SLOT-LOADED SLOT-COUPLED PATCH ANTENNA SUITABLE FOR INTEGRATION WITH POWER AMPLIFIERS

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1. Introduction

Active antennas have been a focus of attention for several years, because they realize high performance by integrating antennas with active circuits such as amplifiers, oscillators, and mixers

Until now, two types of patch antennas has been proposed [1][2] that can be integrated with power amplifiers. They realize class F power amplifier operation [3] by controlling the input impedance of higher-order harmonics, as well as the input impedance of fundamental frequency band.

In this paper, we propose a slot-loaded rectangular patch antenna suitable for integrating power amplifiers. We use slot-coupling as a feed configuration [4], because this feed configuration is thought to be suitable for integrating patch antennas with active circuits.

The proposed antenna can control return loss of even-order harmonics and third-order harmonics in this configuration. The coupling slot just below the patch center and open stub length can control the return loss of the even-order harmonics. The loaded-slots' position and length on the rectangular patch can control the return loss of the third-order harmonics. Additionally, the reference plane has been shifted in order to obtain the short termination at second harmonics and the open termination at third harmonics, without changing return loss characteristics in the fundamental frequency band.

The investigation has been conducted experimentally using the L-band as the fundamental frequency band.

2. Antenna Configuration

Figure 1 shows the schematic view of the proposed rectangular patch antenna. The proposed antenna is fed by a coupling slot which is located just below the patch center. Because the slot is located there, the patch cannot be resonated at the even-order harmonics. The open stub length of feeding microstrip line is set to be a quarter wavelength around the resonant frequency of the dominant TM_{10} mode. So the input impedance of even-order harmonics, seen from the slot center is infinite if the fringing effect is ignored.

Additionally, two slots are loaded on the radiating rectangular patch. The antenna has been set not to resonate at TM_{30} mode, namely third-order harmonics, by changing the location and the size of two loaded slots.

To realize class F power amplifier operation, the input impedance of even-order harmonics of the output circuits should be short, whereas the input impedance of odd-order harmonics of output circuits should be open. The proposed antenna realizes this condition, by changing the reference plane of the antenna.

3. Experimental Results

The antenna parameters used in the experiment are listed in Table 1. The experiment was conducted using the L-band as the fundamental frequency.

Figure 2 shows the return loss characteristics of the proposed antenna when the loaded slots' length was changed from 3 to 17 mm. Here, the loaded slots are located 8 mm from the edge. The TM_{30} mode current is maximum at these points if the loaded slots are removed. At fundamental frequency of about 1.8 GHz, the return loss was less than -15 dB and the resonant frequency shift due to loaded slot length was small. At second-order harmonics of around 3.6 GHz, there was no resonance here. This is because the coupling slot was located just below the patch center and there was no coupling between the feed line and the rectangular patch antenna. At third-order harmonics of 5.4 GHz, there was a resonance when the loaded slots were small. However, the resonant frequency decreased and the depth of the return loss became shallow as the loaded slots became large. No typical resonance was observed if the loaded slots' length exceeded 13 mm.

Figure 3 shows the input impedance characteristics of the second harmonics and the third-order harmonics. The reference plane was on the feed microstrip line just below the coupling slot. The input impedance of the third harmonics approached to pure imaginary j, whereas the input impedance of the second-order harmonics remained around open termination. From Figure 3, the angle made by the third-order harmonics and the second harmonics on the Smith's chart approached to a right angle. Thus, class F power amplifier condition can be achieved by shifting the reference plane to the generator side by 3/8 wavelength of the fundamental frequency.

Figure 4 depicts the return loss characteristics of the antenna when the loaded slots' length was equal to 15 mm. It is seen that the antenna resonated at 1.735 GHz. And no resonance was obtained at the second-order harmonics of 3.47 GHz and the third-order harmonics of 5.205 GHz. Figure 5 shows the input impedance of fundamental frequency, the second-order harmonics and the third-order harmonics of the antenna when the reference plane was shifted 38mm from the slot center to the generator. From this figure, the second harmonics was almost short while the third harmonics was almost open. Therefore, class F power amplifier operation can be achieved if the power amplifier is assembled at this point. Figure 6 depicts the E-plane radiation pattern at 1.735 GHz. The cross polarization level was less than -20 dB. So, the effect of the loaded slots was not observed.

4. Conclusion

This paper has proposed a slot-loaded rectangular patch antennas suitable for integrating with power amplifiers. Slot-coupling is used as a feed configuration

The proposed antenna can control return loss of second-order harmonics and third-order harmonics by the location of the coupling and the loaded slots as well as by the size of the loaded slots. Additionally, the reference plane has been shifted in order to obtain short termination at second harmonics and open termination at third harmonics.

The results obtained will he helpful in the design and fabrication of active antennas of this type.

