A Harmonic Suppression Antenna for an Active Integrated Antenna

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***Abstract*—An inset-fed antenna with a shorting pin and slots is presented for harmonic suppression of an active integrated antenna. Its fundamental resonant frequency is 5.8 GHz. At fundamental and harmonic frequencies, return loss and radiation characteristics are measured and compared with those of the conventional microstrip patch antenna. The second and third harmonic return losses of the proposed antenna are suppressed to 6.7 dB and 17.7 dB with respect to the conventional patch antenna, respectively.**

***Index Terms*—Active integrated antenna, harmonic suppression, harmonic tuning, microstrip antenna.**

I. Introduction

AN ELECTROMAGNETIC interference is an important problem of a microwave system. It is caused by harmonic radiations. Main sources of harmonic signals are nonlinearity of active components (e.g., amplifier, mixer, oscillator, and etc.) and the harmonic signals are generally suppressed by a harmonic suppression filter. In a wireless communication system, a harmonic suppression filter which lies between an antenna and a power amplifier is a convenient way to suppress electromagnetic interference. However, a harmonic suppression filter is a bulky and expensive component and it is difficult to be integrated in MMIC circuit. Therefore, a harmonic suppression filter is difficult to integrate in an active integrated antenna. To overcome these problems, harmonic suppression antennas which have a harmonic radiation suppression have been recently reported [1]–[4].

In this letter, the inset-fed rectangular patch antenna with a shorting pin and slots for harmonic suppression is proposed. The proposed antenna suppresses the second and third harmonic signal like the PBG or H-shaped antenna, but it controls each harmonic resonance independently. Additionally, it provides the low cross-polarization level and good harmonic suppression in a rectangular patch antenna. In experimental results, the return loss, impedance, and radiation properties are shown and discussed in the view of the harmonic signal suppression for active integrated antenna. All results are compared with results of a conventional rectangular patch antenna. It will be needed for high efficiency active integrated antenna system.

Manuscript received May 6, 2002; revised July 31, 2002. This work was supported by the Korea Science and Engineering Foundation (KOSEF), Grant R01-2000-00270. The review of this letter was arranged by Associate Editor Dr. Ruediger Vahldieck.

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Digital Object Identifier 10.1109/LMWC.2003.808716

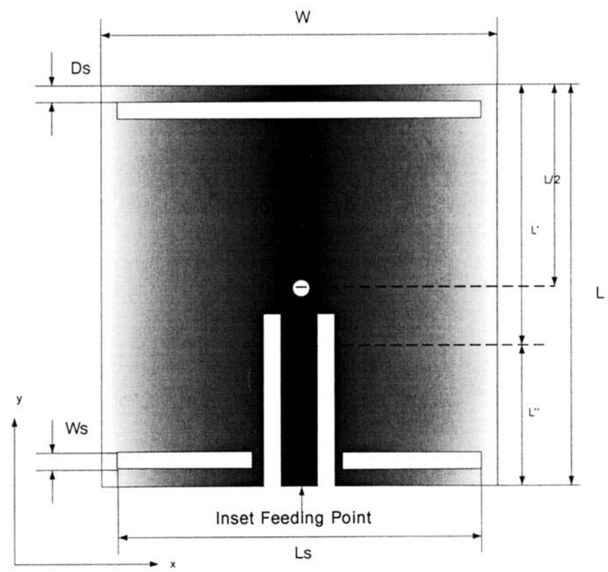

Fig. 1. Geometry of the designed antenna.

II. Antenna Design

To suppress the harmonic radiations from an antenna, harmonic modes which correspond to harmonics of nonlinear microwave components must not be excited. In the proposed antenna, a shorting pin and slots are used for harmonic suppression as shown in Fig. 1. On a microstrip antenna, shorting pin or slot on a patch are used for a dual frequency operation [5]. A shorting pin on the center line of a patch, can suppress the excitation of the (2, 0) and (4, 0) modes, and so on. Points along the center line become positions of current minimum points. Since the shorting pin makes these points maximum current position, these modes cannot be excited due to the distorted current distribution. The cross polarization level can be reduced by symmetrical loading of the patch [4]. Similarly, a slot-loaded antenna is used for dual band operation. The (1, 0) and (3, 0) modes are perturbed by slots near radiating edges. The (3, 0) mode is perturbed more than the (1, 0) mode. So, the (3, 0) mode is controlled by slots near radiating edges. The shorting pin on the center line do not affect the current distribution of the (3, 0) mode.

