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Antenna for Cognitive Radio Applications - A Review

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Abstract – **Advances in wireless technology have sparked interest in multiband reconfigurable antenna, an emerging technique that can shape the future of wireless technology. For various IoTs applications, it is desirable to have an efficient reconfigurable antenna in limited space. Configurability can be achieved by changing the physical parameters through electronic switches, optical switches, or metamaterials. This review paper comprehensively surveys recent cognitive radio antenna (CRA) advancements. The CRA is opportunistic spectrum accessibility (OSA) for "underutilized spectrum" feasible for utilizing resources and boosting licensed spectral occupancy. It significantly integrates two crucial concepts of spectrum sensing and communication. A thorough analysis of several interweave cognitive radio (CR) antennae is done. An explanation of filtering for hybrid CR approaches is also included, which offers a glimpse into the future. The ultra-wideband (UWB) / narrow band (NB) antenna's sensing and communication capabilities have been elaborated, which is best suited for CR.**

Keywords **– Cognitive Radio, filtenna, Hybrid CR, Interweave CR, Reconfigurable Antenna, Software Defined Radio, Spectrum, Underlay CR, UWB.**

I. Introduction

In The explosive expansion of the world's population is powering an extraordinary surge in the number of wireless communication subscribers. Satisfying all the subscribers concerning wireless communication is challenging, especially when the available licensed spectrum is limited [1]. CR techniques have been proposed to determine the solution to spectrum scarcity by allowing users to reuse the assigned frequency spectrum and make the most efficient use of the limited spectrum resource. The CR also intends to enhance spectrum sharing to mitigate spectrum scarcity for new communications companies. Spectrum is divided into two parts. Licensed spectrum: part of the electromagnetic spectrum assigned exclusively to wireless service providers for independent usage within a specific geographical area by paying the pre-decided license fee. Whereas unlicensed spectrum is for nonexclusive usage and can be used by anyone, but it is subject to some regulatory constraints [2]. The CR concept is mainly based on the paid spectrum for which a license is issued.

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The radio spectrum plays a critical role in the present era of wireless communication systems. The entire responsibility for distributing radio spectrum to private operators in any circle remains with government agencies.

In the meantime, the spectrum area is large, and the private company to whom the spectrum is allotted is limited. Primary and secondary networks are two different types of networks [3]. The primary network comprises devices that have been granted permission to use the license spectrum band. These users are the primary users (PU) having priority regarding spectrum access. Secondary devices with CR capabilities comprise the secondary network of secondary users (SU) with no spectrum license. Still, they have permission to access the spectrum of the PU and utilize it dynamically as they do not interfere with the primary devices [4]. In the busy hour, when traffic is at its uttermost level, most of the spectrum remains underutilized, resulting in ineffective use and antagonistic economic impact to the spectrum holder. On the other hand, most of the companies to whom spectrum is not allotted, i.e., secondary networks, cannot operate in the same geographical area as they do not have the accessibility of the spectrum.

This waved the bright path for the new technology where the underutilized spectrum of the primary user is shared with the secondary or auxiliary user. This helps the effective spectrum use and provides substantial financial support to the primary network for the underutilized spectrum.

II. Cognitive Radio

Software-defined radio (SDR) acts as a soft spectrum allocation as per any fixed protocol being finalized by both PU and SU. This protocol-based spectrum utilization dynamic spectrum allocation. SDR first initiated this coordination between the PU & SU regarding spectrum utilization. Later on, the incorporation of intelligence into SDR forms intelligent software-defined radio (ISDR), also known as cognitive radio technology (CRT). The algorithm of CR is not based on any fixed protocol; instead, in this algorithm, PU is the most beneficial. If the PU does not utilize the spectrum, the SU will use the same by providing smart revenue. The spectrum utilization based on priority, mutual utilization, and intelligence in an opportunistic manner is referred to as CR. Table 1 provides the detail of the CR based on various crucial parameters.

This intelligent adoption system acts like a brain capable of knowing, learning, and understanding. It assists in the auto-detection of the spectrum channel and alters all the transmission parameters to enhance the operating behavior of the SU. If PU approaches the spectrum simultaneously, SU has to leave the position in any circumstance by following the spectrum handoff mechanism. CR is the demand for the next-generation network (NGN), which is fully based on artificial intelligence providing a high level of security, fewer data loss, and smooth handoff with intelligent spectrum allocation algorithm and less infrastructure. CR's dynamic nature allows it to optimize its communication performance in real-time, making it a valuable addition to IoT applications that require efficient communication.

