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Rectangular Loop UHF Antenna for utilization of TVWS for Cognitive Radio Application

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Abstract*: To utilize the TV white space 470MHz to 806MHz, several wideband antennas are designed in ultra-high frequency (UHF) band. This paper presents the monopole antenna with resonant structures arranged in rectangular loop shape. The overall dimension of the antenna is 160mm x 100mm x 1.6mm. The performance of the antenna in the operating frequency band 596MHz to 733MHz is evaluated using HFSS software. The overall peak gain of the antenna is 1.653dB. In both elevation and azimuth plane, radiation pattern is omnidirectional and the radiation efficiency is 81.79%

***Keywords*: Cognitive Radio, Monopole antenna, TV white-space, UHF antenna.**

I. INTRODUCTION

For the effective transmission of the radio waves, the antenna must pick the signals from the atmosphere and transfer it to the receiving side with greater efficiency and with the least amount of distortion. As there is rapid growth in the wireless communication technology day-by-day, there is tremendous change in the already existing communicating modules. The sizes of the communicating devices are becoming very small and hand-held. In this paper, an antenna is designed for utilizing the vacant television (TV) band.

Typically, an antenna will permit the radio transmitter to pass energy into the free space whereas the receiver will collect the energy from the free space. Both the transmitter and the receiver are allowed to operate in a restricted range of frequencies. The frequency range of TV differs in two types one is VHF (Very High Frequency) and the other is UHF (Ultra High Frequency). Usually, VHF TV broadcast is done within the frequency range of 54MHz to 88MHz and 174MHz to 216MHz. UHF frequency ranges from 470MHz to 806MHz. The bandwidth required for TV broadcasting is 6MHz. To utilize the TV band effectively Federal Communications Commission (FCC) reported spectrum sharing [1]. The unutilized TV band is noted as TV White-Space (TVWS).

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Radio resource is regulated by agen-cies to have uninterrupted communication between various applications [2].

As per FCC report, the spectrum allocated for TV band is underutilized and there is high demand of spectrum for mobile communication [3]. To utilize the vacant spectrum TV band, Cognitive Radio (CR) is introduced by Joseph Mitola, where the device can intelligently detect the unused spectrum and can transmit data in the vacant spectrum allotted for other applications [4]. This paper shows the design of an antenna operating in the UHF TV Band.

II. RELATED WORK

Many authors have designed antennas operating in TV UHF band. In many literatures, the softwares used for the antenna are Ansys-High Frequency Structure Simulator (HFSS) and Computer Simulation Technology (CST). Mostly the material used as substrate is FR4 substrate with dielectric constant (εr) 4.4 and loss tangent (γ) 0.02 [5].

In literatures, different shapes and sizes of monopole antenna are designed for the UHF operating frequency. Various resonant structures such as stubs, slots, loops and combination of these are considered to have good bandwidth occupancy and gain improvement [6]. The authors in [7] have designed a printed monopole antenna with raised ground operating in the UHF band. This is a spline-shaped antenna with gain between 2dBi to 4dBi. An U-shaped antenna with meandering slot structure is designed by the authors in [8]. The authors in [9] designed a tapered feeding compact U-shaped antenna to operate in UHF frequency. In [10], an omnidirectional monopole antenna with parasitic elements is designed by the authors. M-shaped monopole antenna with 99% efficiency is designed by authors in [11]. Planar trapezoidal shape antenna with peak gain 3.36dB has been reported in [12]. A compact spiral reconfigurable monopole antenna with 1dB transmission gain is achieved in [13]. The reconfigurability in selecting band is achieved by tunable inductor.

The authors in [14] proposed a defected ground structure monopole antenna to operate in the frequency range 623MHz to 860MHz . Folded monopole antenna with meander line structure is used to have the operating band in 647.75MHz to 761.55MHz [15]. A narrow band antenna operating in TVWS with center frequency 800MHz is designed by considering meander line structure in [16]. Table-I gives the comparison between different UHF antenna designed to operate in TV band.

Table-I: Comparison between UHF TV band antennas

References	Antenna Size	UHF Band of Operation	Shape of the Antenna
[7]	$(160x170x1.52)mm^3$	470MHz to 862MHz	Spline-shape
[8]	$(190x180x1.6)\ mm^3$	470MHz to 798MHz	U-shape Meandering Slot
[9]	$(231x35x0.8)mm^3$	470MHz to 884MHz	U-shape Tapered feeding
[11]	$(198.32x111.11x1.6)mm^3$	460MHz to 870MHz	M-Shape
[12]	$(198.9x150x1.6)\ mm^3$	470MHz to 700MHz	Planar Trapezoidal
[13]	$(105x40x0.8)mm^3$	600MHz to 800MHz	Spiral
[15]	$(188x157x1.5)mm^3$	647.75MHz to 761.55MHz	Folded Meander line
Proposed one	$(160x100x1.6)\ mm^3$	596MHz to 733MHz	TV-shape rectangular loop

III. RECTANGULAR LOOP ANTENNA

Rectangular loop antenna designed is shown in Fig. 1 to Fig. 3. Double sided FR4 substrate with ε_r=4.4 and loss tangent=0.02 is used to design the antenna. The overall dimension of the antenna is $(160x100x1.6)mm^3$. Microstrip feed is given to the radiating patch. Radiating patch is of rectangular loop with a width of 2.8mm and is shown in Fig.1. Rectangular raised structure of 30mm is used to have good reflection coefficient and is shown in Fig. 3. Fig. 2 shows the top view of the antenna. The dimensions of the antenna are shown in Table-II. The antenna design is carried out using HFSS software. This antenna utilizes TVWS for cognitive radio applications.