The resonant frequency of the slot loaded patch is lower than a conventional one by loaded slots because loaded slots on a patch make a longer current path. So, the proposed antenna is designed to have the smaller length than a conventional patch and maintain a same resonant frequency.

The designed antenna parameters are shown in Table I.

TABLE I
GEOMETRIC PARAMETERS OF THE DESIGNED ANTENNA

Patch(mm)	Width(W)	14.1
	Length(L)	13.1
Slot(mm)	Width(Ws)	1
	Length1(Ls1)	13.4
	Length2(Ls2)	4.4
	Position(Ds)	1
Inset(mm)	Width	0.950
	Length	5.6
50 Ohms Line(mm)	Width	1.4

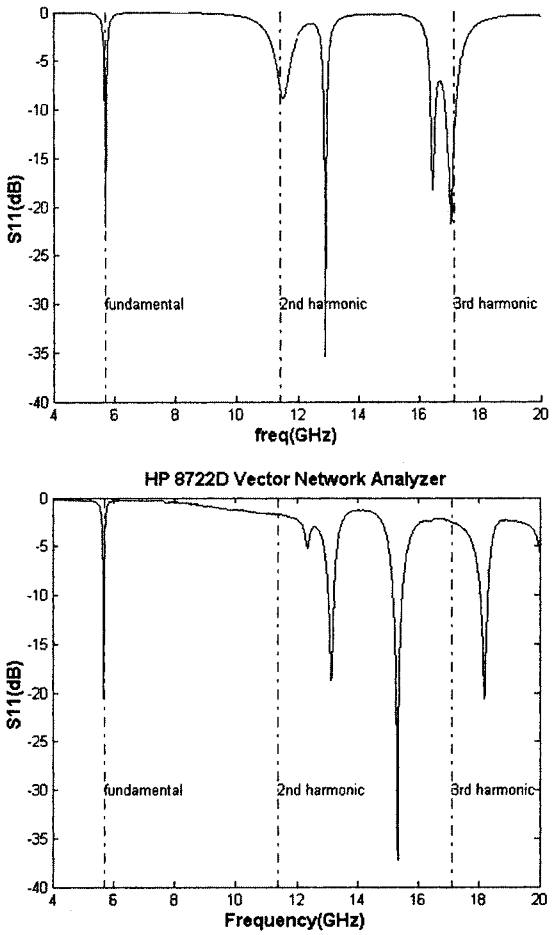

Fig. 2. Return loss comparison between a conventional patch and the proposed patch.

III. EXPERIMENTAL RESULTS

The substrate for the designed antenna is TLX9-0200 substrate with $\varepsilon r = 2.5$ and height = 20 mils. The return loss of a conventional patch antenna is shown in Fig. 2(a). Its fundamental frequency is 5.8 GHz. Its harmonic resonances are observed on each harmonic frequency. The return loss of the second harmonic frequency is −8 dB at 11.6 GHz and the return loss of the third harmonic frequency is −20 dB at 17.4 GHz.

The proposed antenna has the same fundamental frequency. The proposed antenna is designed to be smaller in length because loaded slots on the patch make a longer current path. In contrast, the embedded shorting pin has no effect to a current path. The resonant frequency is controlled by slot length and slot width. A slot length and width makes longer current path and it makes lower resonant frequency. A measured return loss on the proposed antenna is shown in Fig. 2(b). The return loss on the second harmonic is −1.3 dB and the return loss on the third harmonic is −2.3 dB. The suppression of the second and third harmonic return losses on the proposed antenna obtained 6.7 and 17 dB suppression, respectively.

