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Research Article

A CPW-Fed Rectangular Ring Monopole Antenna for WLAN Applications

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We present a simple coplanar waveguide- (CPW-) fed rectangular ring monopole antenna designed for dual-band wireless local area network (WLAN) applications. The antenna is based on a simple structure composed of a CPW feed line and a rectangular ring. Dual-band WLAN operation can be achieved by controlling the distance between the rectangular ring and the ground plane of the CPW feed line, as well as the horizontal vertical lengths of the rectangular ring. Simulated and measured data show that the antenna has a compact size of $21.4 \times 59.4\,\text{mm}^2$, an impedance bandwidths of 2.21–2.70 GHz and 5.04–6.03 GHz, and a reflection coefficient of less than −10 dB. The antenna also exhibits an almost omnidirectional radiation pattern. This simple compact antenna with favorable frequency characteristics therefore is attractive for applications in dual-band WLAN.

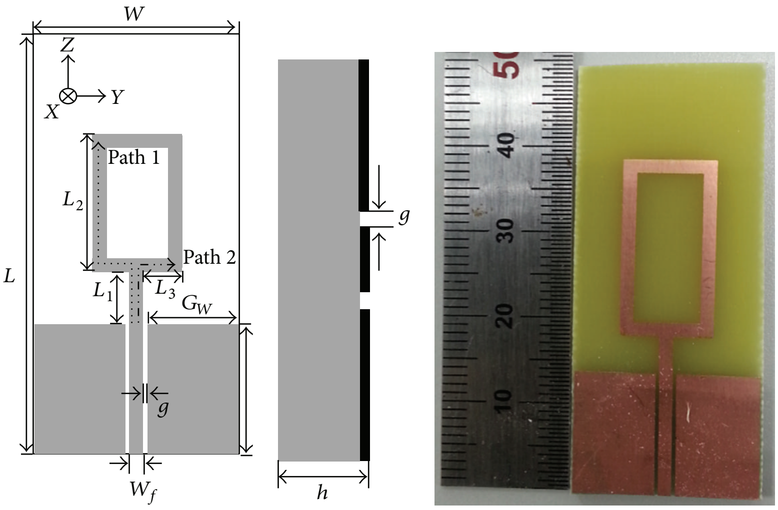
1. Introduction

Wireless local area networks (WLANs), which enable user mobility, are considered to be a cost-effective solution for high-speed data connectivity. The growing demand for WLAN technology has led to interest in integrating the 2.412–2.482 GHz (IEEE802.11b/g) and 5.15–5.825 GHz (IEEE 802.11a) frequency bands into a single device that requires a dual-band antenna [1]. Numerous designs for dual-band antennas have been reported, including a dual-monopole antenna with different lengths [2] or sleeves [3], a bent folded monopole [4–6], a combination of monopole and helical antennas [7], and a slot antenna [8–10]. An antenna should exhibit impedance matching to the feed line, be low in cost and compact, and have a low profile, a high efficiency, and an omnidirectional radiation pattern. Broadband and omnidirectional characteristics of ring antennas have been reported [11–17]; however, to realize dual-band operation, additional structures must be employed on the bottom layer, such as a T-shape, S-shape, vertical strip resonator, or parasitic elements. Coplanar waveguide- (CPW-) fed antennas have received much attention because of their wide operating bandwidth, low profile, low cost, simple fabrication, potential for integration with monolithic microwave integrated circuits, and simple configuration using a single metallic layer [2, 16].

In this paper, we describe a design for rectangular ring-shaped monopole antenna that satisfies the 2.4-GHz and 5.2/5.8-GHz WLAN applications (i.e., it operates at frequencies in the range of 2.4–2.4835 GHz and 5.15–5.825 GHz). The antenna does not require any additional structures for dual-band WLAN operation. Through numerical simulations, we show that the distance between the rectangular ring and the ground plane, as well as the horizontal vertical lengths of the rectangular ring, can be optimized to control the resonant frequencies and hence achieve dual-band operation. Therefore, the proposed antenna achieved the small size, simple structure, and good frequency response with the omnidirectional radiation pattern.

