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SINGLE-FEED CROSS-SLOT LOADED COMPACT CIRCULARLY POLARIZED MICROSTRIP ANTENNA FOR INDOOR WLAN APPLICATIONS

Sachin Kumar,[1] Binod K. Kanaujia,[1] Abhishek Sharma,[1] Mukesh K. Khandelwal,[1] and A. K. Gautam[2]
[1] Department of Electronics and Communication Engineering, Ambedkar Institute of Advanced Communication Technologies and Research, Delhi 110031, India
[2] Department of Electrical and Electronics Engineering, G. B. Pant Engineering College, Uttrakhand 246194, India; Corresponding author: gautam1575@yahoo.co.in

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ABSTRACT: *A novel single-feed circularly polarized microstrip antenna with compact size is proposed for indoor wireless local area network (WLAN) applications. The antenna structure consists of eight slits which are introduced at the boundary and the corners in the radiating square patch with a cross-slot at the center. The proposed antenna shows a compactness of 42% compared with the conventional circularly polarized antenna design at indoor WLAN frequency band. It is found that the resonance frequency of the proposed structure is highly depending on length and width of cross-slot and corner slit for entire band of circular polarization. The 3 dB axial ratio bandwidth of the proposed antenna is 1.9%. Proposed structure is fabricated on the FR-4 epoxy substrate and fed by a single coaxial probe. Measured results show a good agreement with the simulated results. Antenna shows stable radiation characteristics for the entire operating band.* © 2014 Wiley Periodicals, Inc. Microwave Opt Technol Lett 56:1313–1317, 2014; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.28318

Key words: *circularly polarized; compact microstrip antenna; cross-slot; wireless local area network*

1. INTRODUCTION

Microstrip antenna is considered as a good choice for communication devices due to their numerous advantages like light weight, low profile, ease of fabrication, low cost, integrability with millimeter, and microwave circuits [1]. Personal mobile communication and modern transceiver systems need compact antenna to satisfy the severe constraints on the physical dimension of the portable equipments. Multipath interference is a major problem of concern in wireless communication [2]. Circular polarization (CP) combats multipath fading by introducing polarization diversity in radio propagation environment [3]. Circularly polarized compact microstrip patch antennas are widely used nowadays for mobile communication, global positioning system, radio frequency identification readers; wireless local area network (WLAN) applications and so forth due to the high link reliability and spectral efficiency [4].

A circularly polarized microstrip antenna has been realized by exciting two orthogonal modes with equal amplitudes, which are in-phase quadrature with the sign determining the sense of left hand circular polarization/right hand circular polarization (LHCP/RHCP) [5]. CP can be achieved using either single feed or dual feed and usually a square or circular patch is used. The dual feed at orthogonal position excites two orthogonal modes with equal amplitude but in-phase quadrature to achieve CP [6].

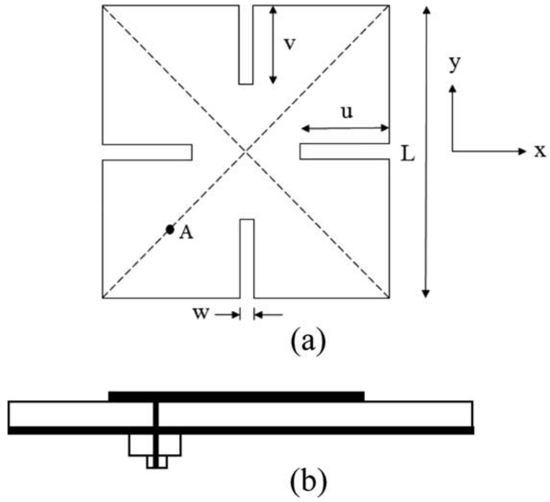

Figure 1 Geometry of single-feed circularly polarized square microstrip antenna (antenna 1): (a) top view and (b) cross-sectional view

