A 200 MHz to 850 MHz VHF/UHF Antenna for Local Area Cognitive Radio Networks Applications

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***Abstract*—Cognitive Radio Networks (CRN) support the optimal usage of licensed vacant spectrum using interviewing and underlay techniques. The aim of this work is to design a Very High Frequency (VHF) and Ultra High Frequency (UHF) range wideband antenna between 200 MHz and 850 MHz for CRN application. Antenna fabrication was done using FR4 substrate which measures a dimension of 108 mm × 108 mm. The underutilized spectrum in the range is effectively utilized by the cognitive user in the absence of a licensed primary user. This is achieved by the spectrum sensing technique by sensing the user environment. Therefore the necessity of spectrum sensing antenna is determined by this work and the same is achieved through meticulous design and extensive testing. The simulated and measured results are well in agreement and achieve wide bandwidth of 650MHz with a peak radiation efficiency of 96%.**

***Index Terms*—Cognitive radio antenna, CPW-feed, UHF antenna, VHF antenna, wideband antenna**

I. Introduction

All over the world, networks are getting upgraded from 4G to 5G or 5G to 6G to enhance the network with a high data rate, improved bandwidth, and high network connectivity. Even though the targeted network has enough channels in the prescribed range of 24 GHz to 100 GHz [1]. Researchers are facing difficulties in the implementation of millimeter wave bands [2]. Hence they are focusing more on low and mid band frequency ranges between 600 MHz and 6 GHz bands for the 5G and beyond. Since the regulation focuses on the UHF band for telecommunication with the network coordination between the licensed bands there is no need for cognitive radio for the telecommunication application.

The cognitive radio concept came by concerning the effective utilization of unused spectrum bands by intelligent software defined radio to reconfigure various parameters like carrier frequency, modulation technique, polarization, beam forming and transmit power, etc. [3, 4]. The important consideration is utilizing the least or rare usage licensed primary user carrier frequency for the deployment. Since the future network can coordinate with the network providers hence these techniques become the least significance in telecommunication but it is more suitable for local area networks.

Local Area Networks (LAN) are working in the free licensed band as carrier frequencies such as the ISM band of 2.4 GHZ and UNII band of 5GHz. When the number of users has increased the channels associated with the above-mentioned band are not sufficient hence additional channel requirement is essential for good connectivity and more coverage. FCC unlicensed the Ultra-Wideband (UWB) frequency ranges (3.1 GHz to 10.6 GHz) for commercial use hence the range of frequency is utilized for LAN. Even though more frequency channels are available for communication, the microwave frequency will not give wider coverage as a result there is a need for carriers less than 1 GHz for wider coverage of the networks. Here cognitive radio plays an important role in identifying unused band less than 1GHz and can be utilized for LAN [5].

In cognitive radio, antenna design plays a major role, and hence for local area networks apart from ISM and UNII band, there is a need for UWB antenna excluding crowded spectrum and frequency less than 1GHz band antenna. UWB antenna is more suitable for underlay cognitive radio networks whereas the cognitive user can utilize the carrier along with its licensed user without exceeding the noise threshold hence cognitive user transmitted power is restricted to −40dBm/MHz [6, 7]. Less than 1 GHz band in the UHF and VHF range is suitable for interviewing cognitive mode whereas a cognitive user can utilize the licensed carrier only when the licensed user is not utilizing the spectrum. Hence for spectrum sensing and communication, there is a need for an antenna working in both UHF and VHF ranges.

Several antenna design techniques was reported in the literature for UWB frequency [8−12] and extended the same with notch band characteristics [13−17] more suitable for the cognitive underlay network. Several articles have been reported in the mentioned UHF range [18−22] regarding antennas covering TV white space. For cognitive radio applications, several antenna design procedures were reported with reconfigurable utility with PIN/Varactor diodes, RF MEMS, FETs, etc. for the interviewing spectrum sensing and communication [23−29].