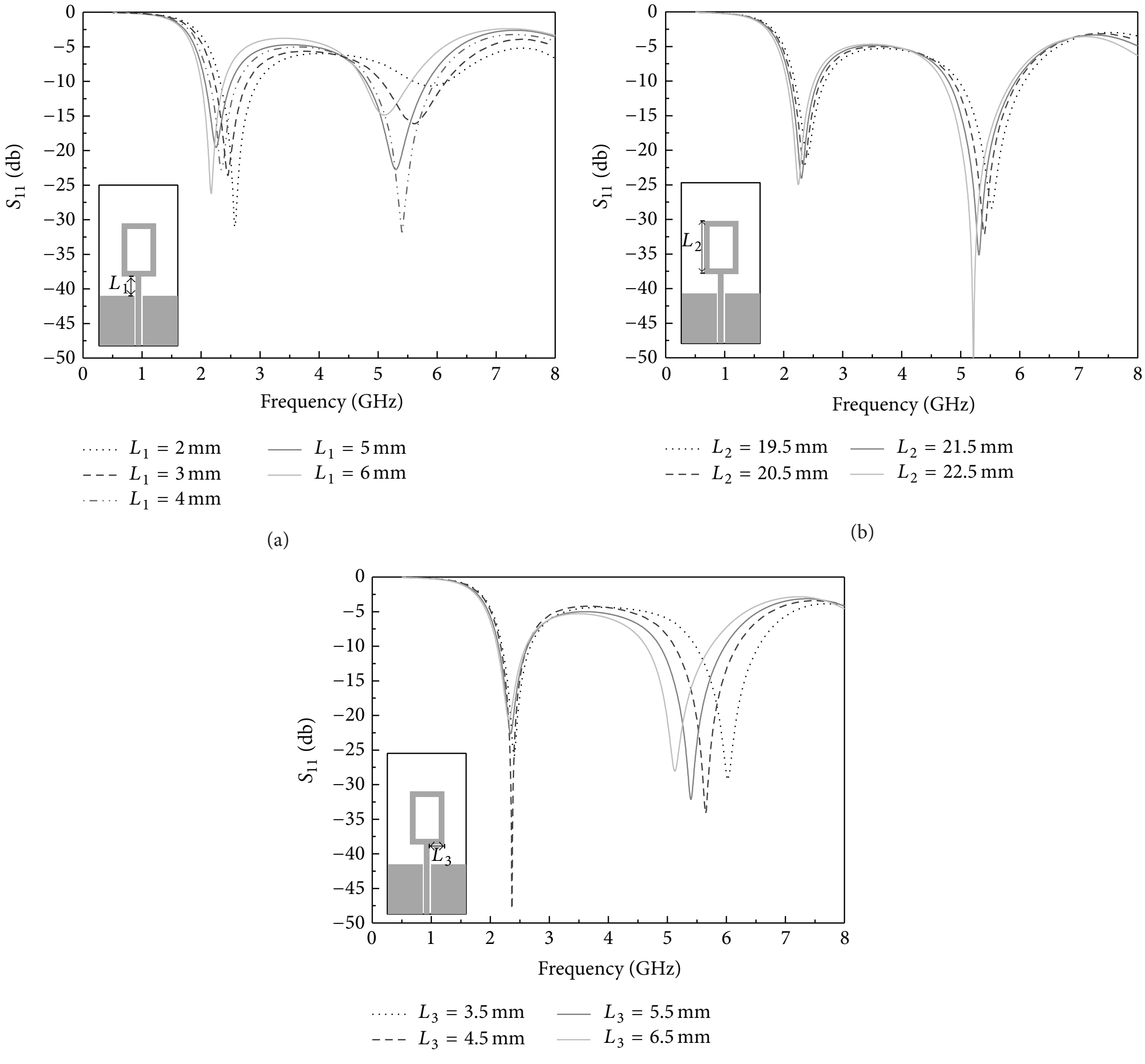
2. Antenna Design

The geometry of the rectangular ring-shaped CPW-fed antenna is shown in Figure 1, together with a photograph of



(a) (b) (c)

Figure 1: Geometry of the printed rectangular ring antenna: (a) top view and (b) side view. (c) Photograph of the fabricated antenna.



(a) (b) (c)

Figure 2: Simulated return losses for various values of (a) L_1, (b) L_2, and (c) L_3.

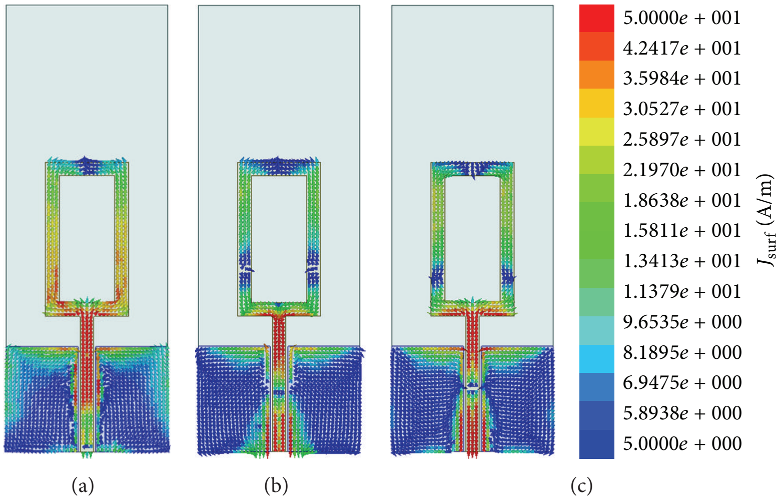


Figure 3: Simulated current density distribution in the proposed antenna at (a) 2.4 GHz, (b) 5.2 GHz, and (c) 5.8 GHz.

