We are IntechOpen, the world's leading publisher of Open Access books
Built by scientists, for scientists

4,800
Open access books available

122,000
International authors and editors

135M
Downloads

154
Countries delivered to

Our authors are among the

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Cognitive Radio: UWB Integration and Related Antenna Design

Mohammed Al-Husseini[1], Karim Y. Kabalan[1],
Ali El-Hajj[1] and Christos G. Christodoulou[2]
[1]American University of Beirut
[2]University of New Mexico
[1]Lebanon
[2]USA

1. Introduction

The emerging feature-rich and high-data-rate wireless applications have put increasing demand on radio spectrum. The scarcity of spectrum and the inefficiency in its usage, as caused by the current radio spectrum regulations, necessitate the development of new dynamic spectrum allocation policies to better exploit the existing spectrum.

The current spectrum allocation regulations assign specific bands to particular services, and grant licensed band access to licensed users only. Cognitive Radio (CR) will revolutionize the way spectrum is allocated. In a CR network, the intelligent radio part allows unlicensed users (secondary users) to access spectrum bands licensed to primary users, while avoiding interference with them. In this scheme, a secondary user can use spectrum sensing hardware/software to locate spectrum portions with reduced primary user activity or idle spectrum slots, select the best available channel, coordinate access to this channel with other secondary users, and vacate the channel when a primary user needs it. To achieve this, the transceiver in a CR system should have awareness of the radio environment in terms of spectrum usage, power spectral density of transmitted/received signals, and wireless protocol signaling, should be able to adaptively tune system parameters such as transmit power, carrier frequency, and modulation strategy. The transceiver should also be ended with an antenna system that can simultaneously operate over a wide frequency band (sensing) and a chosen narrow band (communication), or operate over an ultra-wide frequency band while possibly blocking signals in a narrow frequency range.

Ultra-wideband (UWB) is a transmission technique that uses pulses with a very short time duration across a very large frequency portion of the spectrum. UWB is different from other radio frequency communication techniques in that it does not use RF carriers, but instead employs modulated high frequency pulses of low power with a duration of less than 1 nanosecond. From the perspective of other communication systems, the UWB transmissions are part of the low power background noise. Therefore UWB promises to enable the usage of licensed spectrum without harmful interference to primary communication systems, and can be used as an enabling technology for implementing CR.

In this chapter, we offer a general overview of Cognitive Radio and dynamic spectrum access, discuss the advantages of using UWB as an enabling technology for CR, and give

special attention to the latest research on Antenna Design for CR. The chapter will be organized as follows. Section 2 will discuss the current radio spectrum regulations and spectrum usage, and will focus on the availability of radio spectrum and the efficiency of its use. Section 3 will deal with the concepts of Spectrum Sharing and Dynamic Spectrum Access. Section 4 will investigate the advantages of integrating CR with the UWB technology and the recent research on the topic. Section 5 will review the recent work in antenna design for Cognitive Radio. Finally, a conclusion will be given in Section 6.

2. Current radio spectrum allocations/regulations

Radio spectrum refers to the electromagnetic frequencies between 3 kHz and 300 GHz. Table 1 lists the bands that make up this spectrum. Access to the spectrum is restricted by a radio regulatory regime, which licenses most of it to be exclusively used by traditional communications systems and services. The spectrum allocation regime guarantees that the radio communications systems are protected against interference from other radio systems.

Designation	Frequency	Wavelength
VLF (very low frequency)	3kHz to 30kHz	100km to 10km
LF (low frequency)	30kHz to 300kHz	10km to 1km
MF (medium frequency)	300kHz to 3MHz	1km to 100m
HF (high frequency)	3MHz to 30MHz	100m to 10m
VHF (very high frequency)	30MHz to 300MHz	10m to 1m
UHF (ultra-high frequency)	300MHz to 3GHz	1m to 10cm
SHF (super-high frequency)	3GHz to 30GHz	10cm to 1cm
EHF (extremely high frequency)	30GHz to 300GHz	1cm to 1mm

Table 1. The radio spectrum

Frequency allocation or spectrum allocation refers to licensing parts of the spectrum for exclusive or shared usage, and to declaring other parts as unlicensed or as open spectrum. The process of spectrum allocation is organized by national and international institutions usually called regulators. Internationally, frequency allocation processes are harmonized with the help of the International Telecommunication Union, which is the United Nations agency for information and communications technologies. In Europe, spectrum regulation is the responsibility of the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT). In the United Kingdom, the Office of Communications (Ofcom) handles spectrum regulation, whereas in the United States of America, this responsibility is shared between the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA). In China and Japan, spectrum allocation is respectively conducted by the Ministry of Information Industry (MII) and the the Ministry of Internal Affairs and Communications (MIC).

Four approaches can differentiate the regulation of radio spectrum (Berlemann & Mangold, 2009). These are 1) the licensed spectrum for exclusive usage, 2) the licensed spectrum for shared usage, 3) the unlicensed spectrum, and 4) the open spectrum.

In the first approach, which FCC calls the exclusive use model, the licensee has exclusive usage rights for a specific spectrum. An example of a spectrum licensed for exclusive usage are the frequency bands sold for use in the Universal Mobile Telecommunication System (UMTS) in Europe.

The second approach (called the command-and-control model by FCC) restricts the licensed spectrum for shared usage to a specific technology. An example of this approach could be the spectrum used for public safety services.

In the unlicensed spectrum approach, which FCC calls the commons model or open access, the spectrum is available to all radio systems operating according to regulated standards. The Industrial, Scientific and Medical (ISM) 2.4 GHz band and the Unlicensed National Information Infrastructure (U-NII) 5–6 GHz bands are examples of unlicensed or license-exempt spectrum.

The fourth and last approach, the open spectrum, allows anyone to access any range of the spectrum without any restriction. Yet, a minimum set of rules from technical standards or etiquettes that are required for sharing spectrum should be respected in this approach.

With the licensed spectrum approaches, spectrum resources could often be wasted. For example, portions of the spectrum could become unused because the communications systems licensed to operate in this spectrum have become more spectrum efficient due to technology advancements, and thus these communications systems can operate in only a percentage of the spectrum initially licensed for that specific service. In another direction, if a service to which spectrum is licensed is not economically successful, its licensed spectrum remains largely unused. Furthermore, the spectrum dedicated to public safety and military radio systems is only occasionally used, which means it is unused most of the times. As a result, large parts of the spectrum are currently used inefficiently. Paradoxically, 90 to 95% of the licensed radio spectrum is not in use at any location at any given time (Berlemann & Mangold, 2009), especially that the current radio regulatory regime is too complex to handle the increasingly dynamic nature of emerging wireless applications. Added to the fact that the demand for additional spectrum is growing fast, even faster than costly technologies like Multiple Input Multiple Output (MIMO) and Space Division Multiple Access (SDMA) can improve spectrum efficiency, the conclusion is that the current spectrum regulations should be fundamentally rethought in order to solve the spectrum scarcity and limited radio resources problems.

Could the solution be in more unlicensed spectrum? There is definitely a strong motivation for more unlicensed spectrum, due to its commercial success and the many different radio communications systems that operate within such spectrum. However, as more parties and technologies utilize unlicensed spectrum, it is becoming more crowded and consequently less available to all. This again necessitates the availability of more spectrum, or more efficient radio systems.

3. Dynamic spectrum access and cognitive radio

The increasing demand for wireless connectivity and current crowding of unlicensed spectra necessitate a new communication paradigm to exploit the existing spectrum in better ways. The current approach for spectrum allocation is based on assigning a specific band to a particular service. This is illustrated by the FCC frequency allocation chart shown in Fig. 1. The

utilize this valuable resource. A solution to this inefficiency, which has been highly successful in the ISM (2.4 GHz), the U-NII (5–6 GHz), and microwave (57–64 GHz) bands, is to make spectra available on an unlicensed basis. However, in order to obtain spectra for unlicensed operation, new sharing concepts have been introduced to allow use by secondary users under the requirement that they limit their interference to pre-existing primary users.

Fig. 1. The US spectrum allocation chart (NTIA, 2003)

Cognitive radio (CR) technology is the key enabling technology which provides the capacity to share the wireless channel with the licensed users in an opportunistic way. CRs are foreseen to be able to provide the high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques. In order to share the spectrum with licensed users without interfering with them, and meet the diverse quality of service requirement of applications, each CR user in a CR network must (Chen & Prasad, 2009):

- Determine the portion of spectrum that is available, which is known as Spectrum sensing.
- Select the best available channel, which is called Spectrum decision.
- Coordinate access to this channel with other users, which is known as Spectrum sharing.
- Vacate the channel when a licensed user is detected, which is referred as Spectrum mobility.