A. Antenna for Cognitive Radio

In CR technology, the antenna and the processor's role are crucial. It is essential to design an appropriate antenna with a fast-responding processor for the excellent working of the CR. Designers must consider several vital parameters before mass production. Fig.1 shows the distinct antenna constraints for the CR [5-6]. The choice of materials has greatly shaped the evolution of antennas in cognitive radio systems.

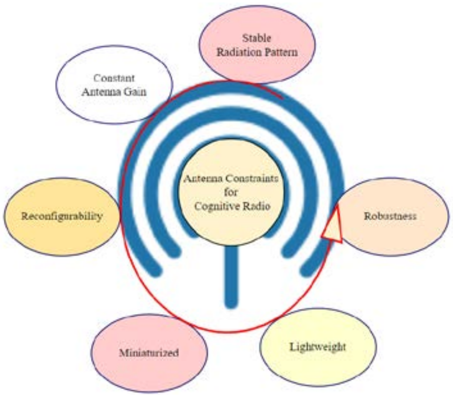


Fig. 1. Pictorial depiction of distinct antenna constraints for the CR [5-6].

TABLE 1
VARIOUS SIGNIFICANT PARAMETERS OF CR [5-6]

Sl. No.	Parameter	Cognitive Radio
1	Function	Spectrum allocation
2	IEEE Std.	802.22 IEEE
3	Working principle	SDR+ intelligence
4	Interference	Minimum
5	Efficiency	High
6	Priority	Primary user only
7	Communication	Point to multipoint
8	Energy Conservation	Highly concerned
9	Ability	To adopt free spectrum
10	Security	Day by day improving
11	Algorithm Complexity	High
12	Handoff	Spectrum handoff
13	Applications	Transmission distance extension, WLAN throughput, and so on

The development of metamaterials, has revolutionized antenna design, enabling compact size, wideband operation, reconfigurability, and adaptability to varying environmental conditions. These advancements not only optimize spectrum utilization but also enhance the overall performance of cognitive radio networks [7]. The distinct CR techniques are elaborated more briefly in the later stages of the paper.

III. ANTENNA FOR INTERWEAVE CR TECHNIQUE

The primary function of the interweaving CR technique is to find out the spectrum hole / white space throughout the spectrum and allow the SU to transmit the information through that vacant white space [8]. So, interweave CR is a collection of two distinct works scanning the spectrum to determine the free space where PU is absent and, after that, signal transmission in full-duplex mode through that free space without any term and condition of transmitted power. The entire process is well illustrated through the flow chart in Fig. 2.

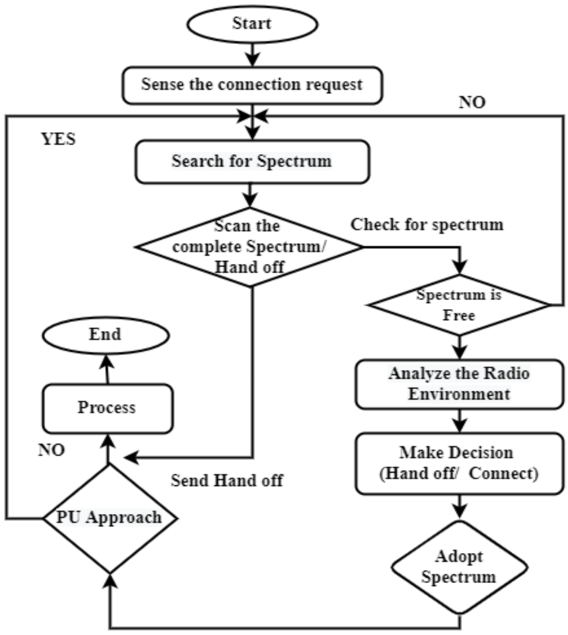


Fig. 2. Flow chart for interweave CR technique [8-9].

