# Cognitive Ultra Wide Band (CUWB) Radio – Implementation and Challenges

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**Abstract**

Software-defined radio (SDR), software radio (SWR), and cognitive radio (CR) are futuristic concepts that promise to significantly impact wireless communications technologies. Today, however, technology ironically is one of the limiting factors in the production of a true software radio that is capable of dynamically reconfiguring itself to meet user requirements or spectral limitations. Specifically, the lack of analog-to-digital converters and digital-to-analog converters fast enough to implement a software or cognitive radio will delay their deployment. Fortunately, fast-developing ultra-wideband (UWB) technologies might provide the solution to this dilemma.

**Keywords:** cognitive radio (CR), software defined radio (SDR), ultra wide band (UWB).

## 1 Introduction

Recently the conception of cognitive radio (CR) has been proposed as a promising solution for improving the efficiency of spectrum by adopting dynamic spectrum resource management. Cognitive radios with both physical and network layer capabilities are expected to improve the prospects for both spectrum compatibility and interoperability among ever proliferating wireless communication standards.

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Cognitive radios are fully programmable wireless devices that can sense their environment and dynamically adapt their transmission waveform, channel access method, spectrum use, and networking protocols as needed for good network and application performance.

CR is an evolution of the software-defined radio (SDR). SDRs use software in place of individual components traditionally implemented in hardware, such as amplifiers, modulators, and demodulators. In this way, instead of having to use separate radios for different standards, spectrum ranges, and capabilities, users could work with a single radio that supports multiple parameters. However, SDR allows only for adaptability. It does not sense what other users are doing in a spectrum range or include the ability to make link-optimization decisions CRs add cognition and the ability to make adjustments to the radio based on algorithms in a cognition engine Ultra Wide Band (UWB) signal typically overlaps with many existing and potential future services. Therefore the combination of UWB and CR not only is able to identify and protect these victim transceivers but also enlarges the utility of UWB. The approach named "Cognitive UWB Radio" has been proposed to explore the extended dimensions of Cognitive Radio as well as UWB wireless world.



## 2 SDR versus SWR

Software-defined radio (SDR), software radio (SWR) and cognitive radio (CR) are futuristic concepts that promise to significantly impact wireless communications technologies Today, however, technology ironically is one of the limiting factors in the production of a true software radio that is capable of dynamically reconfiguring itself to meet user requirements or spectral limitations.

In the case of an SDR (Figure 1), the functions following the radio frequency (RF) down-conversion are software-based and typically performed by a dedicated high-speed processor or a digital signal processor.

The complexities of the RF front end and the speed limitations of today's ADCs and DACs mandate an SDR switch between different RF front-ends in order to span different RF bands or operate with different RF front-end requirements. This is the kind of implementation that is utilized in today's SDRs.

The purpose of an SDR is to dynamically change both frequency of interest and modulation scheme of interest. Current SDRs change frequency of

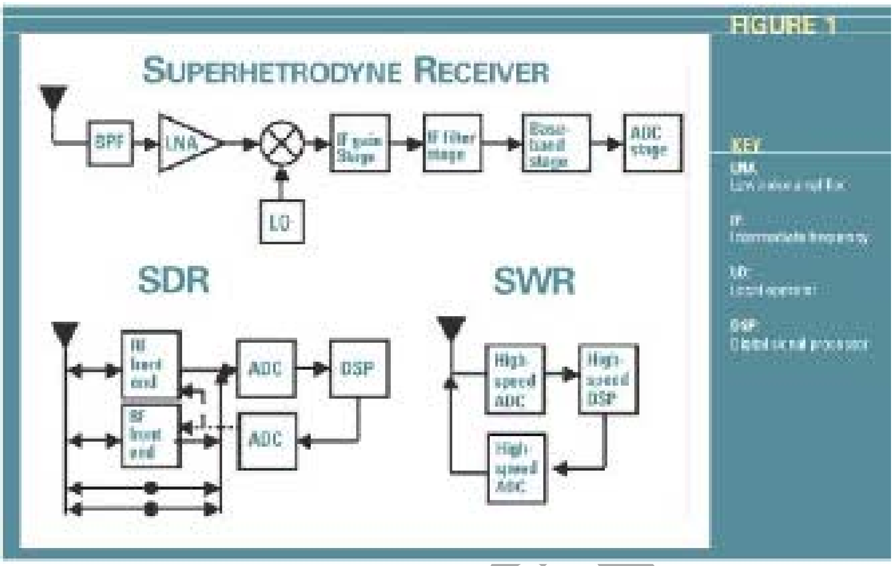


Figure 1 Software defined radio (SDR) versus software radio (SWR).

interest by switching between RF front ends and change modulation schemes by implementing different algorithms in the processor portion of the receiver.

Limitations of both ADCs and digital signal processors (DSPs) force such a typical SDR design, to implement multiple RF modules to cover the different frequency bands and technologies required.