To fulfill these functions of spectrum sensing, spectrum decision, spectrum sharing and spectrum mobility, a CR has to be cognitive, reconfigurable and self-organized. An example of the cognitive capability is the CR's ability to sense the spectrum and detect spectrum holes (also called white spaces), which are those frequency bands not used by the licensed users or having limited interference with them. The reconfigurable capability can be summarized by the ability to dynamically choose the suitable operating frequency (frequency agility), and the ability to adapt the modulation/coding schemes and transmit power as needed. The self-organized capability has to do with the possession of a good spectrum management scheme, a good mobility and connection management, and the ability to to support security functions in dynamic environments.

Dynamic spectrum allocation models

Dynamic spectrum access (DSA) represents the opposite direction of the current static spectrum management policy. It is broadly categorized under three models: the dynamic exclusive use model, the open sharing model, and the hierarchical access model. The taxonomy of DSA is illustrated in Fig. 2.
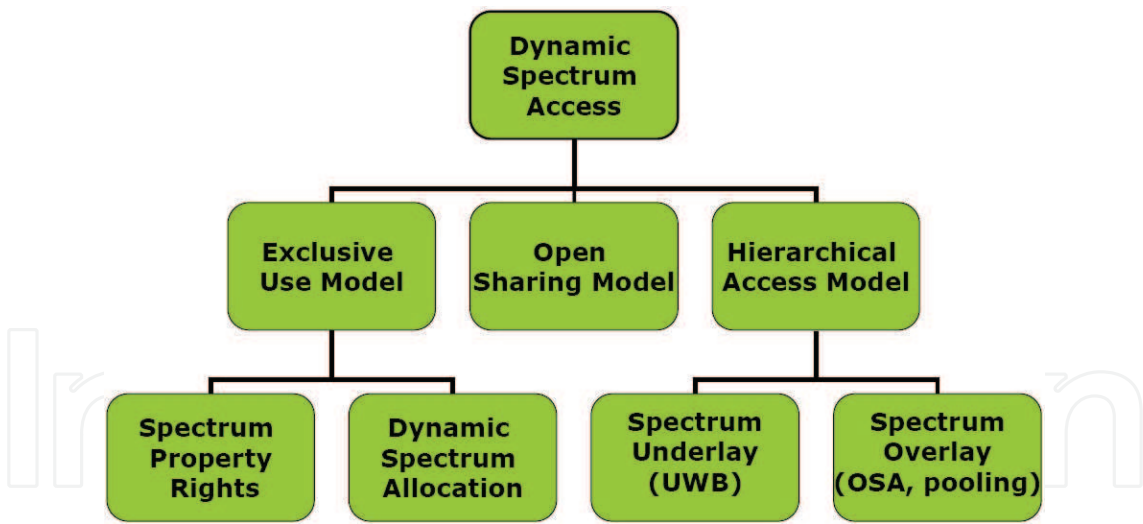
Fig. 2. Dynamic spectrum access models

In the dynamic exclusive use model, the spectrum bands are still licensed to services for exclusive use, as in the current spectrum regulation policy, but flexibility is introduced to improve spectrum efficiency. Two approaches have been proposed under this model: spectrum property rights and dynamic spectrum allocation. The first approach, the spectrum property rights, allows licensees to sell and trade spectrum and to freely choose technology. In the second approach, the dynamic spectrum allocation, the aim is to improve spectrum efficiency through dynamic spectrum assignment by exploiting the spatial and temporal traffic statistics of different services.

The open sharing model employs open sharing among peer users as the basis for managing a spectral region. Supporters of this model rely on the huge success of wireless services operating in the ISM band.

A hierarchical access structure with primary and secondary users is adopted by the third model. Here, the spectrum licensed to primary users is open to secondary users while limiting the interference perceived by primary users. Two approaches to spectrum sharing between primary and secondary users have been considered: spectrum underlay and spectrum overlay.

In the underlay approach, secondary users should operate below the noise floor of primary users, and thus severe constraints are imposed on their transmission power. One way to achieve this is to spread the transmitted signals of secondary users over an ultra-wide frequency band, leading to a short-range high data rate with extremely low transmission power. Assuming that primary users transmit all the time (worst case scenario), this approach does not rely on detection and exploitation of spectrum white space.

The spectrum overlay (also termed opportunistic spectrum access or OSA) approach imposes restrictions on when and where secondary users may transmit rather on their transmission power. In this approach, secondary users avoid higher priority users through the use of spectrum sensing and adaptive allocation. They identify and exploit the spectrum holes defined in space, time, and frequency.
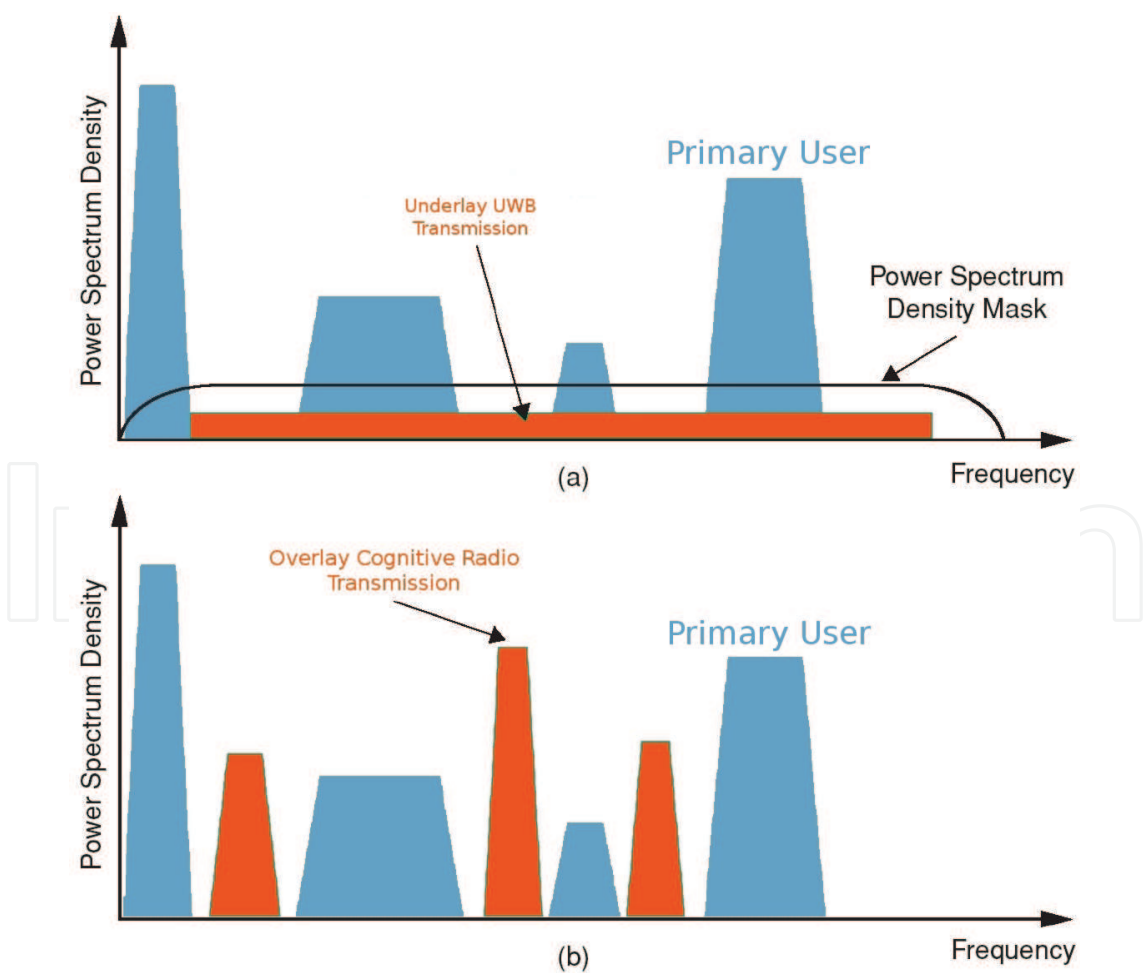
Fig. 3. Underlay (a) and overlay (b) spectrum sharing approaches

The underlay and overlay approaches in the hierarchical model are illustrated in Fig. 3. They can be employed simultaneously for further spectrum efficiency improvement. Furthermore, the hierarchical model is more compatible with current spectrum management policies and legacy wireless systems as compared to the other two models.