For scanning and using the frequency band, two antennae are required. To track the primary users' operation, it is recommended to utilize a wideband/ ultra-wideband/ reconfigurable narrow-band sensing antenna, while enabling secondary users to communicate can be achieved through the use of a reconfigurable antenna structure [9]. One antenna may also be enabled for sensing and communication purposes, but this mechanism may create trouble for the processor and increase the response time. So, generally, single antenna systems for both purposes are avoided. An antenna system comprises two radiating surfaces operating simultaneously; special care should be taken to ensure these two components are effectively isolated [10]. Omnidirectional radiation pattern and miniaturized structure [11] are the other two vital parameters for the interweave cognitive radio antenna design shown in Fig. 3.

Many antennas for interweave CR applications are designed and fabricated based on the above concept. The author proposed a miniaturized frequency reconfigurable multiple input multiple output (MIMO) antenna for interweave CR applications covering WiMAX band, LTE, and Wi-Fi range from 3.2 GHz to 3.9 GHz [12]. The overall dimension of the antenna is (60 X 120 X 1.56) mm3, designed on FR4 substrate with ε_r= 4.4 and 0.02 as the loss tangent. The biassing circuitry and microstrip feeding lines are located on the top layer. At the same time, the bottom layer, which serves as the reference ground plane, is etched with pentagonal radiating slots. The closed slot-line-based design was shown on the bottom substrate as it responds effectively to reactive loading with a varactor diode. The pentagonal slot line was chosen because of its good impedance matching, good radiation qualities, ideal size, and ease of reactive loading. A defective ground structure (DGS) structure is implemented to increase the excellent isolation between the adjacent antenna.

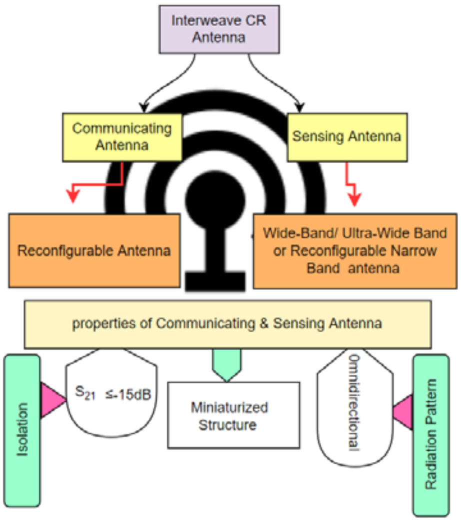


Fig.3. Antenna system detail of interweave CR [11].

To achieve reconfigurability varactor diode as the electronic switch is used. The antenna's top and bottom view is shown in Fig. 4. The role of the biasing circuit is significant. The biasing circuit comprises a resistor and a 1µH RF choke. The current limiting resistor is employed to prevent damage to the varactor diode for reverse bias leakage current. The antenna radiating structure is segregated from the DC supply using an RF choke.

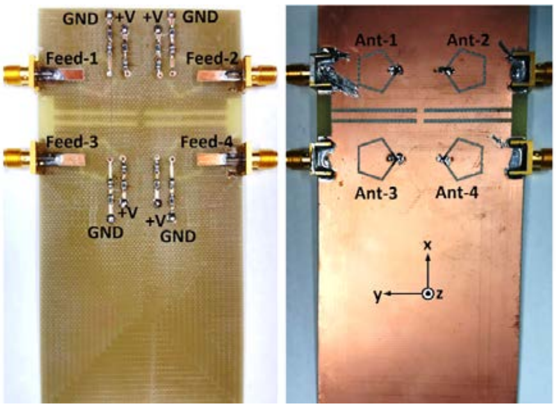


Fig. 4. Pictorial illustration of top and bottom view of fabricated model [12].

A varactor diode (SMV-1233) was employed to achieve frequency reconfigurability. Fig. 5(A), (B) shows the optimized structure's simulated and measured reflection coefficient, which correlate well. Due to biased circuit and fabrication limitations, there were minor differences between the simulated and measured results. The capacitance value across the varactor diode falls as the biassing voltage increases, and the frequency switches to higher values.

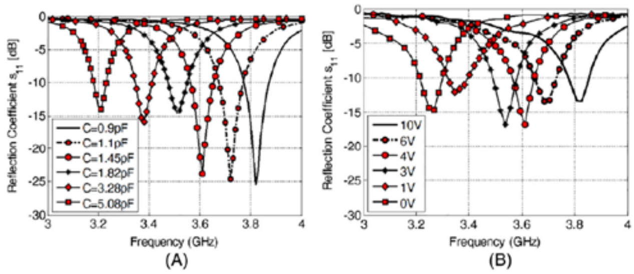


Fig. 5. The S11 of (A) simulated & (B) measured design [12].