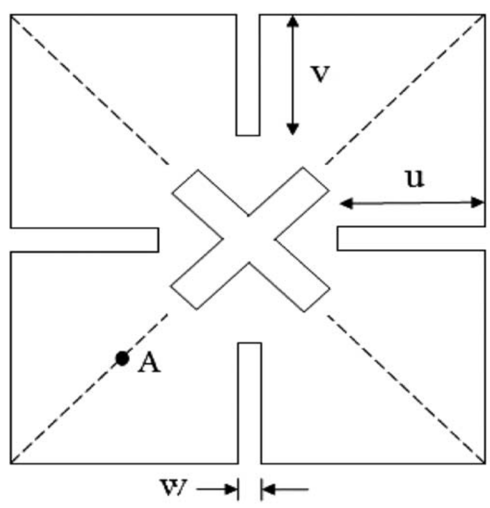

Figure 2 Geometry of cross-slot loaded square microstrip antenna (antenna 2)

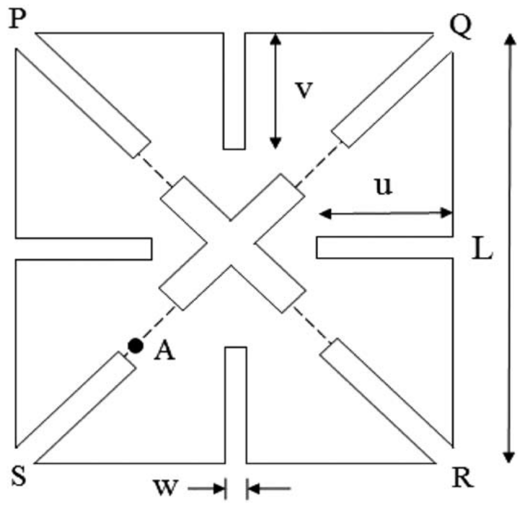

Figure 3 Geometry of proposed compact circularly polarized antenna with slits at the corner (antenna 3)

TABLE 1 Dimensions of the Proposed Structures

Antenna Parameters	Value (mm)
Length of square patch, *L*	30
Length of slit, *u*	10
Length of slit, *v*	9.2
Width of slit, *w*	1.0
Length of cross slot	10
Width of cross slot	1.0
Length of corner slit along diagonal PR	12.5
Length of corner slit along diagonal QS	10.5
Width of corner slits	1.0

However, single-feed circularly polarized antennas are more compact and simple as they do not require an external polarizer. CP generation using single feed can be accomplished by perturbing the patch at the appropriate location with respect to the feed location to excite two orthogonal modes with a 90° phase shift. Conventional designs of single-feed circularly polarized microstrip antenna have been realized by truncating patch corners, using a nearly square patch, or cutting a diagonal slot in the patch [7]. However, in the UHF range the size of these circularly polarized microstrip antennas is large. So, combining the methods to realize compact microstrip antenna [8] along with the techniques of CP generation, a compact circularly polarized microstrip antenna is presented. Several compact circularly polarized antenna structures operating at fixed frequency have been reported over the years [9–18]. These includes square and circular patch loaded with slits and placing single feed along 45° with respect to one of the slit [9–11], corner chopped square microstrip antenna embedded with four slits [12, 13], chip-resistor loaded square patch [14], square ring microstrip antenna with truncated corners [15], truncated square patch embedded with group of four bent slots [16], circular microstrip antenna with peripheral cuts and loaded with a cross-slot [17], and diagonally asymmetric slotted microstrip patch [18].

In this article, a compact square microstrip patch antenna is proposed for CP using single coaxial feed. The compactness is achieved by loading a cross-slot in the center of the single-feed circularly polarized microstrip antenna [10]. Further, compactness is achieved by introducing slits at the corners of the patch maintaining the CP. The proposed structure is simulated and optimized using finite element method based simulator Ansoft HFSS v.14 [19]. The same antenna is fabricated and printed on a FR-4 epoxy substrate. The experimental results show good agreement with the simulated results. This article is organized as follows: Section 2 presents antenna structures. Section 3 presents simulated and experimental results. Finally, a conclusion is presented in Section 4.

2. ANTENNA STRUCTURE AND DESIGN

Figure 1 shows the configuration of the single-feed circularly polarized square microstrip patch antenna [10] and is represented as antenna 1. The structure of the cross-slot loaded circularly polarized antenna is depicted in Figure 2 and is labeled as antenna 2. Figure 3 shows the final proposed antenna structure with four slits inserted at the corners of the patch. The antenna is fed using 50 Ω coaxial probe along the diagonal of the patch.