For local area networks cognitive radio interviewing mode applications less than 1 GHz are considered and literature is investigated. In [18], the author described omnidirectional wideband antennas operating in the TV

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whitespace band of 460MHz to 870MHz. The FR4 fabricated antenna dimension of 261 mm × 30 mm × 0.8 mm attained a simulated gain of 1.6 dB. In [19] rectangular patch monopole antenna was designed for the wideband operating frequency ranges between 470 MHz and 900MHz. The FR4 antenna with the dimension of 185 mm × 45 mm × 1.6 mm obtained an omnidirectional pattern at H-plane and a doughnut shape at E-plane.

In [20], a meandered planar wideband antenna for TV white space band of 470 MHz to 798 MHz was designed with a partial ground plane. The FR4 antenna has the dimension of 190 mm × 180 mm × 1.6 mm. The antenna works between 325 MHz and 815 MHz with gain ranges from 2.2 dBi to 4.6 dBi. In [21] broadband antenna with a passive network of six different loads and a transformer was designed using an optimized genetic algorithm and further LC network attached to the antenna feed point. The antenna has a length of 1.7 metres and operates over the frequency of 30 MHz to 1200 MHz.

In [22], authors reported a rectangular loop wideband antenna targeted for UHF TV white space for the impedance bandwidth of 596 MHz to 733 MHz. The FR4 substrate antenna with microstrip feed of dimension 160 mm × 100 mm × 1.6 mm provided a peak gain of 1.653dB and provided an omnidirectional radiation pattern with a peak efficiency of 81.79%. In addition, several UHF antenna designs were concentrated for the TV white space with various shapes such as planar trapezoidal, spiral, U-shaped meander slot, folded meander line, folded meander line, rectangular loop, and so on.

In the above mentioned literatures they focused only on the TV white space band and targeted the bandwidth between 470 MHz to 900 MHz band. In this work an antenna is designed for the cognitive radio framework in the working range of 200 MHz to 850 MHz band including both VHF and UHF range.

Table I gives the compassion of proposed work with the existing works. The optimized monopole antenna is obtained from various parametric analyses. The detailed antenna design and its parametric analysis are discussed in the following section.

TABLE I: COMPARISON OF PROPOSED WORK WITH LITERATURE

Reference	Band of Operation (MHz)	Band width (MHz)	Antenna size (mm^3)	Gain (dB)/ Radiation Efficiency
[18]	460–870	410	261×30×0.8	NR
[19]	470–900	430	185×45×1.6	1.6
[20]	470–798	328	190×180×1.6	0.05 to 2.45
[22]	596–733	137	160×100×1.6	81.79%
[30]	204–517	313	280×20×0.2	50–100%
Proposed Work	200–850	650	108×108×1.6	96%

II. ANTENNA DESIGN

The structure of the antenna is represented in Fig. 1. A simple rectangular patch antenna with slots merged with the circular loop to obtain the final wideband antenna. The Coplanar Waveguide (CPW) feed antenna with a dimension of 108 mm×108 mm is fabricated on the FR4 substrate of thickness 1.6 mm. The detailed antenna dimension is described in the Table II.

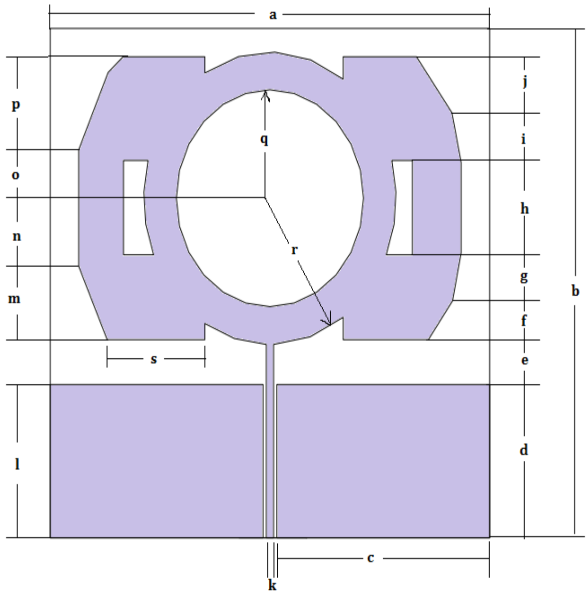


Fig. 1. Antenna structure.