4. Ultra-wideband cognitive radio

Ultra-wideband (UWB) is any wireless technology that has a bandwidth greater than 500 MHz or a fractional bandwidth greater than 0.2. Ultra-wideband systems have been attracting an intense attention from both the industry and academic world since FCC allowed the unlicensed usage of UWB in 2002.

UWB is a promising technology for future short- and medium-range high-data-rate wireless communication networks. The most appealing property of UWB is that it is an underlay system, meaning that it can coexist in the same temporal, spatial, and spectral domains with other licensed/unlicensed radios. Other interesting features of UWB include that it has a multi-dimensional flexibility involving adaptable pulse shape, bandwidth, data rate, and transmit power. On top of these, UWB has a low power consumption, and it allows significantly low complexity transceivers leading to a limited system cost. Another very important feature of UWB is providing secure communications. The power spectrum of a UWB transmission is embedded into the noise floor, thus it is very hard to detect. Combined with other higher layer encryption techniques, this feature introduces very secure transmission.

UWB systems are allowed to operate in the 3.1–10.6 GHz band without a license requirement (according to the current FCC regulations in the USA), but under very strict transmission power limits. Both indoors and outdoors, UWB systems are not permitted to transmit more than -42 dBm/MHz in the specified band. This limitation ensures that the UWB systems do not interfere to the licensed operators that use various frequency bands in the UWB frequency range. However, FCC regulations could be revised and regulatory agencies may consider to allow UWB systems to transmit with higher powers and offer more freedom to UWB if UWB is combined with CR to give it the ability to sense the spectrum to ensure the absence of licensed users operation in their target bands.

There are two common technologies for implementing UWB: the Orthogonal Frequency Division Multiplexing based UWB (UWB-OFDM) and the impulse radio based UWB (IR-UWB). IR-UWB is carried out by transmitting extremely short low-power pulses that are on the order of nanoseconds. An advantage of IR-UWB is that it enables to use various types of modulations, including on-off keying (OOK), pulse amplitude modulation (PAM), pulse shape modulation (PSM), pulse interval modulation (PIM), pulse position modulation (PPM), and phase shift keying (PSK).

Time hopping (TH) codes that are specific to each user can be employed by IR-UWB systems for multi-user access. The TH codes, which are specific pseudo-random noise (PN) codes, enable the UWB system to provide access to multiple users conveniently. The multi-user parameters can be adaptively modified according to the change in number of users. To enable more users to communicate, for example, the UWB system can increase the number of chips in each frame at the expense of decreasing each user's data rate. Coherent receivers (such as Rake and correlator receivers) as well as non-coherent ones, such as energy detector and transmitted reference receivers, can be utilized for IR-UWB communications. Along with the flexibility in modulation methods and receiver types, IR-UWB also offers a variety

of options regarding the shapes of the transmitted pulses. IR-UWB systems have an excellent multi-path resolving capability because of the extremely wide frequency band that they occupy. This property makes IR-UWB a precise radar technology as well as a highly accurate ranging and positioning system, in addition to being a communication system.

In OFDM-based UWB, orthogonal subcarriers are employed to modulate the transmitted data. In the current multi-band OFDM planning, which divides the entire UWB band into 14 sub-bands, each subband is considered to be 528 MHz and contains 128 subcarriers. The subcarrier spacing is usually chosen to be less than the channel coherence bandwidth. This makes each subcarrier go through a flat fading channel. As a result, the UWB-OFDM receiver needs a simple equalizer implementation to recover the originally transmitted signal. With UWB-OFDM, it is easy to avoid interference to licensed systems. By simply turning off the subcarriers that overlap with the spectra of the licensed system, a UWB-OFDM transmitter can avoid jamming a licensed signal.

UWB features meeting cognitive radio requirements

Though usually associated with the underlay mode, UWB offers the possibility of also being implemented in the overlay mode (Arslan & Sahin, 2007). The difference between the two modes is the amount of transmitted power. In the underlay mode, UWB has a considerably restricted power, which is spread over a wide frequency band. When a UWB system is operating in the underlay mode, it is quite unlikely that any coexisting licensed system is affected from it. On top of this, underlay UWB can employ various narrowband interference avoidance methods.

In the overlay mode, however, the transmitted power can be much higher. It actually can be increased to a level that is comparable to the power of licensed systems. But this mode is only applicable if two conditions are met: 1) if the UWB transmitter ensures that the targeted spectrum is completely free of signals of other systems, and 2) if the regulations are revised to allow this mode of operation. UWB can also operate in both underlay and overlay modes simultaneously. This can happen by shaping the transmitted signal so as to make part of the spectrum occupied in an underlay mode and some other parts occupied in an overlay mode. Apparently, in any mode of operation, UWB causes negligible interference to other communication systems. This special feature of UWB makes it very tempting for the realization of cognitive radio.

CR should have a high flexibility in determining the spectrum it occupies, because the bands that will be utilized for cognitive communication could vary after each periodic spectrum scan. Flexible spectrum shaping is a part of UWB's nature. In IR-UWB, the occupied spectrum can directly be altered by varying the duration or the form of the short transmitted pulses. In UWB-OFDM, on the other hand, spectrum shaping can be conveniently accomplished by turning some subcarriers on or off according to the spectral conditions.

CR systems are should be able to adjust their data rates according to the available bandwidth, which varies according to the utilization of the bands by the licensed systems. CR systems are also expected to provide a solution for the cases when the available bandwidth is so limited that the communication cannot be continued.

UWB systems are able to make abrupt changes in their throughput. For example, an IR-UWB system can respond to a decrease in available bandwidth by switching to a different wider pulse shape, and can do the opposite if there is more band to use. In UWB-OFDM, the adjustment of the occupied bandwidth is even simpler. The subcarriers that overlap with the newly occupied bands are turned off, and this way the data rate is decreased, or more subcarriers are used to occupy newly available bands, thus increasing the data rate.

Furthermore, UWB provides an exceptional solution regarding the dropped calls. If UWB is performed in overlay mode, and in cases when it becomes impossible to continue the communication, UWB can switch to the underlay mode. Thus, UWB can maintain the communication link even though it is at a low quality since licensed systems are not affected by UWB operated in the underlay mode.

The spectral masks that are imposed by the regulatory agencies (such as the FCC in the USA) are also determinative in spectrum usage in that they set a limit to the transmit power of wireless systems. UWB offers a satisfactory solution to the adaptable transmit power requirement of cognitive radio. Both UWB-OFDM and IR-UWB systems can comply with any set of spectral rules mandated upon the cognitive radio system by adapting their transmit power.

CR networks should be able to provide multi-user access since there will be a number of users willing to make use of the same spectrum opportunities at the same time. CR is also required to be able to modify its multiple access parameters to cope with the changes that may occur in the overall spectrum occupancy, or with the possible fluctuations in the signal quality observed by each user.

From the point of adaptive multiple access, UWB is a proper candidate for CR applications and is very flexible in terms of multiple access. For example, in IR-UWB, the number of users can be determined by modifying the number of chips in a frame. In UWB-OFDM, on the other hand, more users can be allowed to communicate by decreasing the subcarriers assigned to each user.

UWB has information security in its nature. Hence, it can be considered a strong candidate for CR applications in terms of information security. Underlay UWB is a highly secure means of exchanging information. If a UWB system is working in the underlay mode, because of the very low power level, it is impossible for unwanted users to detect even the existence of the UWB signals. Overlay mode UWB, on the other hand, can also be considered a safe communication method. In overlay IR-UWB, multiple accessing is enabled either by time hopping or by direct sequencing. Therefore, receiving a user's information is only possible if the user's time hopping or spreading code is known. UWB-OFDM also provides security by assigning different subcarriers to different users. The level of security can be increased by periodically changing these subcarrier assignments. Apparently, UWB is a secure way of communicating in both its underlay and overlay modes.

UWB communication can be accomplished by employing very low cost transmitters and receivers. The transceiver circuitries required to generate and process UWB signals are inexpensive, and the RF front-end required to send and capture UWB signals are also quite uncomplicated and inexpensive. This property of UWB makes it very attractive for CR, which aims at limited infrastructure and transceiver costs.