Antenna 2 and antenna 3 are fabricated on a 1.6-mm-thick FR-4 epoxy substrate of relative permittivity 4.4 and loss tangent of 0.0012. The detailed dimensions are listed in Table 1.

(a) (b)

Figure 4 Prototype of the fabricated antennas: (a) antenna 2 and (b) antenna 3. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

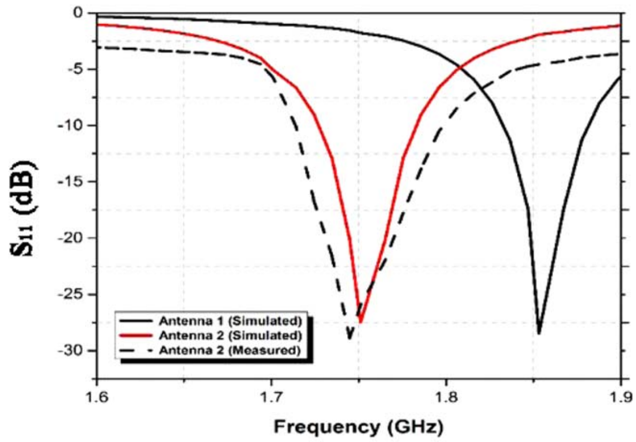

Figure 5 Simulated and measured reflection coefficient (S_{11}, dB) versus frequency (GHz) of antenna 2. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

The size of the ground plane for both the antennas is 46 × 46 mm^2. Figure 4 shows the photograph of the fabricated patches.

3. RESULTS AND DISCUSSION

Fabrication of proposed antennas is done by standard photolithography process. SMA connectors (50 Ω) are used to feed the fabricated antennas. The electrical characteristics of the fabricated antennas are measured on Agilent™ Network Analyzer (PNA L-Series). The S_{11} variations with frequency of the proposed antenna 2 and antenna 3 are shown in Figures 5 and 6, respectively. Antenna 2 shows resonance at 1.75 GHz and a compactness of 27% is achieved in comparison to conventional square patch antenna [7]. Further, antenna 3 resonates at 1.70 GHz and a compactness of 42% is achieved. By integrating slots and slits, the path of the excited patch surface current is increased. Thus, resonant frequency is shifted toward its lower value. A good agreement between the measured and simulated result is observed. The small difference in measurement is due to the fabrication tolerance and soldering of SMA connector.

Figure 7(a) shows the simulation results for axial ratio with frequency for antenna 1 and antenna 2. In Figure 7(b), antenna 2 and antenna 3 simulated and measured results are depicted.

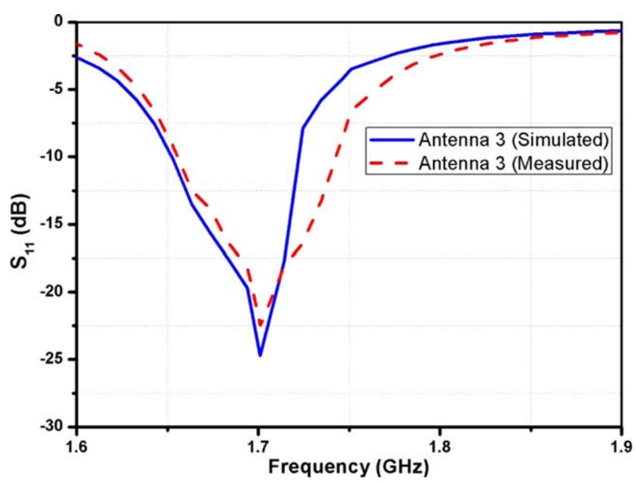

Figure 6 Simulated and measured reflection coefficient (S_{11}, dB) versus frequency (GHz) of antenna 3. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