TABLE II: ANTENNA DIMENSIONS

Variable	Size (mm)	Variable	Size (mm)
a	108	*k*	1.8
b	108	*l*	32.5
c	52.3	*m*	17
d	32.5	*n*	14.5
e	9.5	*o*	10
f	10	*p*	20
g	10	*q*	23
h	19	*r*	31
i	11	*s*	24
j	14.5		

III. PARAMETRIC ANALYSIS

The idea behind the wideband antenna from 200MHz to 850MHz is to merge the component of different frequencies of resonance. The simple circular loop antenna can resonate from 300MHz to 1300MHz and a simple rectangular patch can resonate from 300MHz to 960MHz. The antenna is made from the combination of the above two and makes a hexagonal outline with additional slots for the increasing electrical length of the antenna. Performing several iterations of the strip line width, ground plane length, and circular loop dimensions the final antenna structure evolved with the optimum area of 108mm×108mm. The evolution structure from a rectangular patch, circular ring, and final modified structure is represented in Fig. 2. The performance metric is analyzed such as the reflection coefficient of various structures involved in the design procedures described in Fig. 3 whereas obtained final structure has the reflection coefficient of below −10dB for the wideband range of 200MHz to 850MHz.

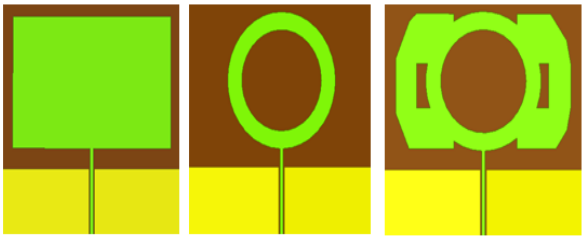


Fig. 2. Configuration of various steps involved in the designed antenna.

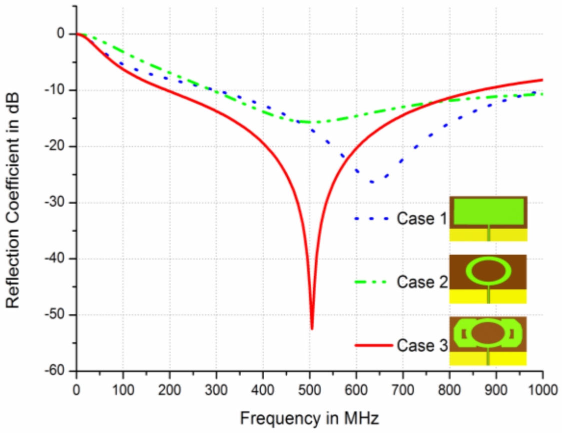


Fig. 3. The reflection coefficient of steps involved in the design.

The parametric studies were made for the optimum dimension of the antenna such as ground plane height, feed line width, and circular ring radius. The parametric study was made for the height of the ground plane in which the ground plane height is iterated to get the optimized structure for the desired frequency. The iteration value for the ground plane is depicted in Table III and the corresponding reflection coefficient is represented in Fig. 4.

TABLE III: PARAMETRIC ANALYSIS OF THE OPTIMUM GROUND PLANE HEIGHT

Iteration	Height of the ground plane (*d*, *l*) (mm)	Center frequency (MHz)	Min. reflection coefficient (dB)	Band width (MHz)
#1	30	445	−22.9	170−750
#2	31	465	−24.9	190−790
#3	32	490	−33.37	200−850
#4	34	540	−30.704	230−920
#5	35	570	−22.36	230−970
#6*	32.5	505	−52.44	200−850