In an SWR (Figure 1), the signal is digitized at the antenna, and all of the radio functions are implemented in software that runs on a high-speed processor or DSP. Capable of utilizing different bands and different modes of operation, an SWR is adaptable and upgradeable through the modification of its software, i.e., new functions, modulation schemes or capabilities may be added by introducing the appropriate software.

While limitations in DAC and ADC technologies have kept SWRs from realizing their full potential that should change as digital technologies continue to evolve and improve.

Cognitive radio (CR) represents the next step. A CR takes the adaptability and reprogrammability of an SWR and adds to it the capability to sense its environment and react in the most appropriate manner. A CR would dynamically support a user's throughput requirements, be they bandwidth-, delay-, or jitter-specific, without a user's intervention. However, as with SWRs, a true cognitive radio cannot be realized today because of the limitations of digital technologies.

UWB technologies are a fairly new development in the wireless domain, and they present a variety of possible implementations. These systems range from systems utilizing impulses to generate UWB spectral content to orthogonal frequency division multiplexing (OFDM) systems that utilize a large number of carriers to span more than 500 MHz worth of bandwidth.

It should be possible to implement a variety of impulsive waveforms, and their associated modulation techniques, entirely in software. This would essentially create an impulsive software radio. Such a radio would be capable of dynamically changing its waveform based upon need, thus reducing the UWB physical layer interface to a software abstraction. It also would be capable of implementing different impulsive physical layers based upon the specific operating environment in which the radio found itself.



## 3 Research Issues and Challenges

While the implementation of a software UWB radio is a realizable goal today due to the existence of programmable pulse generators and fast ADCs, implementing a cognitive UWB radio would require some new development work centered on (i) the creation of spectrum-sensing capabilities, (ii) spectrum-sharing protocols, and (iii) dynamic waveform selection algorithms It should be possible to modify algorithms that are currently being developed for traditional cognitive radios and utilize them in a cognitive UWB radio, thereby benefiting from the work previously accomplished in this domain.

More specifically, they include:

1. Discovery strategies for wireless channel (e.g., sensing the available spectrum resource).
2. Interaction strategies for efficient (co-)operation:determine neighborhood and interference information from anonymous nodes and enable efficient operation (e.g., learning the wireless environment).
3. Negotiation and domination strategies for situations of conflictions: Game Theory approaches for favoring and enabling cooperation, for spectrum sharing and open access to radio resources (e.g., negotiation and decision).
4. Spectrum warfare with spectrum-agile waveforms: primitive control actions and waveform adaptation to strategically teach autonomous radi-

ating nodes in a system to more efficiently share the available spectrum (e.g., adaptation and evolution).

5. Cooperative coding strategies for spectrum sharing: cooperative diversity and coding techniques with varying degrees of cognitive awareness and capabilities for increased spectrum utilization (e.g., cooperation and evolution).

## 4 Proposed Methodology

### 4.1 Reconfigurable Radio

To set up an absolute radio interface, with reconfigurability capability, it can be shown that IR-UWB (Impulse Radio Ultra WideBand) is an adequate wireless technology, which could easily deal with this kind of reconfigurability

In IR-UWB, emitters are very simple. It consists of a UWB pulse generator and a baseband numeric command signal, which activates the generator at the correct time. The difficulty with IR-UWB is located in receiver.

In order to have multi-users capability and confer a noise-like aspect to the IR-UWB signal spectrum, Time Hopping (TH) is implemented.

Receiver characteristics values (such as data rate, TH-code) are made reconfigurable, Modifying the TH properties, (number of slot per frame ($N_c$), frame duration ($T_f$), time slot duration ($T_c$)), leads to data rate change. The data rate could be defined as a function of $T_f$, $T_c$, and $N_c$.

The data rate on the whole TH link (considering all the possible TH-code) is:

$$D_{\text{total}}(\text{bits/s}) = \frac{N_c}{T_f} = \frac{N_c}{N_c \times T_c} = \frac{1}{T_c} \tag{1}$$

Consequently, for changing the data rate, it is enough to change the slot duration ($T_c$). In IR-UWB digital receiver, when implemented on a FPGA, it consists in changing a value in a register. Therefore, it can be shown that IR-UWB has very good properties for radio reconfigurability.

In the reconfigurable receiver, TH-code reconfiguration is also implemented. It consists of being able to change the TH- code reception and consequently the received channel. This reconfigurability is possible because TH-codes are representing in VHDL as integers. Consequently, it is possible to modify them, and so reconfigure the receiver.

