Truncated Compact Circular Microstrip Antenna loaded with Asymmetric Slits

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***Abstract*—A compact circular microstrip antenna is presented. The proposed radiating structure consists of a truncated circular patch loaded with asymmetric slits. A 32% compactness is achieved when compared with conventional circular microstrip antenna. The variation in resonant frequency with the slit dimensions is also investigated and observed that the antenna characteristics are highly dependent on slit dimensions. The resonant frequency can be altered by simply varying the slit dimensions. The proposed antenna may be a good candidate for indoor wireless local area network applications.**

***Keywords*—asymmetric slits, cirular microstrip antenna, compact antenna, WLAN**

I. Introduction

Microstrip Antennas (MSAs) have been extensively used in modern wireless communication due to their numerous advantages like low profile, light weight, ease of fabrication, integrability with microwave and millimeter wave integrated circuits, conformability to curved surface [1]. Compact MSAs recently received much more attention due to the increasing demand of personal mobile communication systems which require smaller antennas in order to meet the miniaturization requirements of mobile units. Since, the size of regularly shaped MSAs operating in the UHF band is quite large because its resonant length is inversely proportional to frequency, therefore, to reduce the size of microstrip antenna at fixed operating frequency, the geometry needs to be modified.

The use of high permittivity microwave substrate in designing the antenna is an effective way to reduce the size of microstrip antenna at fixed operating frequency [2]. However, it degrades the radiation efficiency and bandwidth of the antenna. Thus, numerous techniques have been reported during the past few decades to reduce the size of MSAs [3]-[14]. These methods include shorted patch, meandered patch, meandered ground plane, meta-material loading or combination of mentioned techniques. Enclosing the patch in a metallic cavity is an another effective way for achieving miniaturization along with advantages like enhanced bandwidth, suppression of surface wave, enhanced gain etc. [15]-[18].

In this paper, a compact circular microstrip antenna with pair of peripheral cuts at the opposite side of the patch boundary and loaded with asymmetric slits is proposed. The variation in resonant frequency with slit length and width is investigated using Ansoft‘s high frequency structure simulator (HFSS v14) [19] which is based on Finite Element Method. It is observed that the antenna characteristics are highly dependent on length and width of the slits.

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II. Antenna Structure

Fig. 1 shows the configuration of proposed compact microstrip antenna. Six slits are embedded in the truncated circular patch of radius a. The two larger slit has the dimensions

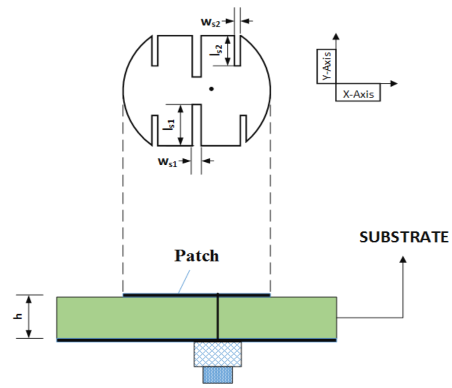


Fig. 1. Geometry of compact circular microstrip antenna

of length l_{s1} and width w_{s1}, and four smaller slit has the dimensions of length l_{s2} and width w_{s2}. The detailed antenna design parameters are listed in Table I. A photograph of the fabricated antenna is shown in Fig. 2. The proposed antenna is fabricated and printed on a 60 mil thick FR4 epoxy substrate of relative permittivity 4.4 and a loss tangent of 0.012. The antenna is fed by a 50Ω coaxial probe using SMA connector.

TABLE I. Antenna Design Parameters

Antenna Parameter	Value
Radius of circular patch a	16.5 mm
Substrate thickness h	1.524 mm
Slit Length l_{s1}	12 mm
Slit Width w_{s1}	1 mm
Slit Length l_{s2}	8 mm
Slit Width w_{s2}	0.5 mm

III. Result and Discussion

The characteristics of the proposed antenna have been simulated and analyzed using high frequency structure simulator (HFSS) which is based on finite element method. With the introduction of slits, path of the equivalent excited patch

Fig. 2. Photograph of fabricated antenna

surface current increases, reducing the resonant frequency of the patch. The resonant frequency reduces from 2.49 GHz to 1.64 GHz, which is about 0.66 times of the reference antenna and this corresponds to antenna size reduction of about 32%. The simulated S_{11} results are shown in Fig. 3. Agilent network analyzer (PNA L-Series) is used to measure