Adaptive UWB spectral mask

Fig. 4 depicts the UWB spectrum and the bands for some existing and dedicated narrowband services. UWB signals, which spread over a very wide spectral region at low power levels near the noise floor, will overlap with some of these systems, such as fixed satellite, radio astronomy, and the services operating in the U-NII bands. Despite the very low power level, there have been some concerns that UWB would increase the interference floor and degrade the performances of licensed users.
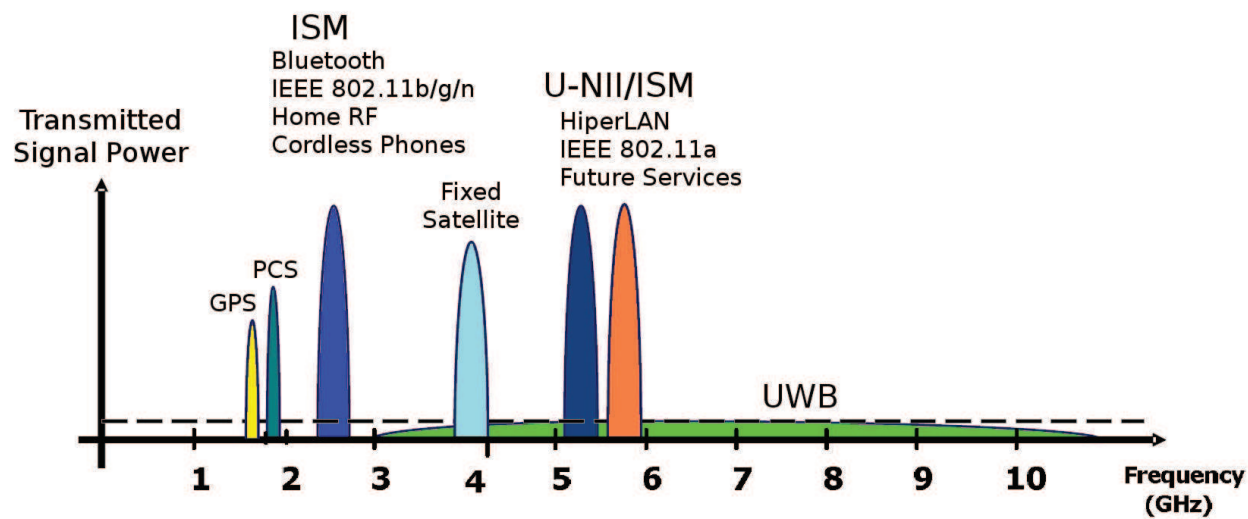
Fig. 4. Narrowband systems and UWB spectrum

A possible solution was discussed by (Zhang et al., 2009). It consists of adapting the UWB pulse to the spectral environment. The UWB pulse can be generated in such a way that its spectral mask exhibits notches in the bands of existing narrow-band wireless services operated in the 3.1–10.6 GHz frequency range. An example of this adaptive pulse is shown in Fig. 5. For this pulse, a limited linear combination of orthogonal pulse wavelets based on prolate spheroidal wave functions (PSWF) and their related auxiliary functions is utilized. The pulse waveform is located in the lower band of 3.1–6.4 GHz, in which several spectral notches (with notch depth of more than 20 dB) are generated, in order to avoid any possible severe interference to the existing narrow-band wireless services, such as radio astronomy, the fixed satellite services, and the 3G wireless communications services.
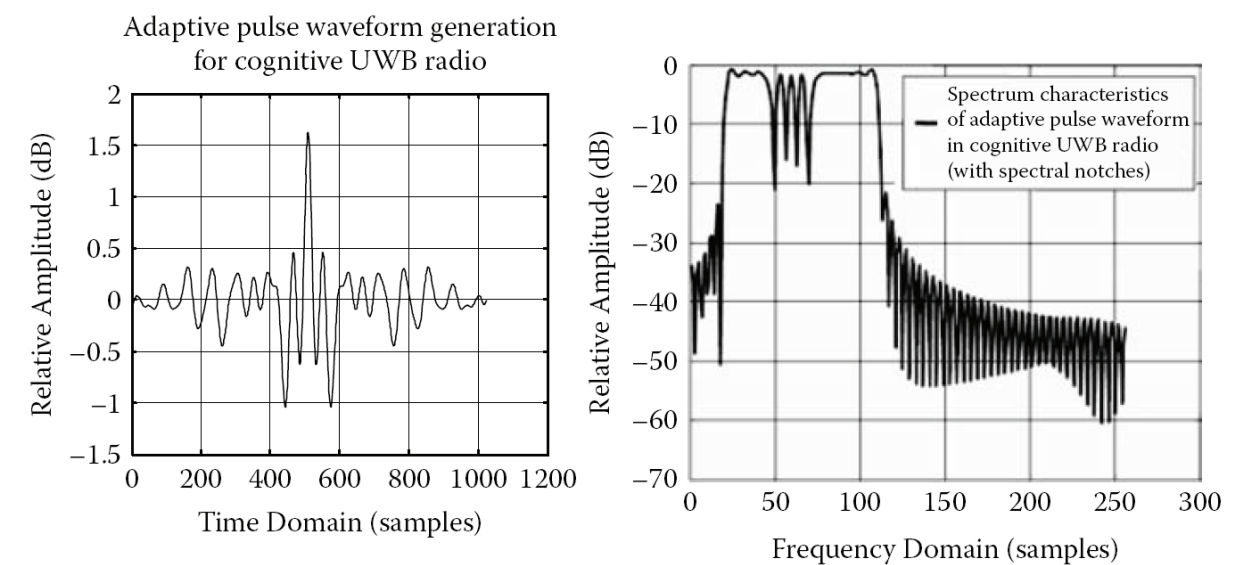
Fig. 5. Adaptive pulse waveform with spectrum-agile characteristics (Zhang et al., 2009)

5. Antennas for cognitive radio

When a CR network implements the opportunistic spectrum access (OSA) approach, secondary users need to identify and use the white space in the spectrum. In this case, the

transceiver of the CR device should be ended with an antenna system that can simultaneously sense the channel over a wide frequency range and communicate over a narrow band once the operating frequency is determined.

If UWB is used as the CR enabling technology, UWB antennas can be employed at the transceiver front-end. In the underlay mode, a UWB antenna can be used to transmit/receive the very-low-power pulse. In the overlay mode, the UWB higher-power pulse could be transmitted if the targeted spectrum is completely free of signals of other systems (time white space), or this pulse should be unique and adaptive with spectral notches to avoid strong interference to existing narrow-band wireless services. In both modes, UWB antennas could still be used, however in the overlay mode UWB antennas with controllable frequency notches are more robust.

CR antennas for opportunistic spectrum access

Antennas designed for CR devices operating using the OSA approach are usually dual-port antenna systems with one port used for sensing and the other used for communication. An example of such an antenna is given by (Kelly et al., 2008). This antenna system integrates a UWB antenna (used for sensing) with a narrowband one (used for communication). The UWB antenna, with the ability to sense the spectrum from 3 to 11 GHz, is a coplanar waveguide (CPW) fed wine-glass shape monopole, whereas the other one, with narrowband operation over 5.15 to 5.35 GHz, is a shorted microstrip patch antenna.