In order to set up this reconfiguration concept, the reconfigurable parameters are implanted as MAC layer outputs and PHY layer inputs (Figure 2). The MAC layer is emulated by Matlab, or Xilinx software, and is in charge

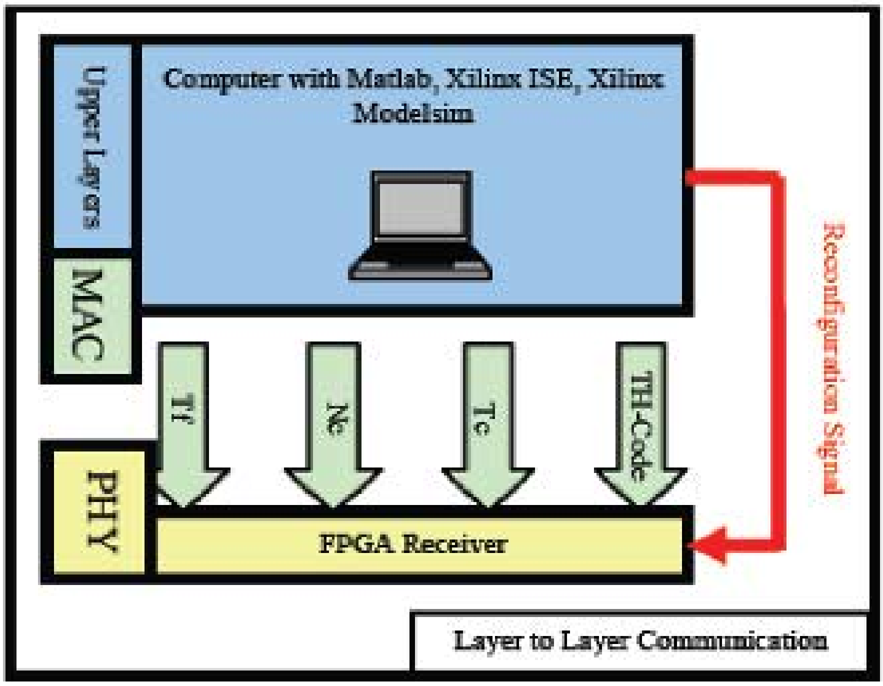


Figure 2 PHY and MAC layer interface.

of sending the configurable parameters to the FPGA; and start the reconfiguration by sending a specific signal, called "reconfiguration signal" in Figure 2.

## 4.2 Spectrum Sensing

(i) Approaches proposed for spectrum sensing are energy detection methods and feature detection methods, along with the time domain transmission statistics of the Primary User.

(ii) And make known these usable channels directly for CUWB transmitter and receiver through sending beacon signals and acknowledgement signals, through dedicated channels for exchange of control and sensing information to accommodate dynamic frequency band operation.

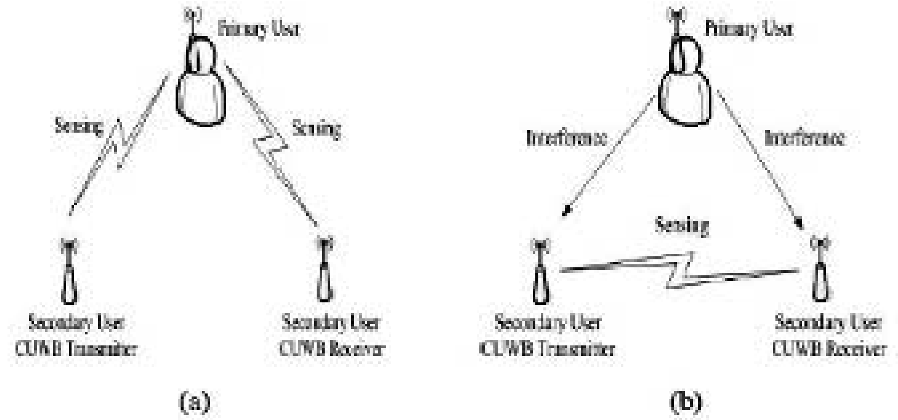


Figure 3 CUWB spectrum sensing model.



## 5 Conclusion

A cognitive radio (CR) is capable of dynamically reconfiguring itself to meet user requirements or spectral limitations. A cognitive radio takes the adaptability and re-programmability of a software defined radio (SDR) also known as reconfigurable radio and adds to it the capability to sense its radio environment and react in the most appropriate manner.

The lack of analog-to-digital converters and digital-to-analog converters fast enough to implement software or cognitive radio will delay their deployment. Fortunately, fast-developing ultra-wideband (UWB) technologies might provide the solution to this dilemma.

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## Biography

**Gerardine Immaculate Mary** received her M.Tech degree with specialization in Wireless Communication from Pondicherry Engineering College, Pondicherry. She is has now Assistant Professor (Senior), School of Electronics Engineering, Vellore Institute of Technology (VIT), Vellore. She has over 12 years of industrial experience as computer hardware engineer in the IT field. Her research areas include wireless communication in vehicular environments, indoor wireless positioning and Ultra Wide-Band Technology applications. She has published several research papers in international journals and conferences