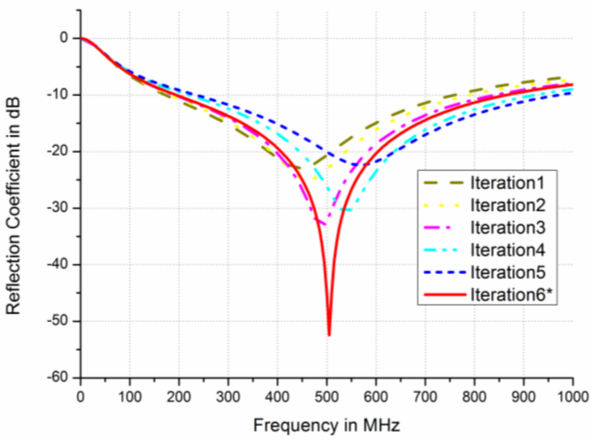


Fig. 4. The reflection coefficient for various ground plane height.

TABLE IV: PARAMETRIC ANALYSIS OF THE OPTIMUM FEED LINE WIDTH

Iteration	Feed line width (mm)	Center frequency (MHz)	Min. reflection coefficient (dB)	Band width (MHz)
#1	1.4	500	−30.59	185−870
#2	1.6	490	−52.23	190−850
#3	2	510	−31.84	210−850
#4	2.2	505	−31.84	215−850
#5*	1.8	505	−52.44	200−850

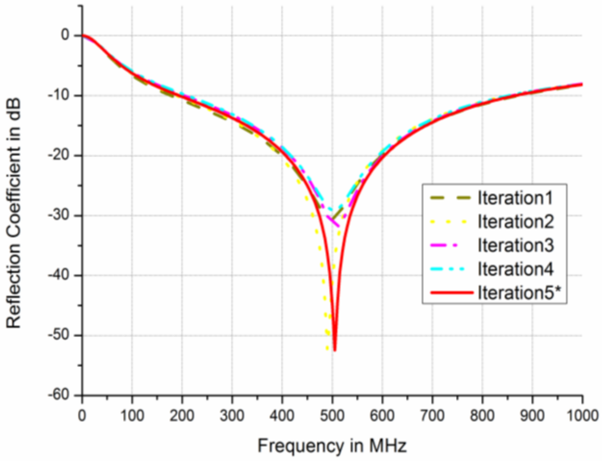


Fig. 5. The reflection coefficient for various feed line width.

The effect of feed line width is illustrated in Table IV and the corresponding reflection coefficient for various iterations is displayed in Fig. 5.

The effect of various circular width dimensions is illustrated in the Table V and the corresponding reflection coefficient for various iterations is displayed in Fig. 6.

TABLE V: PARAMETRIC ANALYSIS OF THE CIRCULAR CROSS SECTION RADIUS

Iteration	Radius (mm)		Center freq. (MHz)	Mini. Reflection coefficient (dB)	Band width (MHz)
	q	*r*			
#1	32	23	535	−39.06	200−850
#2	31	22	510	−39.41	200−860
#3	31	21	510	−49.77	195−865
#4	31	24	490	−33.59	205−840
#5*	31	23	505	−52.44	200−850

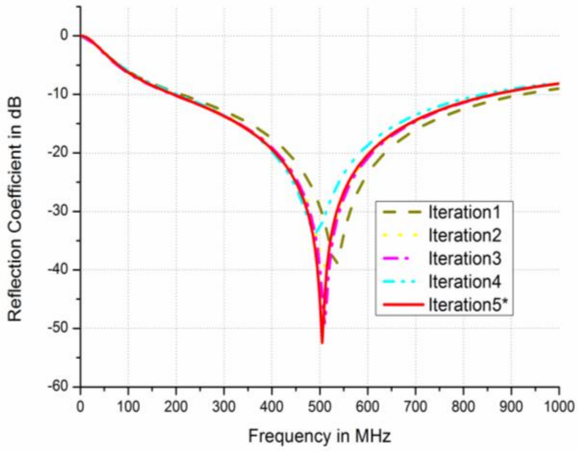
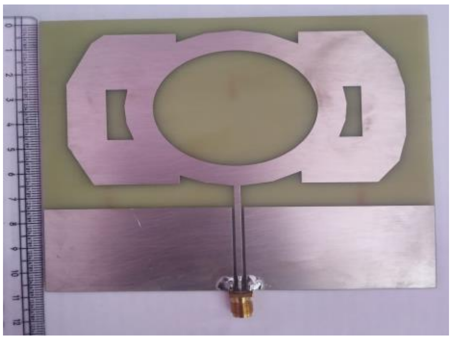


Fig. 6.The reflection coefficient for various circular radiuses.