The CR antenna system design presented by (Al-Husseini et al., 2010) is comprised of two microstrip-line-fed monopoles sharing a common partial ground. The configuration of the two antennas is shown in Fig. 6. The sensing UWB antenna is based on an egg-shaped patch, obtained by combining a circle and an ellipse at their centers. A small tapered microstrip section is used to match the 50-Ω feed to the input impedance of the patch. The UWB response of the sensing antenna is guaranteed by the design of the patch, the partial ground plane, and the feed matching section. The return loss of the sensing antenna is shown in Fig. 7.
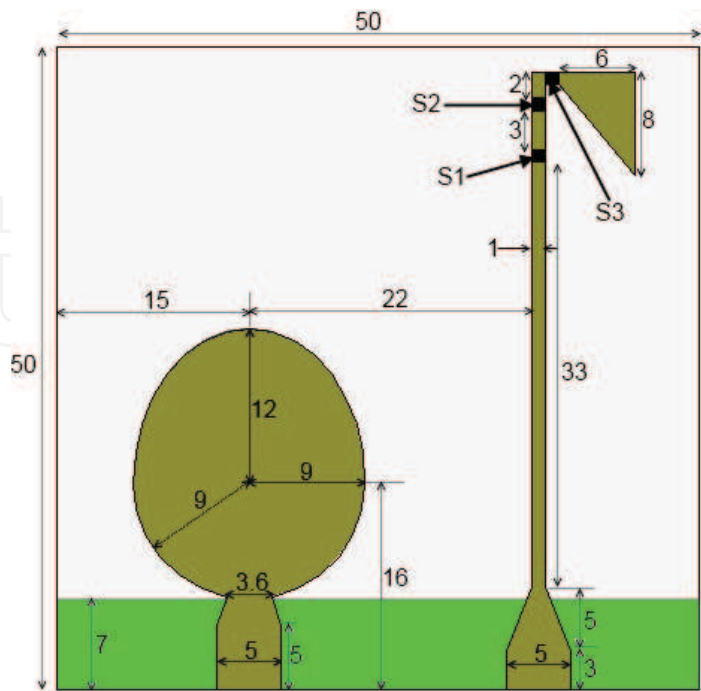

Fig. 6. CR antenna system configuration (Al-Husseini et al., 2010)
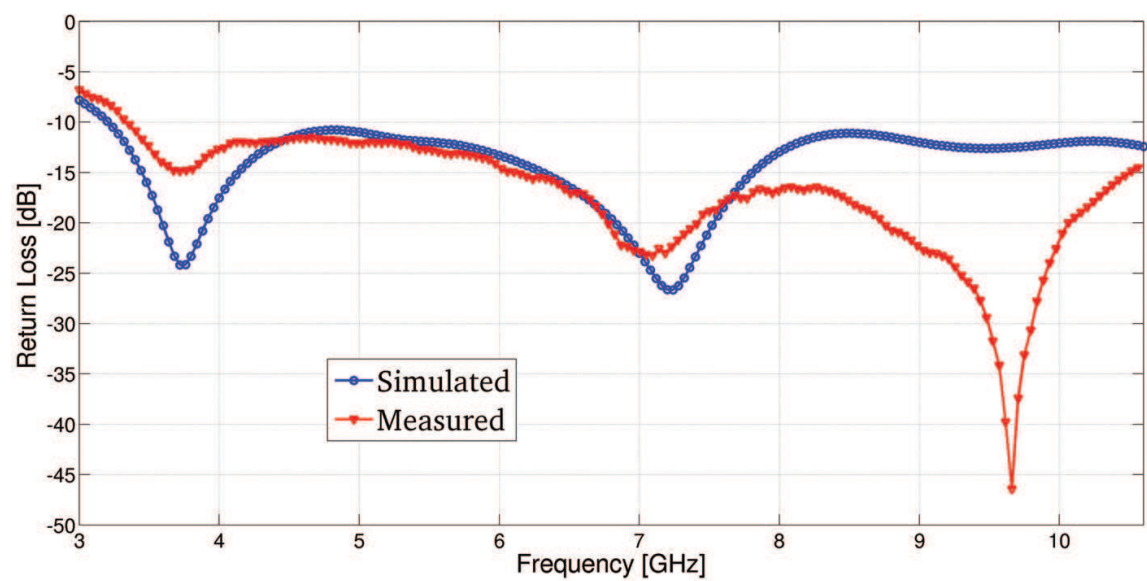
Fig. 7. Return loss of the sensing UWB antenna

The communicating antenna is a combination of a long strip line connected to a 50-Ω feed line via a matching section, and a small triangular conducting part. Two electronic switches are incorporated along the strip line part of the antenna, and a third identical one connects the strip line to the triangular part. By controlling these three switches, the length of the antenna is changed, thus leading to various resonance frequencies in the UWB frequency range. Four switching cases are considered. The resulting measured return loss plots are given in Fig. 8, which shows clear frequency reconfigurability and a coverage of most of the UWB range using only three switches.

The design is simple, low in cost, and easy to fabricate. Both the sensing and communicating antennas have omnidirectional radiation patterns, good peak gain values, and good isolation between their two ports.
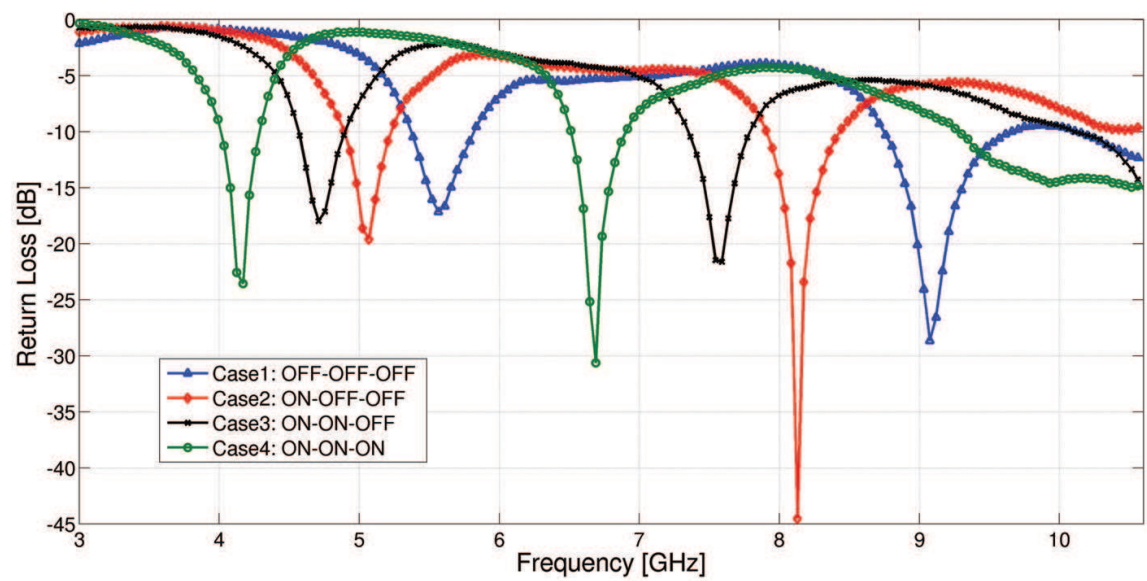
Fig. 8. Measured return loss plots of the communicating antenna

Antennas for UWB-CR

UWB antennas can be used with UWB-enabled CR. The literature is full of research and work pertaining to the design of UWB antennas. (Low et al., 2005) presented a UWB knight's helm shape antenna fabricated on an FR4 board with a double slotted rectangular patch tapered from a 50-Ω feed line, and a partial ground plane flushed with the feed line. Three techniques are applied for good impedance matching over the UWB range: 1) the dual slots on the rectangular patch, 2) the tapered connection between the rectangular patch and the feed line, and 3) a partial ground plane flushed with feed line. Consistent omnidirectional radiation patterns and a small group delay characterize this UWB antenna.