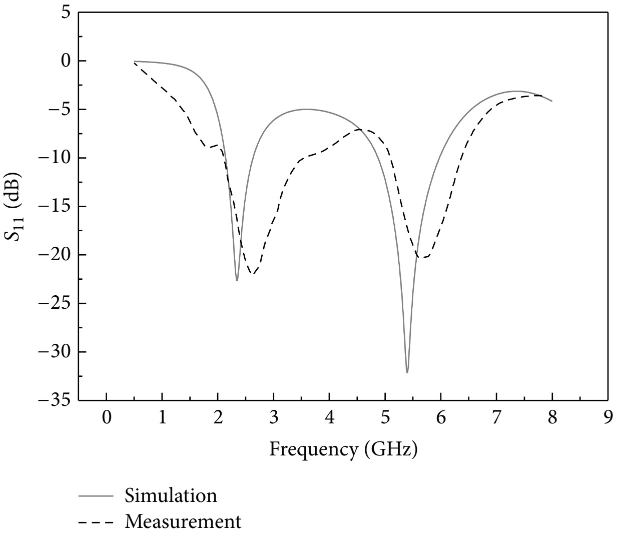
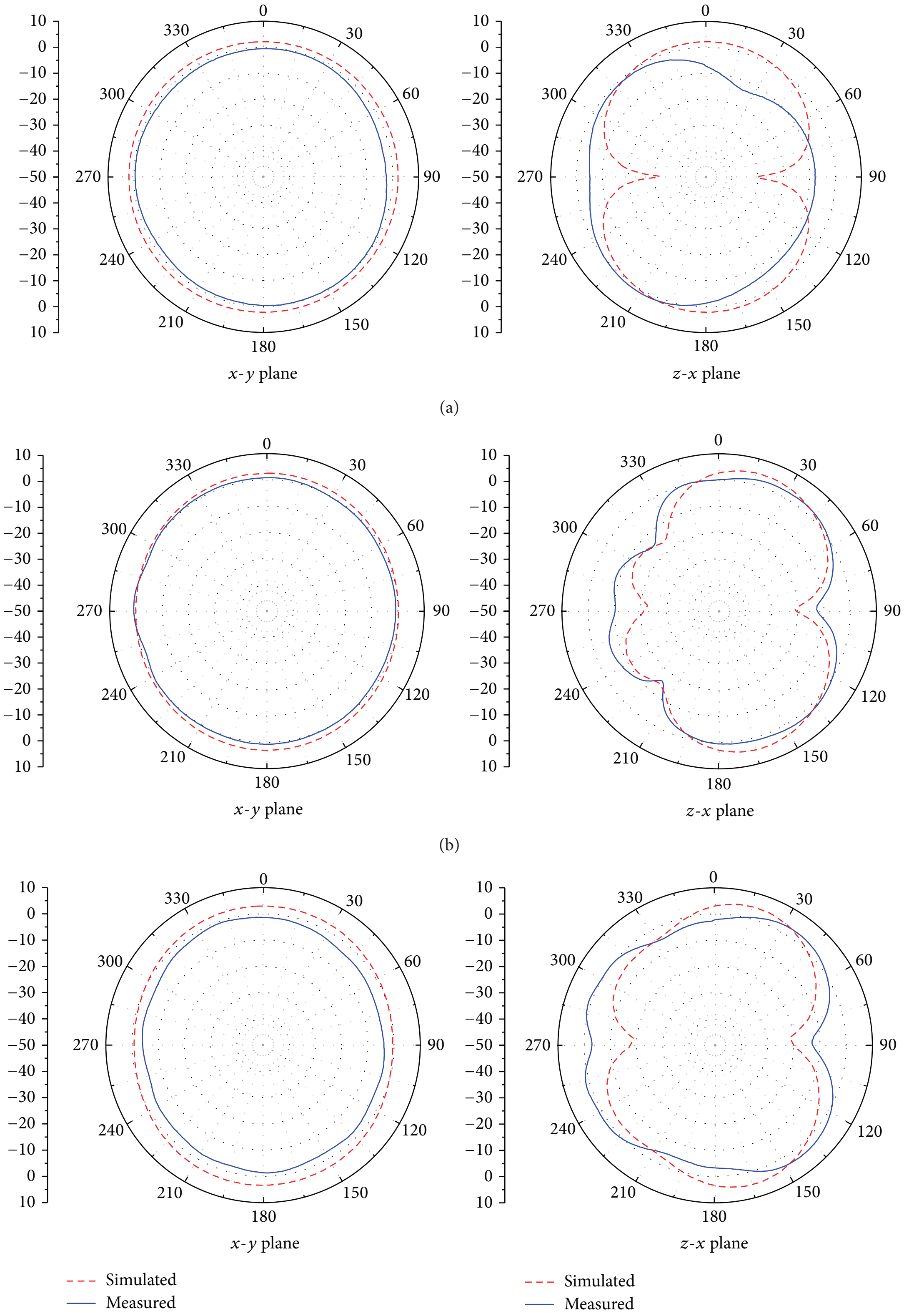


