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Bandwidth Enhancement of a Meander Slot Antenna with Harmonic Suppression

고조파 억압 특성을 갖는 미앤더 슬롯 안테나의 대역폭 향상에 관한 연구

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Abstract

Bowtie shaped meander slot antenna with harmonic suppression is designed and demonstrated experimentally. A substrate with height of 0.508 mm and relative permittivity of 2.5 is used, and the fundamental resonant frequency is 5.536 GHz. With thin conductor line in the antenna, harmonic suppression characteristic is obtained, and return losses at the 2nd and 3rd harmonic frequencies are −0.56 dB and −1.9 dB, respectively. Also, bowtie shape is applied to the antenna design for bandwidth enhancement, and the resulting bandwidth is 3.7 %, which is about three times wider than the reported meander slot antenna with harmonic suppression[1],[2].

요 약

고조파 억압 특성을 갖는 보우타이 형태의 미앤더 슬롯 안테나를 설계, 제작 및 측정하였다. 비유전율 2.5 및 0.508 mm 의 높이를 지니는 기판을 사용하였으며, 공진주파수는 5.536 GHz 이다. 안테나 내부에 금속선로를 삽입하여 고조파 억압 특성을 얻어내었고, 그 결과 제 2차 및 3차 고조파에서의 반사손실은 각각 -0.56 dB 및 -1.9 dB 였다. 또한, 안테나 설계시 보우타이 형태를 적용하여 대역폭 향상 효과를 얻을 수 있었으며, 그 결과 기존의 고조파 억압 특성을 갖는 미앤더 슬롯 안테나[1],[2]와 비교하여 3배 정도 향상된 3.7 % 의 대역폭을 보였다.

Key words : Bowtie, Meander, Harmonic

Ⅰ. Introduction

Harmonic signals created by nonlinear amplifier cause EMI(Electromagnetic Interference) and IMD(Intermodulation Distortion), and lower the efficiency of the amplifier. Thus, additional harmonic tuning circuit such as filter is required, leading to a bulky size of a system. To solve this problem, active integrated antenna (AIA) has been studied over the last few years for its good efficiency, compactness, high linearity, and other high functionality in RF front ends[3]~[5]. In AIA design, the antenna element operates as both a radiator and a part of the tuning network to suppress the harmonics at the output of the amplifier. Therefore, without any additional harmonic tuning circuits such as filters, the system can provide high efficiency, compactness, and solution to EMI problem.

However, the reported conventional AIA system cannot be used in practical mobile communication applications since the used antenna elements are consider-

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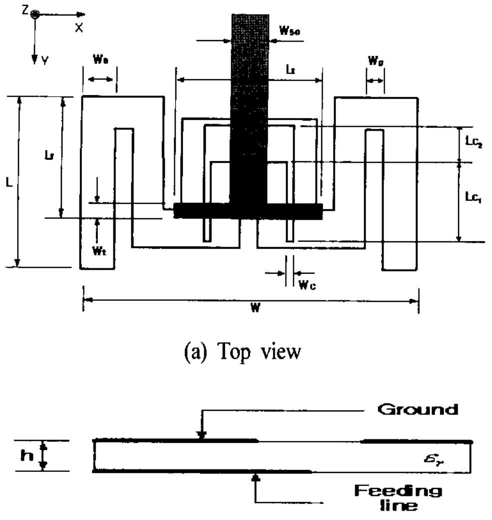


(a) Top view

(b) Side view

Fig. 1. Configuration of the proposed antenna.

ably large in size and do not provide an excellent harmonic suppression[6]~[9]. Harmonic signals are not effectively suppressed in very wide frequency band, and ripples exist in return loss. In order to overcome this problem, a meander slot microstrip antenna which provides both compactness for mobile communication and the excellent harmonics suppression for integration with the output of the amplifier was recently proposed[1],[2]. Nevertheless, the antenna has a narrow bandwidth of 1.7 %, which is an inherent problem of the small-sized antenna, and needs bandwidth improvement.