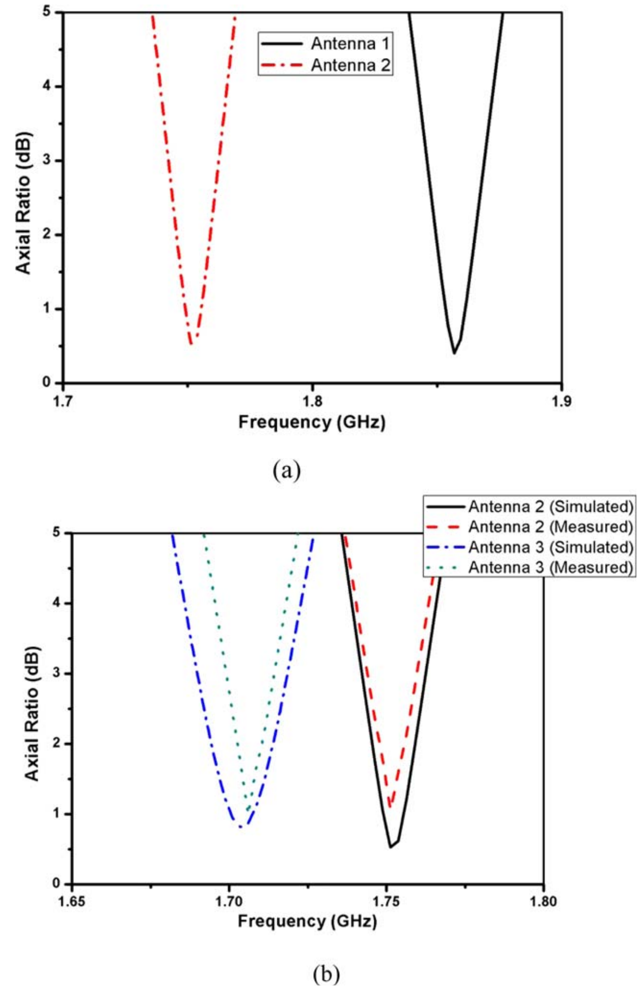

Figure 7 Axial ratio (dB) versus frequency (GHz): (a) simulated and (b) simulated and measured. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

From the figure, it is observed that both the antennas (antenna 2 and antenna 3) have axial ratio below 3 dB, hence, circularly polarized. However, antenna 3 has better axial ratio bandwidth as compared to antenna 1 and antenna 2. A comparison of axial ratio bandwidth is listed in Table 2.

Figures 8 and 9 show the variations of S_{11} with frequency for different cross-slot lengths and cross-slot widths, respectively. The width of the cross-slot is varied for the fixed length of the cross-slot as 10 mm. It is found that the resonance frequency of antenna 2 is depending on length and width of the cross-slot. Further, observed that the resonance frequency of antenna 2 decreases with increase in length and width of cross-slot. The length and width of the corner slits present at the diagonals of the proposed antenna 3 are varied for optimizing the best dimensions and are shown in Figures 10 and 11,

TABLE 2 Comparison of the Axial Ratio Bandwidth

Parameter	Antenna Without Slits	Antenna 1 [10]	Antenna 2	Antenna 3
Resonant (GHz)	2.318	1.85	1.75	1.70
Frequency axial ratio bandwidth (%)	–	1.3	1.14	1.9

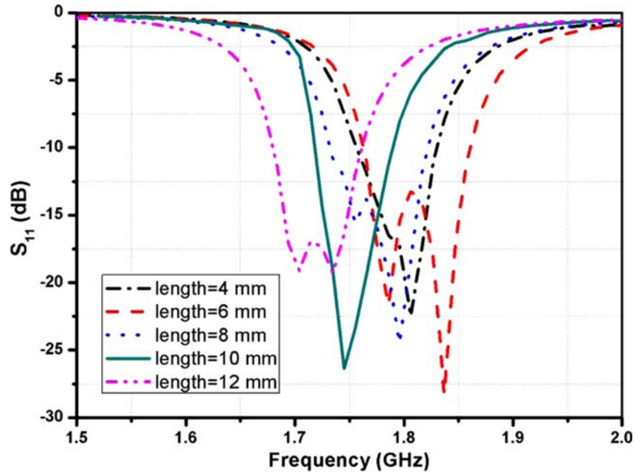

Figure 8 Variation of S_{11} (dB) with frequency (GHz) for different cross-slot lengths. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