Figure 4: Comparison between the simulated and measured return losses for proposed antenna.

the fabricated optimized structure. The antenna had overall dimensions of $21.4 \times 59.4 \times 1.6\,\text{mm}^3$ and was fabricated on an FR4 substrate with a relative permittivity of $\varepsilon_r = 4.4$. A 50-Ω CPW transmission line with a signal strip width of 1.8 mm and a gap distance of 0.3 mm between the single strip and the coplanar ground plane was used to feed the antenna. The size of the rectangular ring was $11 \times 20.5\,\text{mm}^2$, and the two ground planes with dimensions of $9.5 \times 14\,\text{mm}^2$ were located symmetrically on each side of the CPW line. The antenna was symmetrical with respect to the longitudinal direction (i.e., the z-axis).

To investigate the performance of the proposed antenna for dual-band operation, the commercially available simulation software HFSS was used. T-shaped or vertical strip resonators that correspond to radiation around 5 GHz are typically added to square ring structures to achieve dual-band operation [11–14]; however, with the antenna described here, we can achieve dual-band operation by controlling the distance between the rectangular ring and the ground plane, as well as the length and the width of the rectangular ring.

Figure 2(a) shows simulated data that reveal the effect of varying the distance between the rectangular ring and the ground plane L_1 on the return losses of the antenna. The parameter L_1 could be used to control the lower frequency and the upper band matching. Figure 2(b) shows the effects of varying the length of the rectangular ring L_2 on the return losses when the width of the antenna is fixed at L_3 = 5.5 mm. As the parameter L_2 increased, both the lower



(a)

(b)

(c)

FIGURE 5: Simulated and measured radiation patterns of the proposed antenna at (a) 2.4 GHz, (b) 5.2 GHz, and (c) 5.8 GHz.

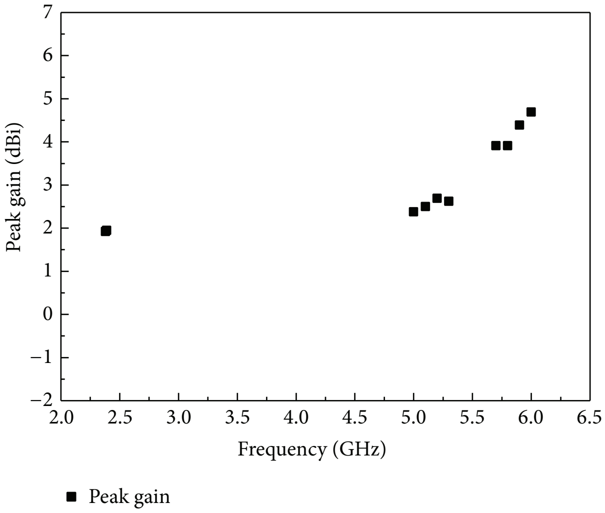


Figure 6: Measured peak gain of the proposed antenna at operational frequency bands.

Table 1: Antenna dimensions.

Parameters	W	L	G_W	G_L	W_f	g	h	L_1	L_2	L_3
Dimensions mm	21.4	59.4	21.4	14	1.8	0.3	1.6	4	20.5	5.5

and upper resonant frequencies were red-shifted. Figure 2(c) shows the effect of varying L_3 when the width was fixed at $L_2 = 20.5$ mm. The parameter L_3 primarily affected the upper band; therefore, L_3 can be varied to tune the properties of the upper frequency band. The optimized antenna dimensions for operation at 2.4 GHz and 5.2/5.8 GHz are listed in Table 1.

