the results are compared with calculation as presented in



(a) Simulation (b) Measurement

Fig. 7. Normalized E-field radiation pattern of the uniform slot width antenna.



(a) Simulation (b) Measurement

Fig. 8. Normalized E-field radiation pattern of the non-uniform slot width antenna.

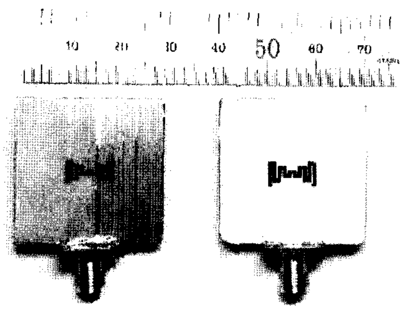


Fig. 9. Fabricated antennas.

Fig. 7. For the uniform slot width meander slot antenna as well as the non-uniform width bow-tie-shaped one, the measured radiation patterns do not show any nulls at 90° and 270° directions due to the finite size ground plane of the fabricated antennas. The ripples in the measured radiation patterns are also rooted on the similar reason.

The fabricated antennas, on the Teflon substrate (dielectric constant = 2.3, thickness = 0.508 mm) are shown in Fig. 9.

V. Conclusion

We proposed a novel bow-tie-shaped meander slot antenna for 5 GHz applications. The proposed antenna is combined with the bow-tie slot antenna having large bandwidth and the meander slot antenna. Simulated results show that the bandwidth of the uniform slot width bow-tie-shaped meander slot antenna is 3 times wider than that of the meander slot antenna, and the size is 65.5 % smaller than that of the bow-tie slot antenna. Moreover, non-uniform slot width bow-tie-shaped meander slot antenna has about 3.5 % wider bandwidth and 60 % smaller size.

The measured bandwidth is about 100 MHz larger than the simulated antennas due to various loss mechanisms. The bandwidth of the fabricated uniform slot width bow-tie-shaped meander slot antenna is about 4.13 % (218 MHz) and the non-uniform slot width bow-tie-shaped meander slot antenna is about 4.48 %(235 MHz). The non-uniform slot width bow-tie-shaped meander slot antenna has wider bandwidth and slightly larger size than the uniform slot width antenna. Consequently, both antennas have been successfully implemented in the size and bandwidth.

From the above discussion, we can conclude that the proposed bow-tie-shaped meaner slot antennas can be applicable to the 5 GHz small area network system.

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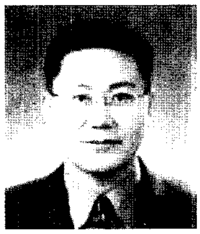

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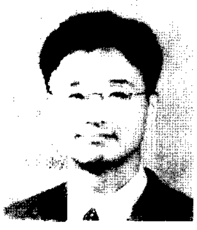

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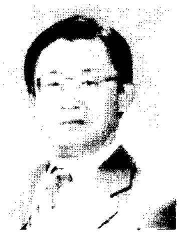

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