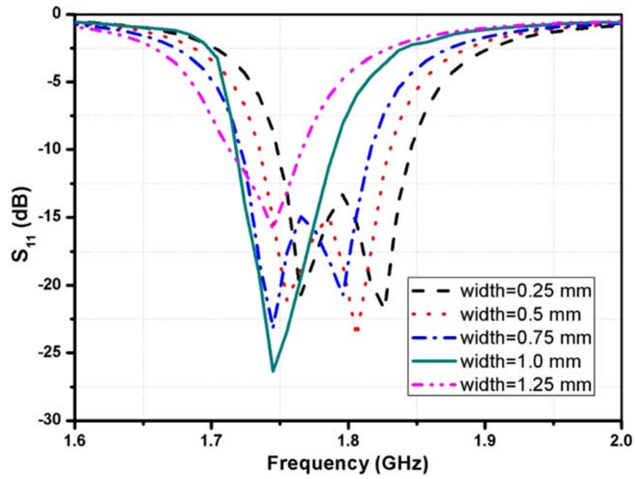

Figure 9 Variation of S_{11} (dB) with frequency (GHz) for different cross-slot widths. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

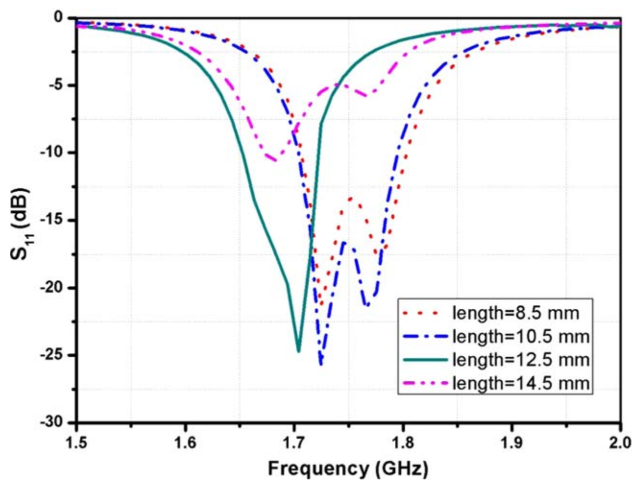

Figure 10 Variation of S_{11} (dB) with frequency (GHz) for different corner slit lengths for compact square microstrip antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

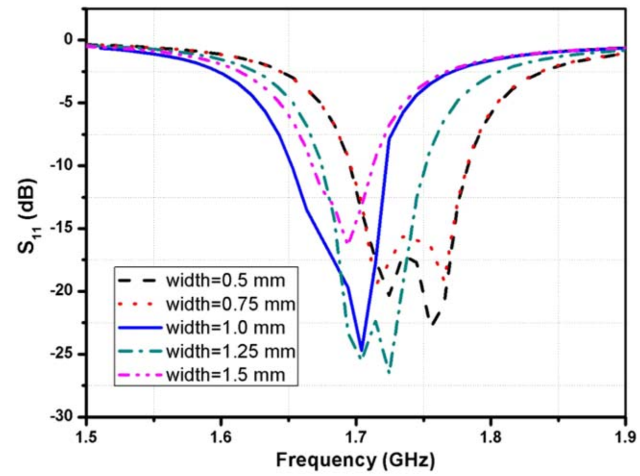

Figure 11 Variation of S_{11} (dB) with frequency (GHz) for different corner slit widths for compact square microstrip antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