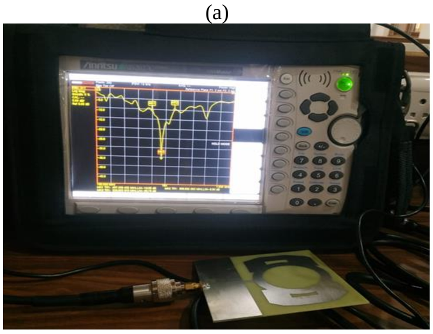
IV. Result and Discussion

The fabricated antenna and measurement setup is shown in Fig. 7. The proposed antenna is simulated using HFSS software version.15 and the same is fabricated and measured using network analyzer Anritsu (MS2027C VNA).

The simulated and measured reflection coefficient of the proposed antenna is shown in Fig. 8. The simulated reflection coefficient of the proposed antenna is below –10 dB for the entire desired operating range of 200 MHz to 850 MHz with a minimum of –52.44 dB at the center frequency of 505 MHz. The measured reflection coefficient is less than –10dB for the frequency ranges from 370MHz to 680 MHz and less than -5 dB for the frequency ranges from 200 MHz to 370 MHz and less than –8 dB for the frequency ranges from 680 MHz to 850 MHz. The simulated and measured VSWR of the proposed antenna is shown in Fig. 9. The simulated VSWR of the proposed antenna is less than 2 over the entire operating range of 200 MHz to 850 MHz. The measured VSWR is almost less than 2.5 over the entire operating range.



(a)



(b)

Fig. 7. (a) Fabricated antenna and (b) measurement setup.

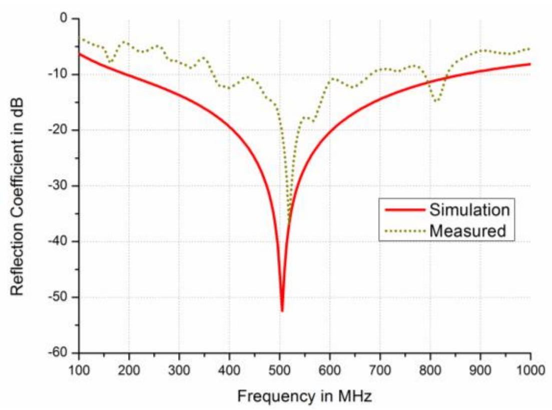


Fig. 8. Simulated and measured reflection coefficient.

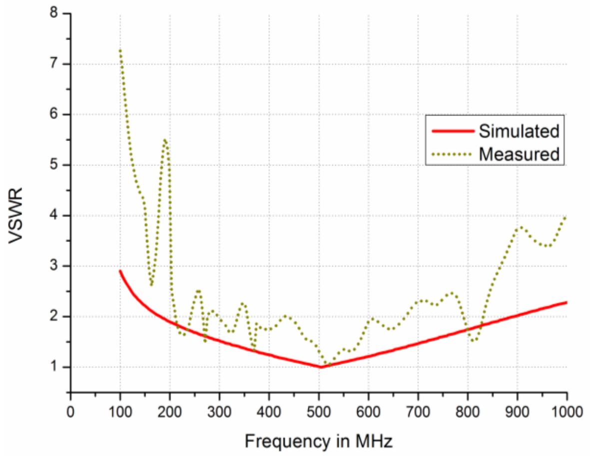


Fig. 9. Simulated and measured VSWR.