MIMO antennas are extensively employed in wireless systems to meet high data rate needs and spectrum efficiency. The potential drawbacks of the paper include complex design and implementation, high cost, performance limitations, issues related to power consumption, and practical implementation challenges.

Interweave CR is achieved using a frequency reconfigurable MIMO antenna by the reverse bias voltage of two varactor diodes adjusted in the annular slot by changing the coupling capacitance [13]. Fig. 6 shows the fabricated design of the proposed antenna, which is fabricated on the FR-4 substrate having a dielectric constant of 4.4; the physical dimension of the antenna is (50 X 100 X 0.8) mm^3.

The design starts with a typical single-patch antenna with specific dimensions and a resonant frequency of 2.5 GHz. A 50-ohm microstrip transmission line is inset into the patch for the best impedance matching. The antenna was miniaturized in the second step by etching an annular slot in the ground plane to lower the resonant frequency (2.5 GHz to 1.75 GHz). An annular slot with a varactor diode adds frequency reconfigurability to the structure. The position of the reactive loading was investigated for various positions of the varactor diode along the annular slot.

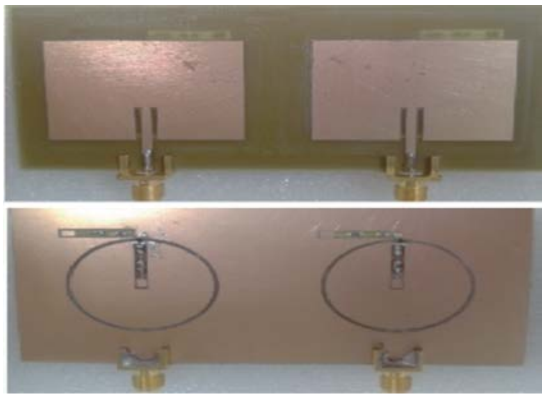
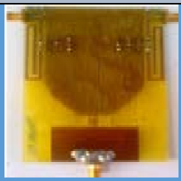
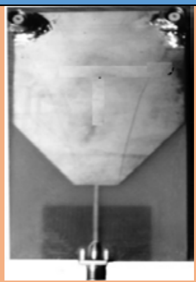


Fig. 6. Pictorial depiction of the top and bottom view of frequency reconfigurable MIMO antenna [13].

TABLE 2
DIFFERENT ANTENNA FOR INTERWEAVING CR APPLICATIONS

Ref. No.	Antenna	Pictorial view	Design Parameters	Performance Parameters	Advantages
[14]	MIMO Antenna		FR-4 Substrate εr = 4.3, Dimension: (65X120X1.56) mm^3	Wide-band: (0.720 to 3.44) GHz Other tuning bands: (0.573 to 0.68) GHz (0.834 to 1.12) GHz.	Compact, Good performance, Omnidirectional radiation pattern.
[15]	Frequency Reconfigurable Antenna		FR-4 EPOXY, ε_r= 4.3, tanδ =0.0018, Dimension: (68X51X1.6) mm^3	Wide-band: (2.63 to 3.7) GHz	Omnidirectional radiation pattern, The biasing circuit doesn't affect the circuit so much.
[16]	UWB Sensing Antenna		RO-4350, ε_r= 3.48, tan δ=0.0036, Dimension: (60X120X1.56) mm^3	UWB: (0.73 to 7.65) GHz Tuning Freq. Band: (0.77 to 2.51) GHz	Compact, Low profile, Planer structure, Good performance, Gain 3.2dBi, Efficiency 81%
[17]	MIMO Antenna		FR-4 Substrate ε_r= 4.3, tanδ =0.0018 Dimension: (65X120X1.56) mm^3	Wide-band: (0.7 to 3.6) GHz Other tuning frequencies: 1.95 GHz ,1.945 GHz 3.05 GHz, 0.77 GHz, 1.66 GHz ,1.0 GHz, 1.50 GHz, 2.45 GHz, 3.35 GHz, 1.06 GHz, 1.76GHz	Small wireless hand-held device, Good performance, Compact Size.
[18]	SISO Reconfigurable Antenna		ε_r= 2.33, tanδ =.0012 Dimension: (65X120X0.78) mm^3	Wide-band: 0.8 GHz to 2.2 GHz N.B frequency: 0.9 GHz, 1.15 GHz, 1.5 GHz, 1.85 GHz	Stable gain of 9dBi, Controlled radiation pattern, High efficiency, Simple structure.