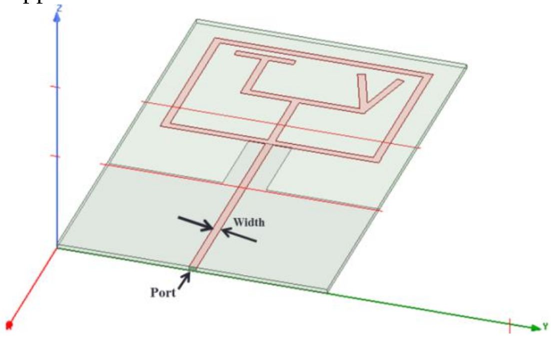


Fig. 1.Rectangular Loop Antenna-3D view in HFSS

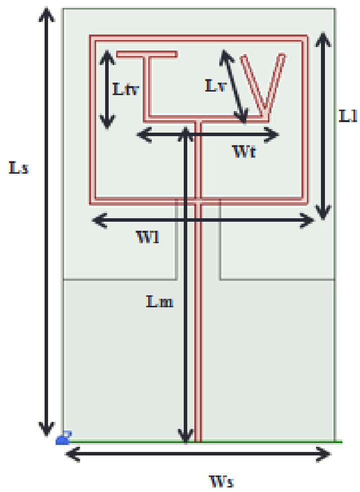


Fig. 2.Rectangular Loop Antenna-Top view

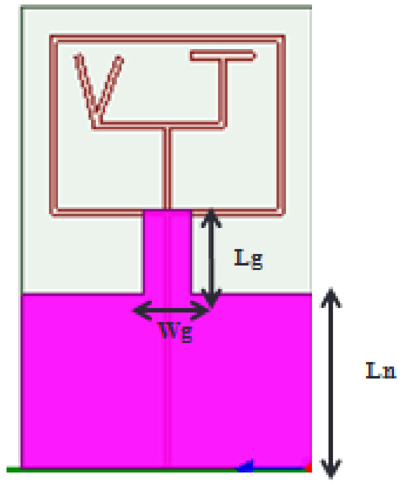


Fig. 3.Rectangular Loop Antenna-Bottom view

Table-II: Antenna Design Parameters in millimeter(mm)

L_m	120	W_t	46
W_l	80	L_{tv}	22
L_l	60	L_v	24
W_s	100	L_g	30
L_s	160	W_g	16
L_n	60	Width	2.8

Using parametric analysis in HFSS, the antenna parameters are optimized to give the best results. The length and width of the rectangular loop decides the operating frequency of the antenna.

IV. RESULTS AND DISCUSSIONS

The parametric analysis is considered for the width of the rectangular loop and is shown in fig.4. In the diagram fig.4, it has been observed that the width of the rectangular loop (width=2.8mm) has the highest bandwidth and therefore it is been selected for the design. The reflection coefficient (S11) simulated for the rectangular loop width of 2.8mm is shown in fig.5 at 667GHz, S11 is -57dB.