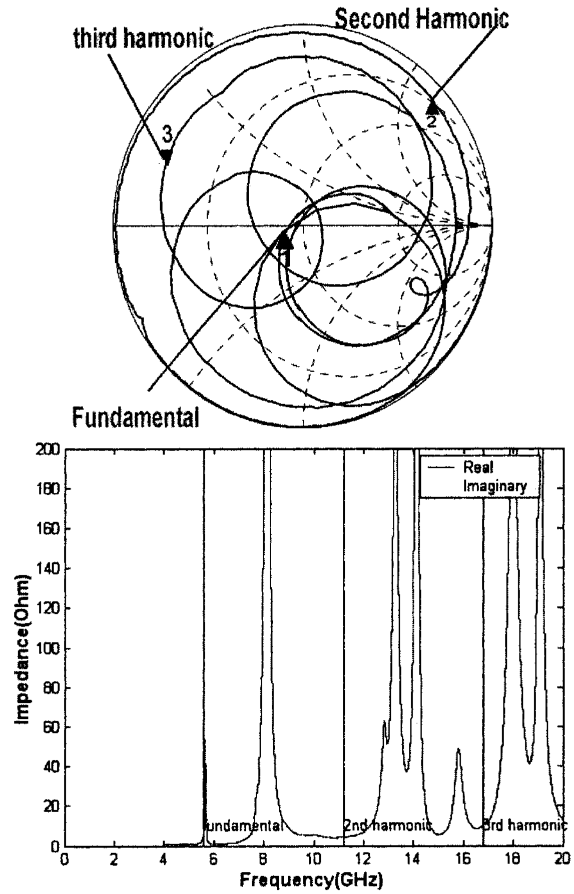

Fig. 3. Impedance property of the proposed patch.

In Fig. 3(a), harmonic impedances are close to short or open circuits. Its harmonic resistances are 2 Ω and 8 Ω for second and third harmonic frequencies in Fig. 3(b), respectively. The short or open impedances are useful for a high efficiency amplifier like a class F amplifier as harmonic tuning circuits.

The comparisons of their gains and return losses are summarized in Table II. In the proposed antenna, the gain of the fundamental frequency is 7.0 dBi and it is similar to the gain of the conventional patch. The second harmonic gain is less than −5.5 dBi and 3 dB lower than those of the conventional patch. The third harmonic gain is less than −4.9 dBi and it is 14.2 dB lower than those of the conventional patch. Because its effective area is larger than that at the fundamental frequency, the gain at the third harmonic is larger than the fundamental but it suppressed 14.2 dB by the proposed antenna. It is sufficient to replace the harmonic suppression filter.

TABLE II
GAIN AND RETURN LOSS COMPARISON BETWEEN THE RECTANGULAR PATCH AND PROPOSED PATCH

	Return Loss		Gain (at 0° of elevation)	
	Rectangular Patch	Proposed Patch	Rectangular Patch	Proposed Patch
Fundamental	-23dB	-20dB	6.9 dBi	7.0 dBi
Second harmonic	-8dB	-1.3dB	-2.2 dBi	-5.5 dBi
Third harmonic	-20dB	-2.3dB	9.3 dBi	-4.9 dBi

IV. CONCLUSION

In this paper, we propose the shorting pin and slot-loaded antenna for the second and third harmonic suppression. Additionally, the antenna can be used for a harmonic tuning load of a class F amplifier. By perturbing the current distribution on a patch antenna, the second and third harmonic return losses on the proposed antenna suppressed 6.7 dB and 17.7 dB with respect to the conventional patch antenna, respectively. The proposed antenna can be a harmonic tuning load and be used for an active antenna to integrate a high efficiency amplifier.

REFERENCES

[1] V. Radisic, Y. Qian, and T. Itoh, "Novel architectures for high-efficiency amplifiers for wireless applications," *IEEE Trans. Microwave Theory Tech.*, vol. 46, pp. 1901–1909, Nov. 1998.

[2] Y. Horii and M. Tsutsumi, "Harmonic control by photonic bandgap on microstrip patch antenna," *IEEE Microwave Guided Wave Lett.*, vol. 9, pp. 13–15, Jan. 1999.

[3] A. F. Sheta and S. F. Mahmoud, "A novel H-shaped patch antenna," in *IEEE APS Int. Symp. Dig.*, vol. 2, July 2001, pp. 720–723.

[4] S. Kwon, H. K. Yoon, and Y. J. Yoon, "Harmonic tuning antennas using slots and short-pins," in *IEEE APS Int. Symp. Dig.*, vol. 1, July 2001, pp. 118–121.

[5] R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, *Microstrip Antenna Design Handbook*. Norwood, MA: Artech House, 2001.