Two more slots in the ground plane per element constitute the DC biassing circuit for the varactor diode. For six distinct biasing voltages, six different transitions are reported, that is 2.31GHz, 2.29GHz, 2.24GHz, 2.20GHz, 2.15GHz, 2.14GHz, and 2.12GHz. Fig. 7 shows the fabricated antenna's measured reflection coefficient at various bias voltages [13]. Adjusting the DC bias voltage results in a smooth transition in the antenna's resonant frequency. The varactor diode's capacitance is lowest at 6 V by resonating at 2.32 GHz. Any further increase in the bias voltage does not affect the antenna's resonant frequency since the diode's capacitance remains unchanged. Also, the isolation between the elements is high, which is suitable for communication. The design complexity increases with the installation of the diode in the structure. Also, the gain and efficiency of the antenna reduce due to frequency switching.

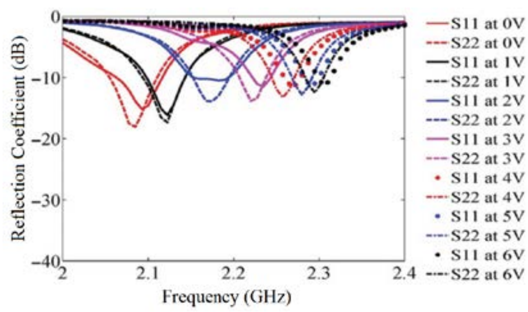
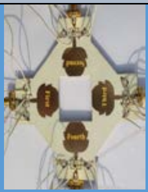
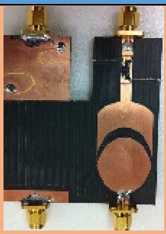
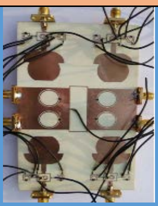


Fig. 7. Schematic illustration of measured reflection coefficient at various bias voltages [13].

TABLE 3
DIFFERENT ANTENNA FOR INTERWEAVING & UNDERLAY CR APPLICATIONS

Ref. No.	**Antenna**	**Pictorial view**	**Design Parameters**	**Performance Parameters**	**Advantages**
[19]	MIMO Filtenna		RO-4350, ε_r= 3.48, Dimension : (109.2X109.2) mm^2	Wide-band: 2.00GHz to 5.70GHz Narrow-band: 3.21GHz to 4.00GHz Notch band: 3.37GHz to 4.0GHz	High spectrum efficiency, High data Rate, Efficient filtenna system
[20]	MIMO Filtenna		Roger Duroid 5880, ε_r= 2.2, Dimension : (30X30X1.6) mm^3	UWB : 3GHz to 10GHz	Less fading, High channel capacity, Less impact of switch in operation, Acceptable gain
[21]	MIMO Filtenna		Dimension: (110X70X1.52) mm^3	Sensing range: 2.5 GHz to 4.2 GHz Interweave range: 2.5GHz to 4.2GHz Underlay range: 2.15GHz to 3.3GHz	Efficiency is greater than 60%, Good far-field performance, The entire design is on a single substrate.
[22]	MIMO Filtenna		Dimension: (120X100) mm^2	Wide-band: 2.5 GHz to 4.2 GHz Interweave range: 2.8GHz to 3.65GHz Notch -band: 2.15 GHz to 3.3 GHz.	Entire design on a single substrate, Isolation is under the acceptable range, Biasing circuits and lump elements don't have any effect on radiation patterns.

In Table 2, different antenna for interweaving CR applications is discussed based on design parameter, performance parameters, and the advantages of the antenna. A frequency reconfigurable MIMO antenna based on two meander lines with a UWB sensing antenna was designed on the adjacent side with a FR-4 substrate [14] having a relative permittivity of 4.4 and physical dimension (65X120X1.56) mm^3. To make the antenna frequency reconfigurable, two radiating structures are connected with the PIN diode; however, a varactor diode is used for fine-tuning. The sensing antenna having the omnidirectional radiation pattern and MIMO reconfigurable antenna covers the frequency range from 0.72 GHz to 3.44 GHz and 0.57 GHz to 2.55 GHz, respectively. The frequency band's limitations and the large size of the substrate limit its use for CR applications. Limitations also include high complexity and cost due to multiple elements of reconfigurability.