Acknowledgment:

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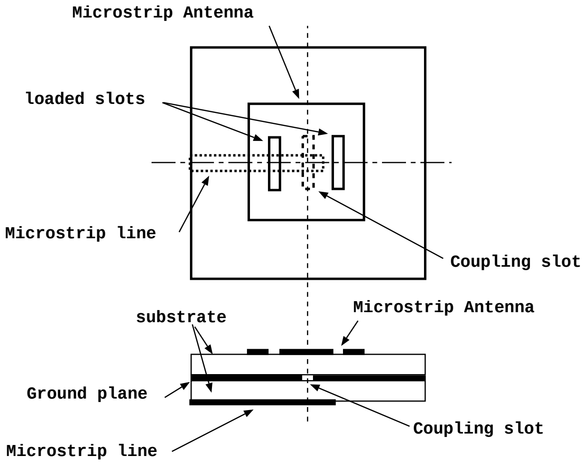

Figure 1: Slot-loaded rectangular patch antenna
for integration with power amplifier

Table 1: Antenna parameters

Items	Value
dielectric constant (both antenna & feed line substrates)	2.6
substrate thickness (antenna side)	1.6 mm
substrate thickness (feed lines side)	0.8 mm
patch size	48 X 48 mm
coupling slot location	patch center
coupling slot size	15 X 1 mm
loaded slot location	16.0 mm from the center
open stub length	26.0 mm

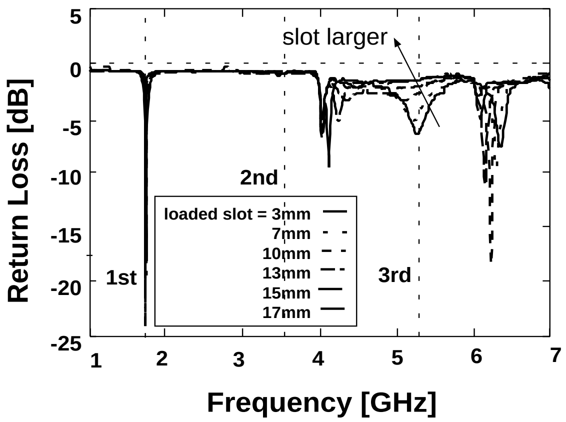

Figure 2: Return loss characteristics as a function of loaded slot length

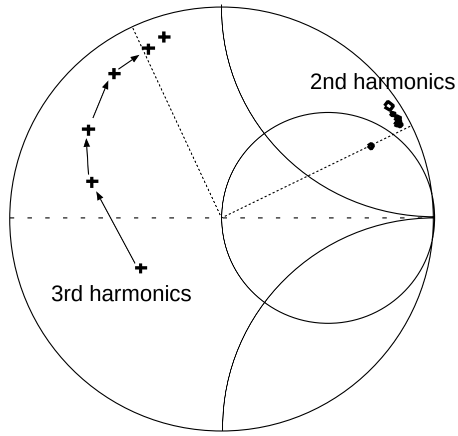

Figure 3: Input impedance characteristics of the second- and the third-order harmonics.

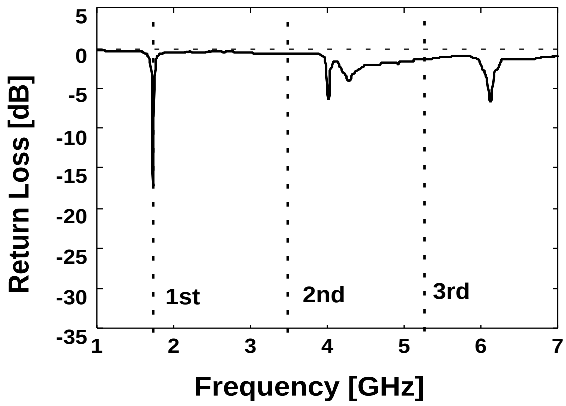

Figure 4: Return loss characteristics when the loaded slot length was equal to 15.0 mm.

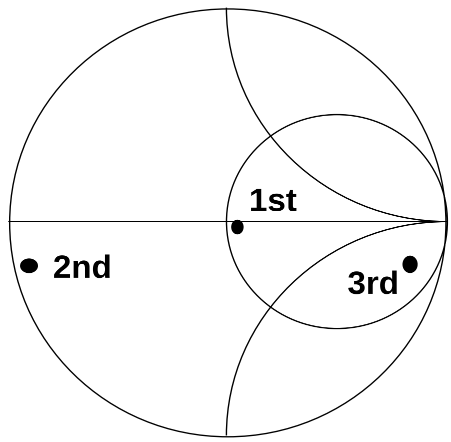

Figure 5: Input impedance characteristics when the loaded slot length was equal to 15.0 mm.

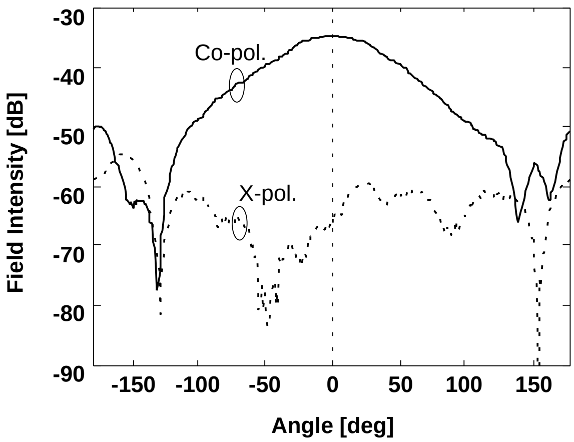

Figure 6: E-plane radiation pattern of the antenna at 1.735 GHz.