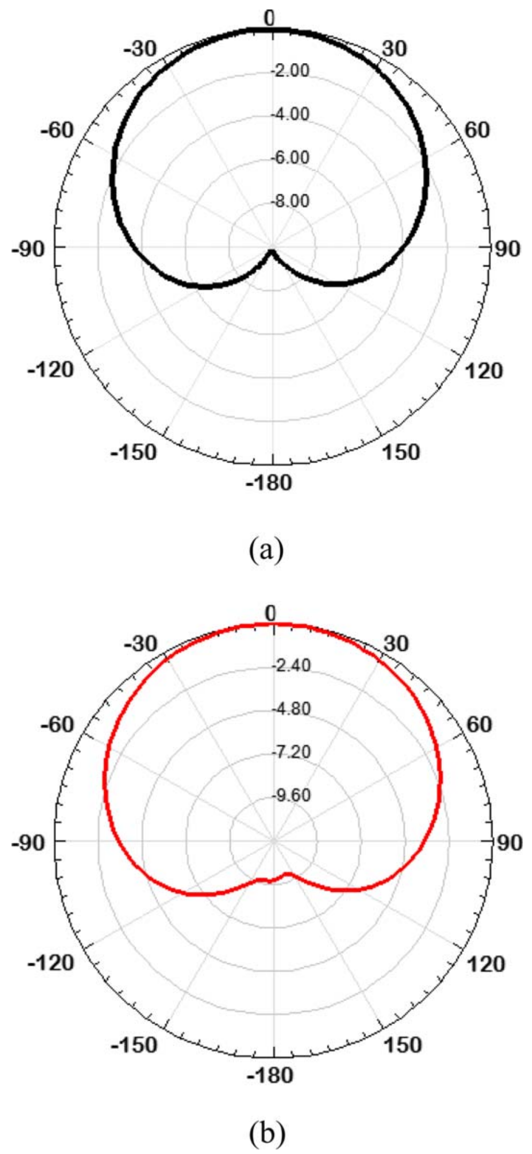

Figure 12 Simulated radiation pattern at 1.7 GHz: (a) *E*-plane and (b) *H*-plane. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

respectively. In Figure 10, the length of the slits present along the diagonal PR is varied keeping the slits length at the other diagonal QS constant as 10.5 mm. In the same manner, the variation of S_{11} with frequency for different widths of the slits is also shown keeping slits at the diagonal PR and QS as 12.5 and 10.5 mm, respectively. The resonance frequency of antenna 3 decreases with increase in length and width of the corner slits for entire band of operation in CP region.

The total radiated power of the proposed antenna 3 is shown in Figure 12. The sense of rotation can be changed by simply changing the position of feed along another diagonal of the square patch. Total radiated power remains same with change in frequency. Both the antennas show stable radiation characteristics in both *E*-plane and *H*-plane. More than -3 dB power is achieved within angle of 170° in *E*-plane and 130° in *H*-plane. Both the antennas have almost same radiation characteristics.

4. CONCLUSION

Compact circularly polarized microstrip antennas have been designed and fabricated. When compared with the conventional design of circularly polarized microstrip antenna, the proposed antenna is ~42% compact in size maintaining good CP. The proposed antenna may be a good choice for indoor WLAN applications which require small antenna with CP to mitigate multipath fading in wireless communication environment.

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COMPACT QUASI-SELF-COMPLEMENTARY ANTENNA FOR PORTABLE UWB APPLICATIONS

Jinze Zou, Li Liu, and S. W. Cheung
Department of Electrical and Electronic Engineering, The University of Hong Kong, Pokfulam, Hong Kong; Corresponding author: liuli@eee.hku.hk

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ABSTRACT: *A quasi-self-complementary (QSC) antenna with microstrip fed and a compact size of 19.7×19 mm^2 is proposed for portable ultrawideband (UWB) applications. The antenna consists of a half-elliptical conductor patch with two small half-circular structures (HCSs) printed on one side of the substrate, and a slot with the complement of the conductor shape cut on the L-shaped ground plane on the other side of the substrate. Computer simulation is used to design the QSC antenna. Results show that the HCSs can increase the lengths of the current paths on the antenna and hence, increase the operation bandwidth. As a result, for the same operation bandwidth, the size of the antenna can be reduced by 15% using the HCSs. Simulation is used to study the performance of the antenna in terms of S_{11}, radiation pattern, realized gain, and efficiency. For verification of simulation results, the prototype of the antenna is measured using the antenna measurement system, Satimo Starlab system. The effects of the feeding cable used in measurement are also studied using computer simulation. The simulated cable effect on efficiency is evaluated and used to remove the cable effect on the measured result. Then, the simulated and measured efficiencies agree very well. Results show that the antenna has a bandwidth from 3.1 GHz to more than 12 GHz and efficiency of over 60%, making it suitable for portable UWB applications.* © 2014 Wiley Periodicals, Inc. Microwave Opt Technol Lett 56:1317–1323, 2014; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.28317

Key words: *ultrawideband; small antenna; quasi-self-complementary antenna; cable effect*

1. INTRODUCTION

Self-complementary antenna (SCA) has received much attention for its wideband impedance characteristics [1]. An ideal SCA having an infinite-extended structure has constant input impedance which is independent of frequency. Thus, SCA is a promising technique for use in portable ultrawideband (UWB) applications in the frequency band from 3.1–10.6 GHz which is allocated by the Federal Communications Commission (FCC) for unlicensed use with low power emission [2]. To design SCAs for portable applications, some practical considerations