IV. ANTENNA FOR UNDERLAY CR TECHNIQUE

In spectrum underlay CR, SU can communicate their information within the allowable interference threshold level defined by the primary users by sharing a common channel [9]. Low power with shorter distance communication is the condition for the underlay CR for the SU. For communication and sensing purposes, wide-band or ultra-wideband antenna are used.To avoid interference between the PU and SU, a notch is produced in the operating band of the communicating antenna, which reconfigures itself by the performance of the PU. For sensing purposes, no notch frequency is required by a wideband (WB) / UWB antenna. There are three vital constraints for the underlay CR antenna. Firstly, at the notch frequency, the reflection coefficient must approach zero or as close as possible to zero. Secondly, throughout fixed radiation in the required direction so that the magnitude of the gain remains less fluctuated. Thirdly the radiation of the antenna sustains an omnidirectional pattern. Fig. 8 provides all the details of the underlay CR with antenna properties.

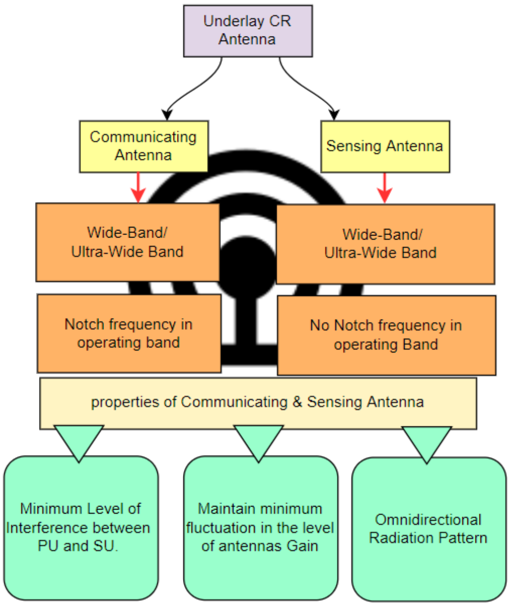


Fig. 8. Antenna System detail of underlay C.R [11].

V. Antenna for Hybrid CR Technique

In the hybrid CR technique, interweave and underlay CR techniques are achieved. Several antenna design constraints are discussed in separate sections in both CR techniques. These constraints can be fulfilled by incorporating a tunable filter into the antenna structure-fed line design. The integration of the filter with the antenna is called filtenna. For interweave CR, a tunable band pass filter (BPF) is needed, which changes its notch frequency as per the primary user engagement and analysis of the white space. The antenna input must match with the BPF output for proper optimized working. Also, the antenna fed line width and BPF must be the same to avoid any mismatch and maximize signal transmission.

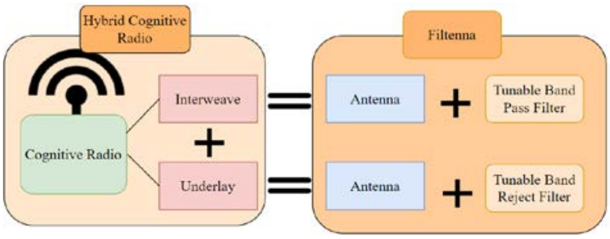


Fig. 9. Pictorial presentation of Filtenna concept for hybrid CR technique [19].

For the underlay CR technique, the tunable band reject filters are incorporated on the antenna's fed line, which is also based on the primary user activities. For maximum transmission, perfect matching is required. Fig. 9 provides the details of the hybrid CR technique antenna details. Along with the fed line of the antenna, the filter is also implemented on the ground plane. This helps in the implementation of two filters on the antenna. If tunable BPF is implemented on the fed line of the antenna, then it shows the performance of the interweave CR technique. If, in the same structure, we incorporate a tunable band reject filter on the ground plane, and by appropriate switching, we can change the mode from interweave CR to underlay CR.

When two CR techniques are achieved, it's an excellent example of the hybrid CR technique reconfigurable filtering [19-22]. The author first simulated a multipurpose filter comprised of an all-pass filter, a tunable bandpass filter, and a tunable band reject filter separately [19]. This will assist in three sensing's, interweave and underlay communicating antenna functionalities. These multipurpose antennae are later integrated with the wideband MIMO antenna.