The effect of the ground plane on the performance of UWB antennas is discussed by (Al-Husseini et al., 2009a). Here, two CPW-fed antennas based on the same egg-shaped conductor and same substrate are presented and compared. In the first, the ground plane features a large egg-shaped slot, and in the second, the ground plane is partial and rectangular in shape. The configuration of the two designs is given in Fig. 9. Both designs exhibit UWB response, with Design I offering a larger impedance bandwidth and better omnidirectional radiation pattern but a slightly smaller efficiency.
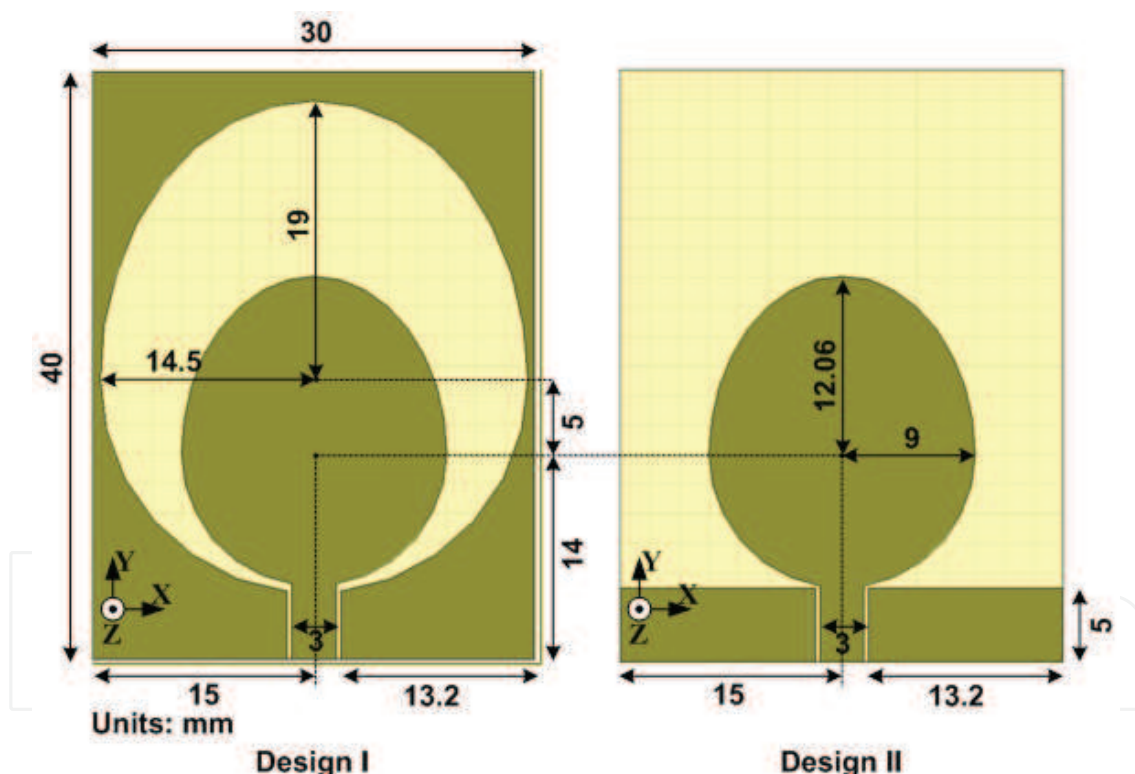
Fig. 9. Configuration of the two UWB designs (Al-Husseini et al., 2009a)

The paper by (Al-Husseini et al., 2009a) presents a low-cost UWB microstrip antenna featuring a microstrip feed line with two 45° bends and a tapered section for size reduction and matching, respectively. The ground plane is partial and comprises a rectangular part and a trapezoidal part. The patch is a half ellipse, where the cut is made along the minor axis. Four slots whose location and size relate to a modified Sierpinski carpet, with the ellipse as the basic shape, are incorporated into the patch. The configuration of this antenna is shown in Fig. 10.
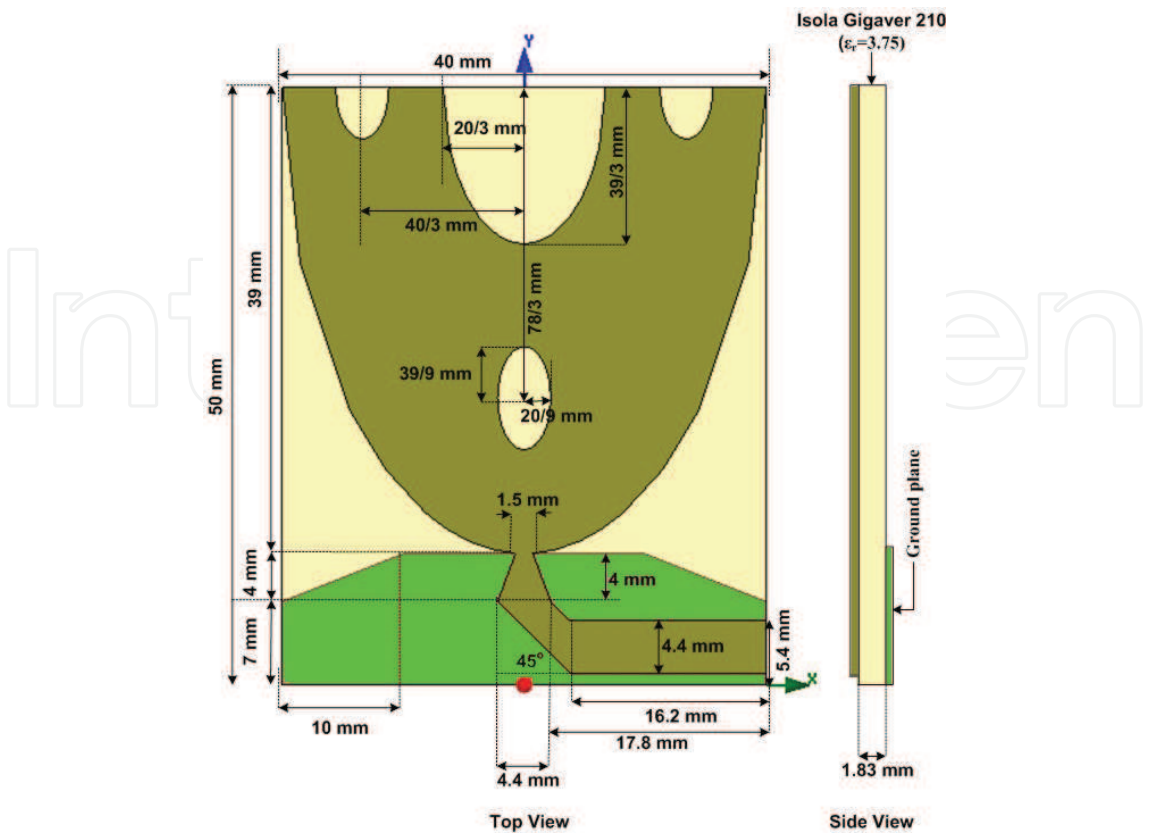
Fig. 10. Configuration of the UWB antenna (Al-Husseini et al., 2009)