In this paper, maintaining its small size and excellent harmonic suppression characteristic, the antenna with much enhanced bandwidth is proposed. Conventional bowtie slot antenna has broadband characteristics, but its dimension is quite large. In contrast, most meander slot antennas have small size, but the bandwidth is relatively narrow. By applying bowtie shape to meander slot antenna, both of small size and broadband characteristics can be obtained[10].

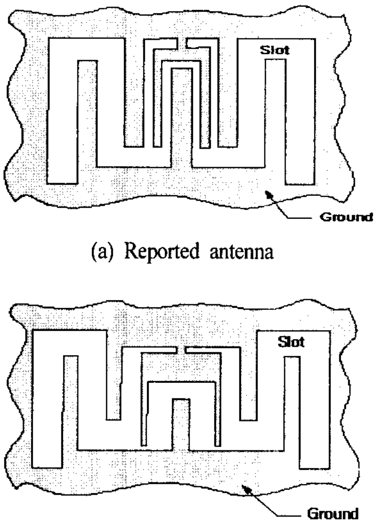
Ⅱ. Antenna Design

The proposed antenna is shown in Fig. 1. A substrate with height of 0.508 mm and relative permittivity of 2.5 is used, and the antenna is composed of a meandered slot line with inserted conductor line on the ground plane and a T-shaped microstrip feeding line on the other side.

The meandered line antenna requires almost 1 resonant length just as the conventional patch antenna. To obtain the required resonant length within the smallest dimensions, several narrow slits are inserted into the rectangular patch. It leads to a greatly lengthened current path for a fixed dimension, resulting in lowered resonant frequency. Therefore, great size reduction for the antenna can be obtained[11],[12].

Although most meander slot antennas have small size, the bandwidth is relatively narrow. This inherent problem can be alleviated by combining meander and bowtie geometries[10]. In this work, bowtie shaped meander slot line is used as shown in Fig. 1.

To verify the effect of bowtie configuration, both of the reported meander slot antenna with harmonic suppression[1],[2] and the proposed bowtie shaped meander slot antenna with harmonic suppression, shown in Fig. 2, are simulated with IE3D simulation tool. Return losses versus frequency are shown in Fig. 3. As can be seen, the proposed antenna has approximately three times wider bandwidth than the reported one, and respective numerical simulation result for both antennas



(a) Reported antenna

(b) Proposed antenna

Fig. 2. Antenna geometries.

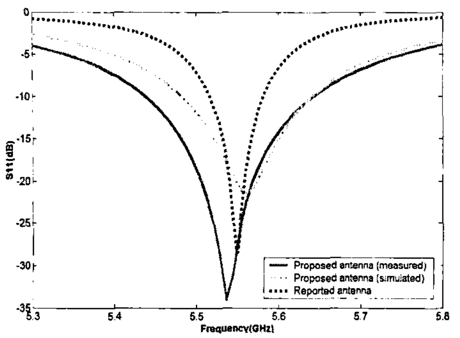


Fig. 3. Simulated return loss of each antenna.

is shown in Table 1.

Also, conductor line is inserted into the middle of the proposed antenna for harmonic suppression, and T-shaped feeding line is used for impedance matching, as shown in Fig. 1. Conductor line length generates inductance, and the gap between conductor line and the ground generates capacitance. Therefore, conductor in the antenna is equivalent to a series L-C resonator, shunt connected with ground and has wide band-stop characteristics, suppressing resonances at the harmonic frequencies. Important key parameters are L_{c1}, L_{c2}, and L_t, and they are shown in Fig. 1(a). IE3D simulations for various values of each parameter are performed, and their return losses are shown in Fig. 4~6.