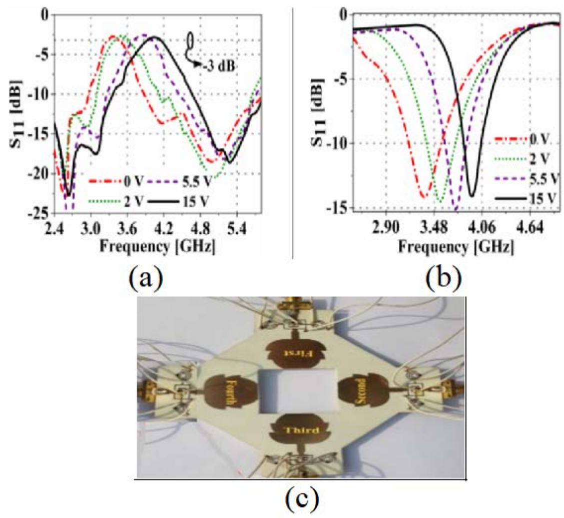
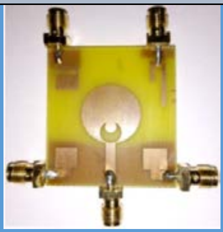
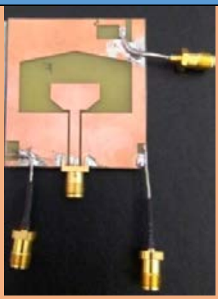
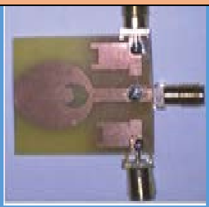


Fig. 10. Pictures displaying (a) S11 of the underlay CR (b) S11 of the interleave CR (c) Fabricated structure of the antenna [19].

To avoid any inconvenience, the width of the feed line of the antenna and filter is kept equal to 3mm. The role of three switches is significant for switching the filter as per the requirement. The fabricated antenna structures are shown in Table 3. The filter tuning after fabrication is done with the help of six varactor diodes. Integrating the filter and the DC biasing circuit increases the complexity and reduces the efficiency of the circuit to some extent but under the tolerable range. The measured S11 of the underlay and the interleave CR communicating antenna are shown in Fig. 10 (a) and (b), respectively, and (C) illustrates the fabricated structure of the antenna. Underlay communication antennas with frequency tunable ranges of (3.37-4.0) GHz, i.e., 630 MHz, interweave communication antennas with frequency tunable ranges of (3.21-4.0) GHz, i.e., 790 MHz is clear from Fig. 10 (a) and (b). Multiple varactor diode with biasing circuit makes the design and implementation complex. As the antenna size is relatively large, its practical implementation is also tough. In Table 3, different antenna types for interweaving CR and underlay CR applications are discussed based on design parameters, performance parameters, and the advantages of the antenna.