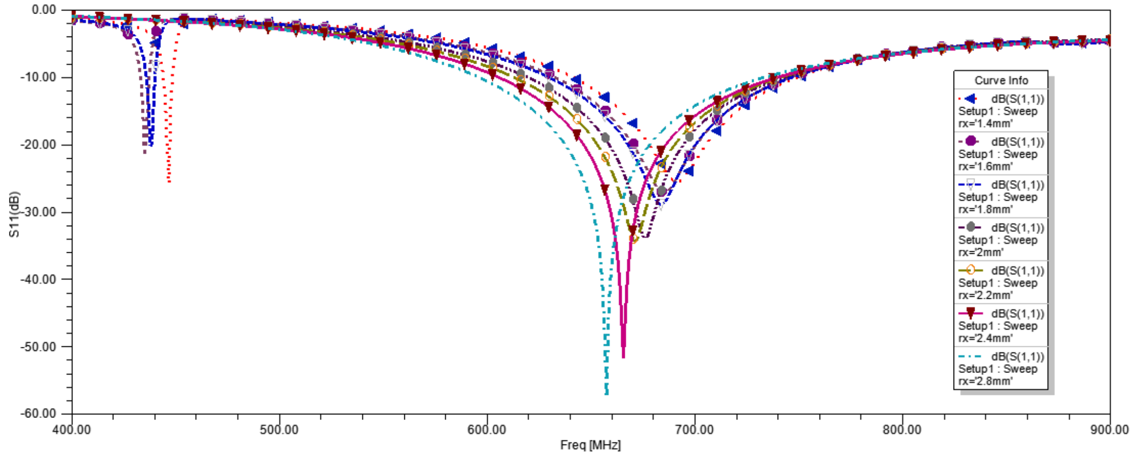


Fig. 4.Parametric Analysis for the width of Rectangular Loop

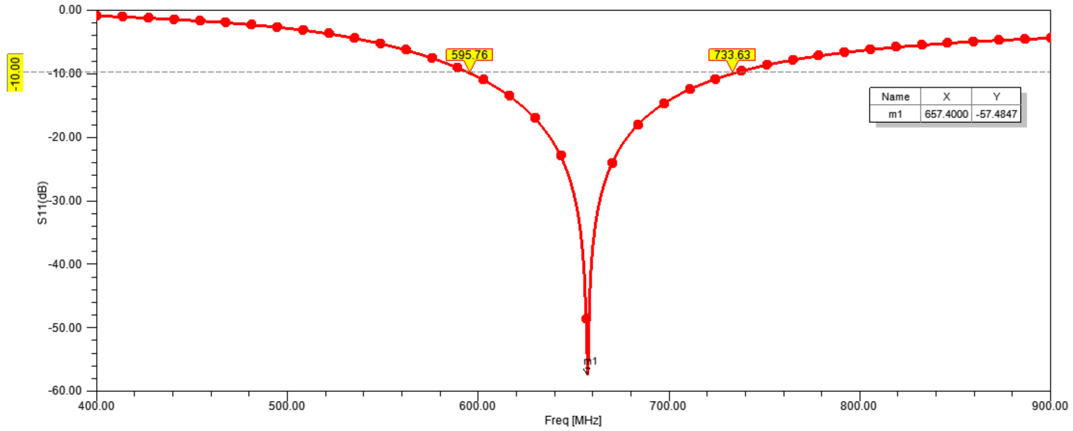


Fig. 5.Reflection Coefficient (dB) Vs Frequency (MHz)

In fig.5, the reflection coefficient is observed and there is less power loss with respect to the efficiency of the antenna and a good amount of reflected waves are also received without any fluctuations as well.

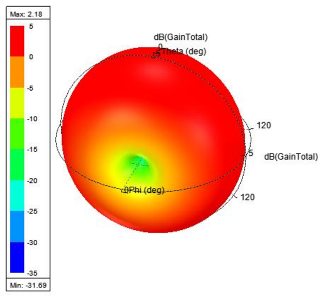
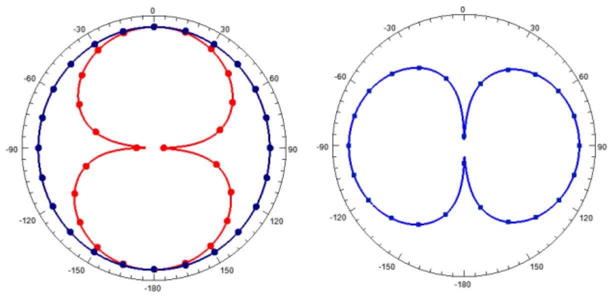


Fig. 6.3D Radiation Pattern

The 3D radiation pattern with gain is shown in fig.6. The maximum gain of 2.18 dB is obtained and this proves that this antenna is more effective in converting input power to radio waves.

Fig.7 shows the 2D radiation pattern obtained with good amount of radiation pattern in elevation (side view) in E-plane and azimuth (top-down) in H-plane. For the frequency range 596MHz to 733MHz, the voltage standing wave ratio (VSWR) is less than 2 and is shown in fig.8. A VSWR value under 2 is considered suitable for most antenna applications and which describes good impedance match.



(a) (b)

Fig. 7.2D Radiation Pattern (a) Elevation (b) Azimuth

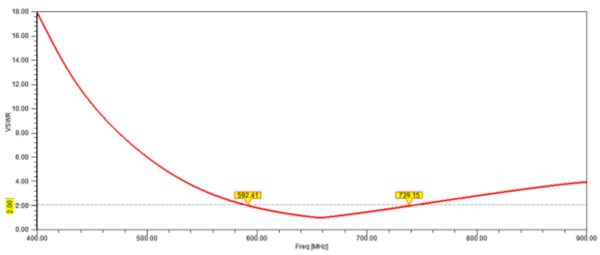


Fig. 8.VSWR vs Frequency(MHz)

V. CONCLUSION

Thus the rectangular loop monopole antenna for TV white space CR application has been evaluated and analyzed using the HFSS software and below mentioned are the observations that have been envisaged for the operating band 596MHz to 733MHz are return loss: -57.48dB and Gain: 1.653dB. The findings prove that this antenna works well in TV white space and is able to configure the TV frequencies which are left unused in the cosmos for other communication applications using cognitive radio technology with no interference with already existing users.

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