As shown in Fig. 4, L_{c1} plays an important role in 2^{nd} harmonic tuning. As L_{c1} increases, resonace at the 2^{nd} harmonic frequency decreases while it has little influence on other values such as fundamental frequency impedance matching and the 3^{rd} harmonic resonance. The optimum result is obtained when L_{c1} is 1.8 mm.

Fig. 5 shows return losses for various L_{c2} values, and

Table 1. Bandwidth results.

	Fundamental Frequency(GHz)	Bandwidth
Reported antenna	5.55	74 MHz(1.3 %)
Proposed antenna (simulated)	5.56	159 MHz(2.9 %)
Proposed antenna (measured)	5.536	205 MHz(3.7 %)

the 3^{rd} harmonic resonance depends greatly on L_{c2}. Fundamental frequency impedance matching and 2^{nd} harmonic resonance are not greatly dependant on L_{c2}, and the best return loss at the 3^{rd} harmonic frequency is obtained when L_{c2} equals 1.25 mm.

L_t has the greatest influence on impedance matching at the fundamental frequency as shown in Fig. 6 with little effect on other values, and the optimum value for L_t is 3.8 mm.

As shown in Fig. 4~6 and analysis above, each

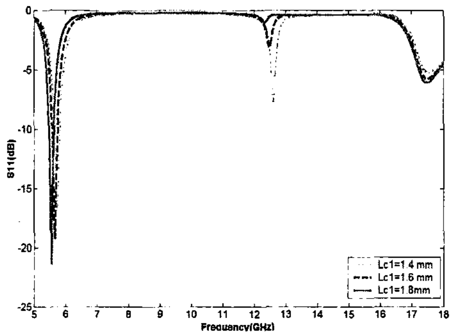


Fig. 4. Return losses for various L_{c1} values.

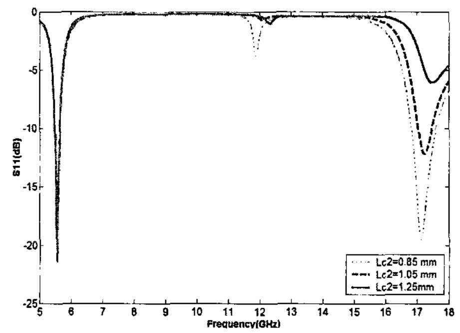


Fig. 5. Return losses for various L_{c2} values.

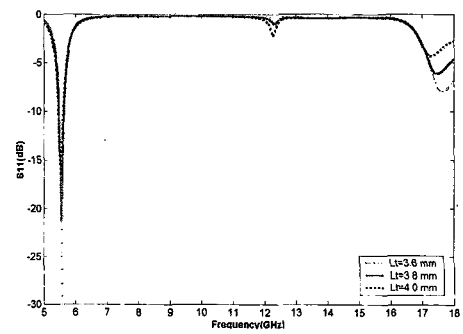


Fig. 6. Return losses for various L_t values.

Table 2. Parameter values.

Parameter	Value(mm)	Parameter	Value(mm)
L	4.85	L_f	3.38
W	9.3	W_c	0.2
W_{50}	1.427	W_s	0.9
W_t	0.4035	L_{c1}	1.8
L_t	3.8	L_{c2}	1.25

parameter has great influence on each of impedance matching at the fundamental frequency and resonances at the 2^{nd} and the 3^{rd} harmonic frequencies, with little effects on the others. Considering all of these impedance matching at the fundamental frequency and resonances at the harmonic frequencies, the optimum values for L_{c1}, L_{c2}, and L_t are 1.8, 1.25, and 3.8 mm, respectively. All the design parameters shown in Fig. 1 is summarized in Table 2. Also, at the 2^{nd} and 3^{rd} harmonic frequencies, return losses are nearly 0 dB, which means total reflection. Thus, it is sure that the proposed antenna can operate not only as a radiator but also as a harmonic tuning network.

Ⅲ. Results

The proposed antenna operates at 5.536 GHz, and the simulated and measured return losses are shown in Fig. 7.