Four techniques are applied for good impedance matching over the UWB range: 1) the specially designed patch shape, 2) the tapered connection between the patch and the feed line, 3) the optimized partial ground plane, and 4) the slots whose design is based on the knowledge of fractal shapes. As a result, this antenna has an impedance bandwidth over the 2–11 GHz range, as shown in Fig. 11, and thus can operate in the bands used for UMTS, WLAN, WiMAX, and UWB applications.
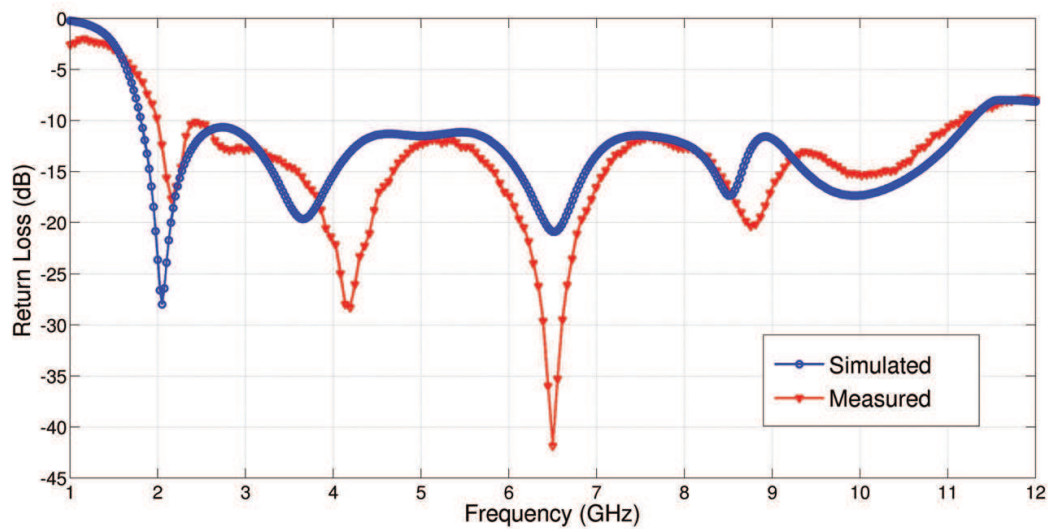
Fig. 11. Return loss of the UWB antenna by (Al-Husseini et al., 2009)
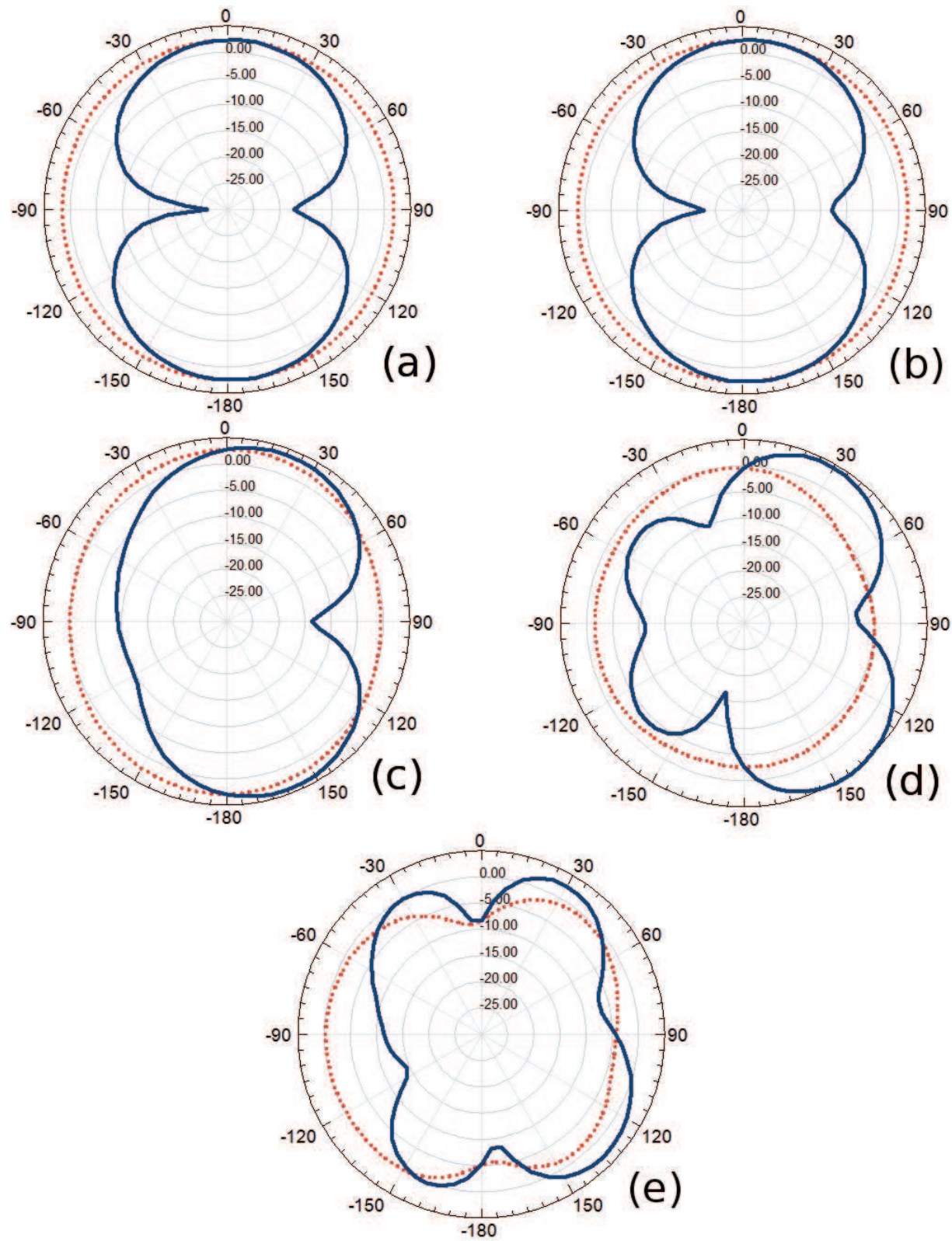
Fig. 12. Patterns in the X - Z plane (dotted line) and Y - Z plane (solid line) for (a) 2.1 GHz, (b) 2.4 GHz, (c) 3.5 GHz, (d) 5.1 GHz, and (e) 7 GHz (Al-Husseini et al., 2009)

Consistent omnidirectional radiation patterns, and good gain and efficiency values characterize this UWB antenna. The radiation patterns are shown in Fig. 12.

In the overlay mode of UWB-enabled CR, UWB antennas with notched bands are tempting. Many UWB antennas with frequency band notches are available in the literature. However, (Al-Husseini et al., 2010a) present a design where the notch is switchable, meaning that it can be turned ON or OFF by controlling an electronic switch. The design makes use of complementary split-ring resonators (CSRRs). A CSRR is etched in the patch of the antenna, and an electronic switch is mounted across its slot. The OFF-state of the switch leaves the corresponding CSRR active, thus causing a band notch. Putting the switch to its ON-state deactivates the resonance of the CSRR and cancels the notch. The configuration of the antenna is illustrated in Fig. 13.

The return loss of the antenna is shown in Fig. 14. The frequency band notch appears when the CSRR is active (switch OFF), and disappears when the CSRR is inactive (switch ON), thus retrieving the UWB response of the antenna. This original UWB response is guaranteed by the design of the original antenna, mainly the use of the partial ground plane and the good matching attained by etching a slit in the ground below the feed.

A variation of this design is obtained by including another CSRR, of a slightly different size, in the patch of the antenna. The combined effect of the two CSRRs leads to a larger and stronger band notch, which still can be canceled by turning both switches (on the two CSRRs) ON. One implication of this variation is the ability to control the width of the notched band.
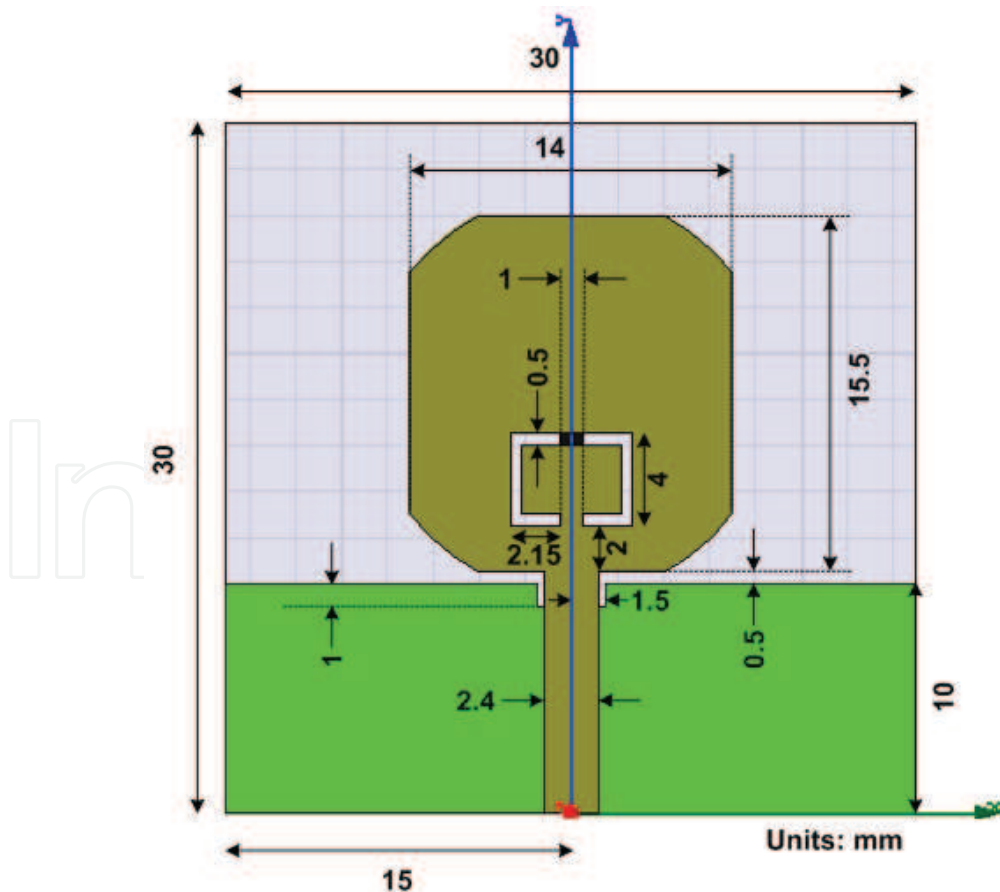