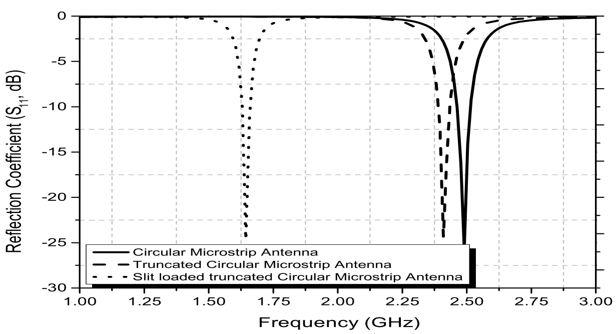


Fig. 3. Simulated reflection coefficient (S_{11}, dB) of the antenna versus frequency (GHz)

the reflection coefficient of the proposed antenna. Fig. 4 shows the measured and simulated S_{11} of the antenna element. A

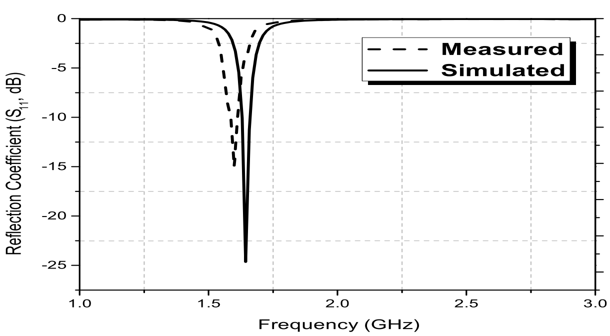
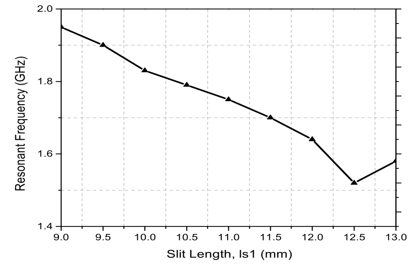


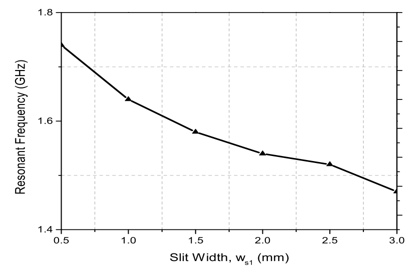
Fig. 4. Simulated and measured reflection coefficient (S_{11}, dB) of the antenna versus frequency (GHz)

good agreement between the measured and simulated result is observed. The small difference is due to the fabrication tolerance and soldering of SMA connector.

Based on the above design concept, various antennas with different slit length and slit width, were designed and analyzed. Fig. 5(a) and Fig. 5(b) shows the variation of resonant frequency with length and width of larger slit, respectively. The variation of resonant frequency with length and width of shorter slit is depicted in Fig. 6(a) and Fig. 6(b), respectively. Results clearly indicate that, with increasing slit length, resonant frequency decreases. This behavior is mainly due to the lengthened patch‘s surface current path. It is also found that

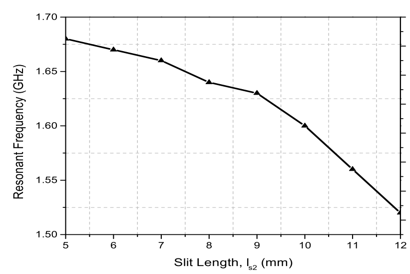


(a)

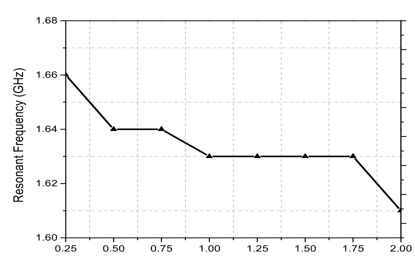


(b)

Fig. 5. Resonant frequency versus (a) Slit Length (l_{s1}) (b) Slit Width (w_{s1})



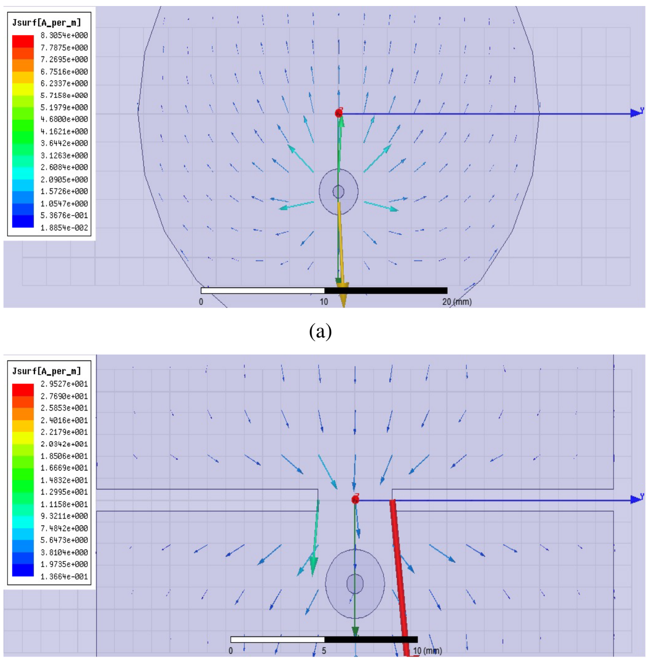
(a)