Measured result agrees well with simulated one. The measured result has a little wider bandwidth at fundamental frequency than simulated one, and nearly 0 dB return losses at the 2^{nd} and 3^{rd} harmonic frequencies. Harmonic suppression characteristic is also verified by input impedance of the proposed antenna, as shown in Fig. 8. The real impedance at the 2^{nd} and 3^{rd} harmonic is relatively low and nearly zero compared to that at fundamental frequency, thus ensuring stable operation as a part of harmonic tuning network.

Also, an excellent harmonic suppression characteristic of the proposed antenna can be verified by

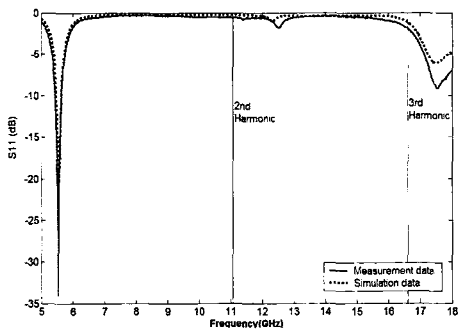


Fig. 7. Simulated and measured return losses.

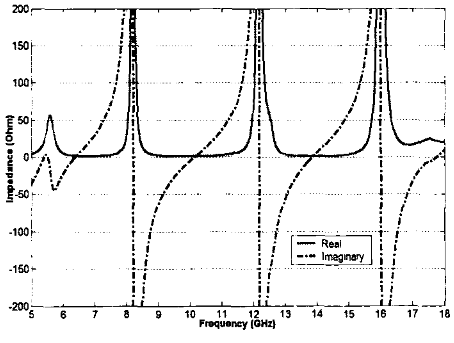
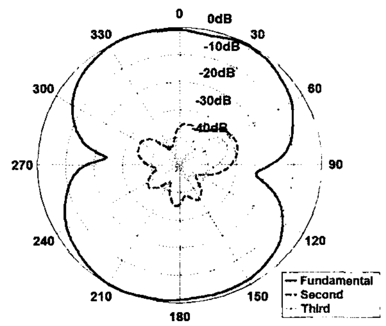
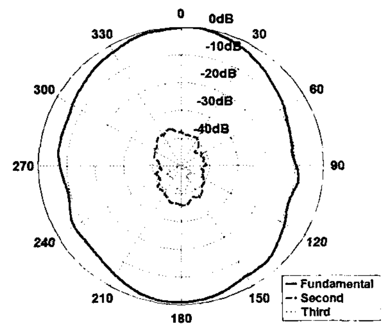


Fig. 8. Measured input impedance of the proposed antenna.



(a) E-plane



(b) H-plane

Fig. 9. Measured radiation patterns of the proposed antenna.

radiation pattern, as shown in Fig. 9. In both E- and H-plane, radiated power at the harmonic frequencies is suppressed more than -30 dB when compared to the normalized peak radiated power at the fundamental frequency. Therefore, harmonic signals are very effectively suppressed, and EMI problem can be solved by the proposed antenna itself without any additional harmonic tuning circuits such as filters.

Ⅳ. Conclusion

In this paper, a bowtie shaped meander slot antenna with small size, harmonic suppression, and broadband characteristic is proposed. The antenna has dimensions of 9.3×4.85 mm^2, fundamental frequency of 5.536 GHz, and harmonic suppression characteristic of -0.56 dB and -1.9 dB return losses at the 2^{nd} and 3^{rd} harmonic frequencies, respectively. Also, by applying bowtie configuration, moderate bandwidth of 3.7 % is obtained, which is almost three times wider than that of the conventional meander slot antenna[1],[2]. Therefore, the proposed antenna operates as a harmonic suppression network as well as a radiator in moderate bandwidth, with its small size maintained.

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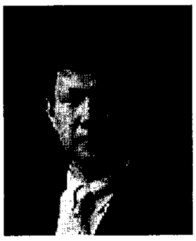

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