TABLE 4
DIFFERENT UWB/NB ANTENNA FOR THE CR APPLICATIONS

Ref. No.	Antenna	Pictorial view	Design Parameters	Performance Parameters	Advantages
[23]	UWB & NB Antenna		FR-4 Substrate, ε_r= 4.4, tanδ = 0.019 Dimension: (40 X 36 X 1.6) mm^3	UWB: (3.1 to 10.6)GHz, NB: (8.7 to 9.92G)GHz, (9.82 to 10.74)GHz, (3.06 to 4.23)GHz, (6.33 to 8.83) GHz (4.00 to 6.37)GHz.	Compact and simple, less cost, 5 antenna on a single substrate, Better performance, Isolation less than 16 dB.
[24]	CPW Fed UWB Antenna		FR-4 Substrate, ε_r= 4.4, tanδ = 0.02, Dimension: (42X50X0.8) mm^3	UWB: (3.1 to 10.6)GHz, Other: (2.96 to 5.38)GHz, (5.31 to 8.62)GHz, (8.48 to 11.02)GHz.	Simple size, Orthogonal characteristics mode, No extra structure for isolation, Better performance, 4 antenna on a Single substrate, Isolation of 17.3 dB maintained.
[25]	3 Port WB & NB Antenna.		FR-4 Substrate, ε_r= 4.4 Dimension: (30X30X1.6) mm^3	UWB: (3.1 to 10.6)GHz, Other: (6.36 to 6.63)GHz, (7.33 to 7.77)GHz.	Compact structure, 3 antenna on a single substrate, Better performance.
[26]	CPW FED, UWB Conformal Monopole Antenna		ROGER RO-3033, ε_r= 3, tanδ = .0013 Dimension: (63.6X37X.25) mm^3	UWB: (2 to 12) GHz, Other: (5.7 to 5.9) GHz.	Good impedance matching, Better isolation, Stable radiation pattern, Better performance, Conformal design.
[27]	UWB Antenna		R.T./Duroid-5880, ε_r= 2.2, tanδ = 0.0009, Dimension: (60X100X0.78) mm^3	UWB: (1 to 5)GHz, Other: (0.43 to 1) GHz.	Compact reconfigurable UWB antenna, Overcome RF spectrum crowd, Simple structure.
[28]	UWB/ NB Planar Antenna		FR-4 Substrate, ε_r= 4.3 Dimension: (60X58X1.6) mm^3	UWB: (3.4 to 10.2)GHz, NB: (4.7 to 5.1)GHz, (5.3 to 6.0)GHz.	Flat and conformal structure, Omnidirectional radiation pattern for all frequencies.
[29]	Reconfigurabl e Compact Antenna		R.T./Duroid-5880, ε_r= 2.2 Dimension: (163X80)mm^2	(1 to 4) GHz, NB: (0.4 to 1) GHz	Compact size, Omnidirectional radiation pattern, Varactor diode used for reconfigurability.

VI. UWB/NB ANTENNA FOR THE CR APPLICATIONS

The application of UWB antenna for spectrum sensing purposes and narrow band antenna for communication purposes is quite common. Table 4 describes several UWB/NB antennas used for the CR applications. The author reported a compact integrated multiport UWB and NB antenna whose dimension is (40 X 36 X 1.6) mm^3 in FR-4 substrate with a dielectric constant of 4.4 and a loss tangent of 0.019. UWB of (3.1 to 10.6) GHz is obtained with the help of specific defects created in the antenna's ground plane [23]. At the same time, the NB antenna consists of 5 different frequency band slots, i.e., (8.7 to 9.92) GHz, (9.82 to 10.74) GHz, (3.06 to 4.23) GHz, (6.33 to 8.83) GHz, and (4.00 to 6.37) GHz. Out of the four NB antenna two antenna are partial ground. These can perform up to four communication tasks simultaneously. Hardware design, signal routing, and calibrating the five-port system by maintaining isolation is challenging.

The paper reported by the author is a four-port coplanar waveguide (CPW) fed antenna [24]. In this paper, three-loop operates at (2.96 to 5.38) GHz, (5.31 to 8.62) GHz, and (8.48 to 11.02) GHz for communication purposes, having its application in 5G and sub 6G. UWB from (3.1 to 10.6) GHz detects the cognitive radio's free spectrum band. The three-port UWB and NB integrated antenna is reported dual band are obtained by each narrow band antenna used for communication purposes [25]. The dimension of the FR-4 substrate is (30 X 30 X 1.6) mm^3 having a dielectric constant of 4.4. As the number of narrow-band antennae increases, the size and efficiency of the frequency band utilization also improve. But it may hurt the isolation of the antenna, and maintaining compactness is quite challenging.

The conformal antenna proposed as a CPW-fed integrated UWB / NB antenna is designed in Roger (RO-3033) substrate [26]. The thickness of the antenna is optimized up to a great level so that it can easily bend on the cylindrical structure without any wear and tear. The antenna provides a UWB of 2 to 12 GHz and a narrow band from 5.7 GHz to 5.9 GHz.

VII. CONCLUDING REMARK

It is challenging to satisfy the world's massive population through communication with limited resources, but it can be achieved through the effective spectrum utilization technique. Along with previous accomplishments, several fundamental concepts, theories, properties, and requirements for CR are discussed. Interweave and underlay CR are the two distinct techniques to share the spectrum. Recently, a new hybrid technique has gained popularity in which the interweave and underlay techniques are implemented by filtenna in a single structure. Here, an attempt has been made to discuss various antenna types used for the CR technique. A particular emphasis is placed on the interweave and hybrid CR techniques. Several UWB GHz and narrow-band antenna are discussed separately, which is used for sensing and communication.

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