(b)

Fig. 6. Resonant frequency versus (a) Slit Length (l_{s2}) (b) Slit Width (w_{s2})

larger slit width has sublime effect on the resonant frequency but the width of shorter slit has relatively small effect on resonant frequency. It almost remains constant on increasing the width of shorter slit.
The simulated patch surface current distribution is shown in Fig. 7(a) and Fig. 7(b). From the figure it can be observed that, due to slits path of the excited patch surface current increases, which in turn responsible for lowering the resonant frequency, and thus a large antenna size reduction at a fixed operating frequency can be obtained. Performance of antenna



(a)

(b)

Fig. 7. Simulated patch surface current distribution for (a) Reference Antenna (b) Proposed Antenna at 1.64 GHz

with different slit length and width is listed in Table II and Table III, respectively. It can be inferred from the tables that,

TABLE II. PERFORMANCE OF THE COMPACT MICROSTRIP ANTENNA WITH w_{s1} = 1 MM AND w_{s2} = 0.5 MM

	l_{s1}, l_{s2} (mm)	f_r (GHz)	Bandwidth (MHz, %)
Antenna 1	9, 0	1.99	31, 1.55
Antenna 2	10, 10	1.76	30, 1.70
Antenna 3	12, 8	1.64	30, 1.83
Antenna 4	13, 0	1.53	25, 1.63
Reference Antenna	0, 0	2.49	52.1, 2.1

TABLE III. PERFORMANCE OF THE COMPACT MICROSTRIP ANTENNA WITH l_{s1} = 12 MM AND l_{s2} = 8 MM

	w_{s1}, w_{s2} (mm)	f_r (GHz)	Bandwidth (MHz, %)
Antenna 1	0.5, 0.25	1.76	33, 1.88
Antenna 2	1, 0.5	1.64	30, 1.83
Antenna 3	1.5, 1	1.57	30, 1.91
Antenna 4	2, 2	1.53	25, 1.63
Reference Antenna	0, 0	2.49	52.1, 2.1

with increase in slit length and width, bandwidth of the antenna decreases. This is due to the reduction in electrical thickness of the substrate.
The simulated radiation efficiency of the proposed antenna is about 72% while for conventional patch antenna it is about 58%. The results clearly indicates that the proposed structure is efficient than conventional microstrip antenna.
The simulated radiation pattern of the proposed antenna is shown in Fig. 8.

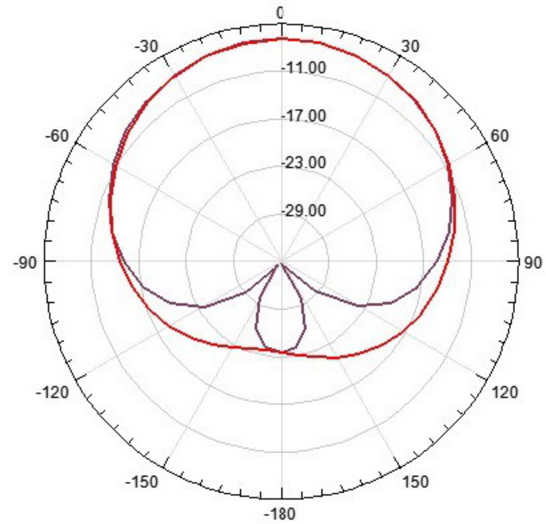


Fig. 8. Simulated gain radiation pattern of the antenna at 1.64 GHz

IV. CONCLUSION

In this paper, a compact truncated circular microstrip antenna loaded with asymmetric slits have been analyzed using Ansoft HFSS. The size reduction of about 32% has been achieved as compared to conventional circular microstrip antenna. Experimental result shows good agreement with the simulated result. It has also been observed that the antenna characteristics are dependent on the dimensions of the slits. The proposed antenna may be a good candidate for indoor wireless local area network applications.

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