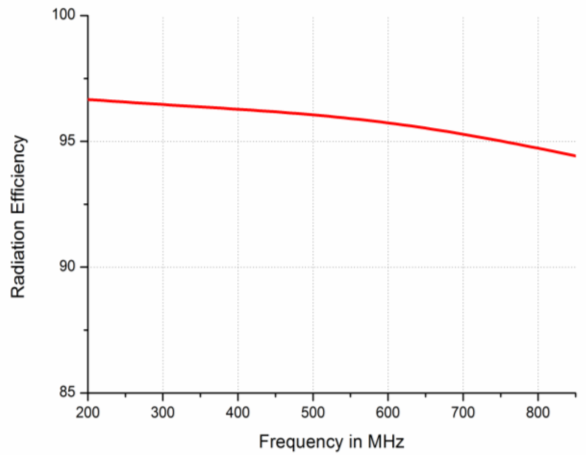


Fig. 10. Radiation efficiency.

The performance of a radio antenna's transformation of the radio-frequency power received at its terminals into radiated power is known as radiation efficiency. The radiation efficiency of the proposed antenna is above 94% with a maximum value of 96% at 200 MHz as represented in Fig. 10. The 3D radiation pattern of the antenna is displayed in Fig. 11. The 2D radiation pattern with the E-plane and H-plane is represented in Fig. 12. An omnidirectional radiation pattern is obtained at the E-plane where as doughnut shape pattern is obtained at H-plane throughout the operational band.

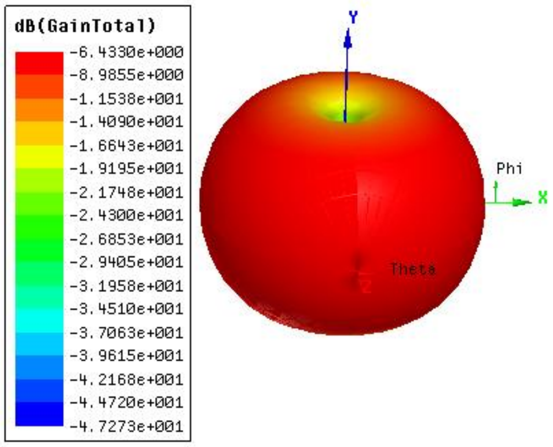


Fig. 11. 3D radiation pattern.

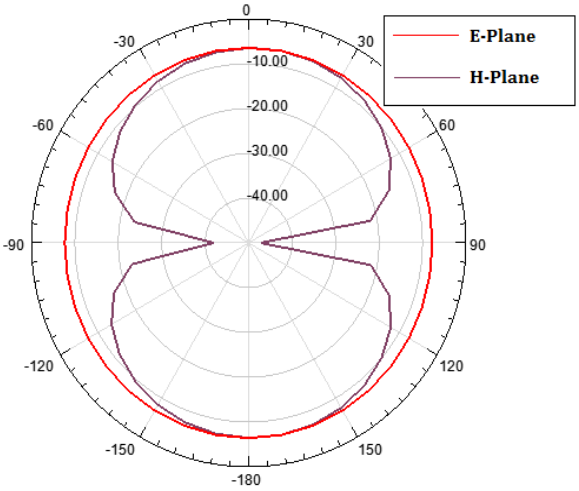


Fig. 12. 2D radiation pattern.

V. Conclusion

In this work, a VHF/UHF antenna for local area CRN application was proposed, designed, and tested. The simulation and measured performances were discussed in detail throughout the paper and the results obtained are agreed with each other. A slight deviation is accounted due to calibration and cable losses. The antenna radiation pattern is omnidirectional in E-plane and doughnut shape in H-plane which is more suitable for local area networks application. It can be seen that a radiation efficiency of 94% in the entire operational band with a peak efficiency of 96% was achieved. This work is open for future enhancement to improve the performance characteristics.

Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

Under the supervision of Prof. Dr. G Aloy Anuja Mary, Imran Javeed Settu conducted the research, simulation and measurement of antenna. Both authors had approved the final version of the paper.

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