Figure 3 shows the simulated current distributions in the optimized structure at the different frequencies. The current distributions varied significantly depending on the resonant frequency. It is evident from these current distributions that, at a frequency of 2.4 GHz, the radiation mainly resulted from the vertical strip line of the rectangular ring. The current distributions at a frequency of 2.4 GHz are similar to resonant Path 1, as shown in Figure 1(a). The horizontal strip line of the rectangular ring contributed mainly to radiation at frequencies of 5.2 and 5.8 GHz. The resonant currents at frequencies of 5.2 and 5.8 GHz are distributed on the horizontal strip line which is similar to resonant Path 2, as shown in Figure 1(a). Hence, by appropriately adjusting the lengths of the vertical strip line and the horizontal strip line of the rectangular ring, the suitable resonant current paths can be created to radiate the electromagnetic energy at the different resonant frequencies.

3. Experiment Result

Figure 4 compares the simulated return losses with those measured from the fabricated antenna shown in Figure 1(c). Good agreement was evident between the simulated and measured data. At the lower resonant frequency of 2.4 GHz, the measured return loss was approximately −20 dB with a bandwidth of 500 MHz. At the upper resonant frequencies of 5.2 and 5.8 GHz, the return losses were less than −20 dB and the bandwidth was 1 GHz.

The measured *x-y* plane and *z-x* plane radiation patterns are shown in Figure 5. The electric field patterns exhibited some lobes in the radiation patterns, whereas the magnetic field distributions were almost completely omnidirectional. The measured peak gains in the 2.4-GHz and 5.2/5.8-GHz bands are shown in Figure 6; the peak antenna gain in the 2.4-GHz band was 2.0 dBi, and that in the 5.2/5.8-GHz band was 5.0 dBi.

4. Conclusion

We have described a CPW-fed rectangular ring monopole antenna for WLAN applications. The antenna design is compact, with dimensions of only $21.4 \times 59.4 \times 1.6\,\text{mm}^3$. The antenna had a simple geometry and is relatively easy to fabricate. Because the bandwidths of the lower and upper bands of the proposed antenna were sufficient for operation at the 2.4-GHz and 5.2/5.8-GHz bands, the antenna is suitable for dual-band WLAN applications. Furthermore, the antenna provides omnidirectional radiation patterns and stable gains within the bands, making this CPW-fed rectangular ring antenna design suitable for dual-band WLAN applications.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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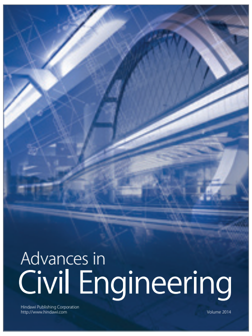
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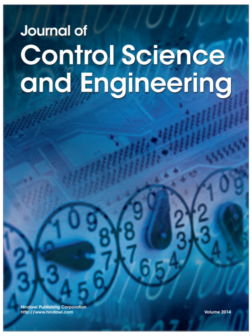
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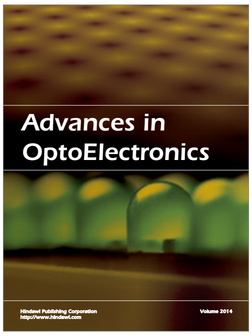
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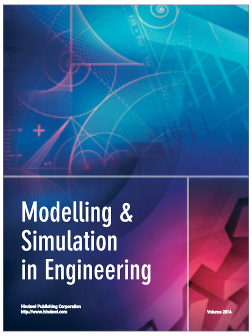
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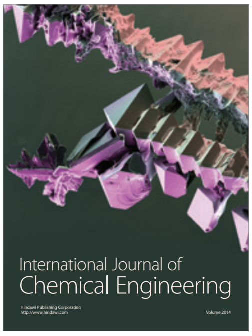
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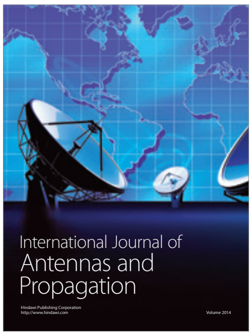
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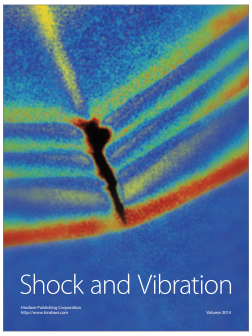
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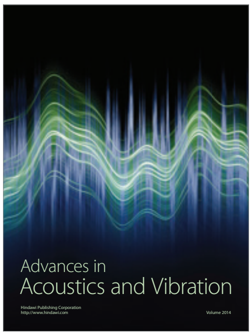
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