Fig. 13. Configuration of a UWB antenna with switchable band notch (Al-Husseini et al., 2010a)
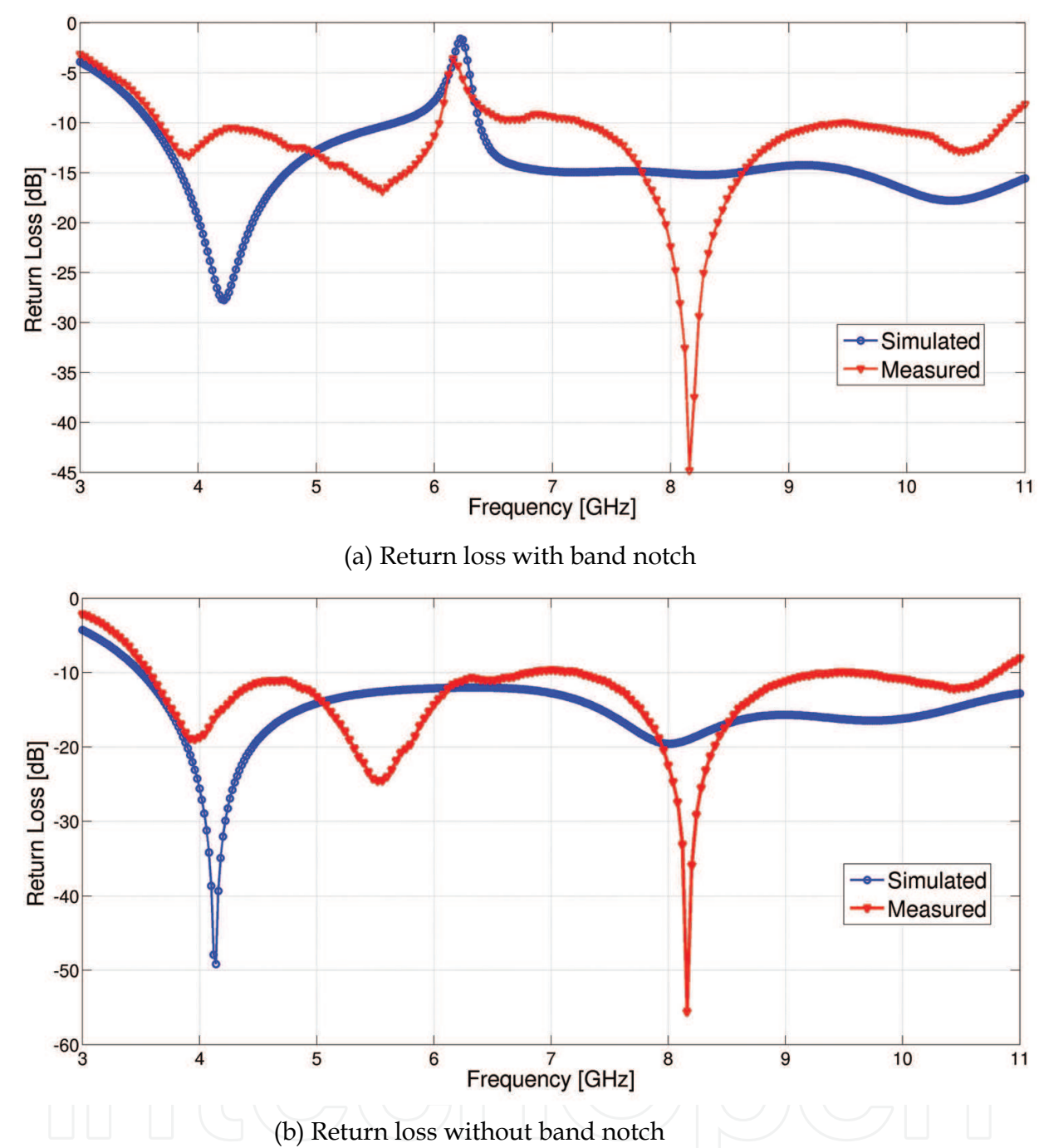
(a) Return loss with band notch

(b) Return loss without band notch

Fig. 14. Notch appears when CSRR is active (switch OFF) and disappears when CSRR is inactive (switch ON) (Al-Husseini et al., 2010a)

6. Conclusion

This chapter has discussed the current spectrum allocation regulations and their shortcomings and has given a general overview of Cognitive Radio and dynamic spectrum access, mainly the exclusive use, the open sharing, and the hierarchical access models of DSA and the difference between the underlay and overlay approaches in the hierarchical access model. The chapter has also discussed the advantages of using UWB as an enabling

technology for CR. A major part of the chapter has been a survey of the latest work on antenna design for cognitive radio. Two categories of antennas have been included: antennas that could be used for CR when the OSA approach is implemented, and antennas that could be used for UWB-CR. Further research on both categories of antennas is still under way.

7. References

Al-Husseini, M.; Tawk, Y.; El-Hajj, A. & Kabalan, K.Y. (2009). A low-cost microstrip antenna for 3G/WLAN/WiMAX and UWB applications, *Proceedings of the 2009 international conference on advances in computational tools for engineering applications (ACTEA'09)*, pp. 68–70, ISBN 978-1-4244-3833-4, Jul 2009, Zouk Mosbeh, Lebanon

Al-Husseini, M.; Ramadan, A.; Tawk, Y.; El-Hajj, A. & Kabalan, K.Y. (2009). Design and ground plane consideration of a CPW-fed UWB antenna, *Proceedings of the 2009 international conference on electrical and electronics engineering (ELECO'09)*, pp. II-151–II-153, ISBN 978-1-4244-5106-7, Nov 2009, Bursa, Turkey

Al-Husseini, M.; Tawk, Y.; Christodoulou, C.G.; El-Hajj, A. & Kabalan, K.Y. (2010). A simple dual-port antenna system for cognitive radio applications, *Proceedings of the 2010 international conference on high performance computing and simulation (HPCS'10)*, pp. 549–552, Jun-Jul 2010, Caen, France

Al-Husseini, M.; Costantine, J.; Ramadan, A.; Christodoulou, C.G.; Kabalan, K.Y. & El-Hajj A. (2010). Ultrawideband antennas with switchable band notch using complementary split-ring resonators, *Proceedings of the 2010 international conference on high performance computing and simulation (HPCS'10)*, pp. 560–563, Jun-Jul 2010, Caen, France

Arslan, H. & Sahin, M. (2007). UWB-Based Cognitive Radio Networks, In: *Cognitive Wireless Communication Networks*, Hossain, E. & Bhargava, V.K., (Ed.), 213–230, Springer US, ISBN 978-0-387-68830-5, New York.

Berlemann, L. & Mangold, S. (2009). *Cognitive Radio and Dynamic Spectrum Access*, John Wiley & Sons, ISBN 978-0-470-51167-1, West Sussex, United Kingdom.

Chen, K.-C. & Prasad, R. (2009). *Cognitive Radio Networks*, John Wiley & Sons, ISBN 978-0-470- 69689-7, West Sussex, United Kingdom.

FCC, (2002). *Spectrum Policy Task Force Report*, Tech. Rep. TR 02-155

Kelly, J.R.; Ebrahimi, E.; Hall, P.S.; Gardner, P. & Ghanem, F. (2008). Combined wideband and narrowband antennas for cognitive radio applications, *Proceedings of the 2008 IET seminar on cognitive radio and software defined radios: technologies and techniques*, pp. 1–4, ISBN 978-0-86341-939-3, Sept 2008, London, UK

Low, Z.N.; Cheong, J.H. & Law, C.L. (2005). Low-cost PCB antenna for UWB applications. *IEEE Antennas and Wireless Propagation Letters*, Vol. 4, Aug 2005, 237–239, ISSN 1536 - 1225 NTIA, (2003). *U.S. Frequency Allocation Chart*
http://www.ntia.doc.gov/osmhome/allochrt.pdf

Zhang, H.; Zhou, X. & Chen, T. (2009). Ultra-wideband cognitive radio for dynamic spectrum accessing networks, In: *Cognitive Radio Networks*, Xiao, Y. & Hu, F., (Ed.), 353–382, CRC Press, ISBN 978-1-4200-6420-9, Boca Raton, Florida.

New Trends in Technologies: Control, Management,
Computational Intelligence and Network Systems
Edited by Meng Joo Er

The grandest accomplishments of engineering took place in the twentieth century. The widespread development and distribution of electricity and clean water, automobiles and airplanes, radio and television, spacecraft and lasers, antibiotics and medical imaging, computers and the Internet are just some of the highlights from a century in which engineering revolutionized and improved virtually every aspect of human life. In this book, the authors provide a glimpse of the new trends of technologies pertaining to control, management, computational intelligence and network systems.

How to reference
In order to correctly reference this scholarly work, feel free to copy and paste the following:

INTECH
open science | open minds