International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:2682
Vol.4, No.4, April 2015 DOI:10.15693/ijaist/2015.v4i2.385-390

Transceiver Design for Processing of 5G Cellular Signals

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***Abstract* - 5G cellular systems choose the optimum radio access network, modulation scheme and other parameters to configure it to gain the best connection and optimum performance. In case of 4G cellular network, there are still some challenges that cannot be accommodated such as the spectrum crisis and high energy consumption. These disadvantages can be overcome and also increasing demand for high data rates and mobility required by new wireless applications and therefore has started research on fifth generation cellular network. We propose that performance can be increased in frequency domain using overlay cognitive radio MIMO-OFDM system for 5G cellular networks compared to 4G cellular networks. Our paper presents a real-time transceiver design using cognitive radio and Orthogonal Frequency-Division Multiplexing signaling scheme on FPGAs platform. The Transceiver is implemented on a Field-Programmable Gate Array (FPGA) through Xilinx System Generator with the combination of Matlab and simulink. RTL schematic and TECHNOLOGY diagram can also generated using ISE Modelsim Xilinx tool for future research.**

***Index Terms*-5G,4G, MIMO-OFDM, Cognitive radio, RTL Schematic, TECHNOLOGY diagram, FPGA.**

I. INTRODUCTION

5G technology offer high resolution for cell phone users and bi-directional large bandwidth. 5G technology is providing large broadcasting of data in Gigabit which will support almost 65,000 connections. The traffic statistics by 5G technology makes it more accurate. Through remote management offered by 5G technology a user can get better and fast solution. The uploading and downloading speed of 5G technology will touch the peak value [2]. 5G is the combination of 4G and WWWW (World Wide Wireless Web) [11].

Orthogonal Frequency Division Multiplexing (OFDM) is a promising technique for high-speed data transmission over multipath fading channels and has been considered to be the best candidate for next generation mobile networks [1]. It uses the principles of FDM to allow multiple messages to be sent over a single radio channel.

Cognitive Radio (CR) is a system or model for wireless communication. It is built on software defined radio which an emerging technology is providing a platform for flexible radio systems. It uses the methodology of sensing and learning from the environment and adapting to statistical variations in real time.

An IMT-Advanced system is expected to provide a comprehensive and secure all IP based mobile broadband solution and it satisfies the specifications for 5G cellular signal with frequency above 10GHz. The DTV signal used here is DVB-T2 (Digital Video Broadcasting-Second Generation Terrestrial) and is used to transmit compressed digital audio, video, and other data by using OFDM modulation with concatenated channel coding and interleaving.

Figure 1. Relationship between 4G and 5G

The cognitive radio (CR), built on a software-defined radio, is defined as an intelligent wireless communication system that is aware of its environment and uses the methodology of understanding-by-building to learn from the environment and adapt to statistical variations in the input stimuli, with two primary objectives of highly reliable communication and efficient utilization of the radio spectrum.CR technology has already been adopted as a core platform in emerging wireless access standards such as the IEEE 802.22 Wireless Regional Area Networks [4] .

Xilinx designs are to develop and market programmable logic products, including integrated circuits (ICs), software design tools, predefined system functions delivered as intellectual property (IP) cores, design services, customer training, field engineering and technical support. Xilinx software is used to implement the hardware architecture about simulink 802.11 MIMO-OFDM system designs [5]. Xilinx has generic features such as High Performance at different voltages, Footprint Compatibility, Low power consumption, high performance, Integrated and Software Technology independence (EDIF, VHDL, Verilog, SDF interfaces). Xilinx FPGAs are excellent computing platforms for Software Defined Radio (SDR) and cognitive radio applications, since they are used to measure performance and power efficiency closer to that of ASICs [7]. In this paper we propose a design methodology, a reconfigurable platform, and associated high-level tools for the implementation of cognitive radios on modern FPGAs.

II. OFDM

OFDM has become practical to implement and has been proposed as an efficient modulation scheme for applications ranging from modems, digital audio broadcast to next-generation high-speed wireless data communications [1]. Orthogonal FDM's spread spectrum technique spreads the data over a lot of carriers that are spaced apart at precise frequencies. This spacing provides the "orthogonality" in this method which prevents the receivers from seeing frequencies other than their own specific one.

The main benefits of OFDM are high spectral efficiency and low multi-path distortion. In a standard terrestrial broadcasting situation, there are high amounts of multipath-channels therefore the various versions of the signal interfere with each other known as inter symbol interference (ISI) and it becomes incredibly hard to extract the original information [3].

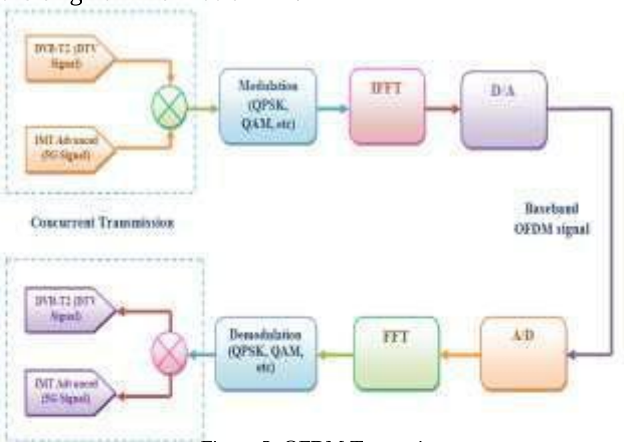

Figure 2. OFDM Transceiver

FFT and equalization algorithm can be implemented to suppress both ISI and inter subcarrier interference, which is caused by the channel impulse response, timing and frequency errors. OFDM has many advantages such as High spectral efficiency, Simple implementation by FFT, Low receiver complexity, High-data-rate transmission over multipath fading channel, and High flexibility in terms of link adaptation. However, OFDM systems have some disadvantages in 4G network includes that the system become Sensitive to frequency offsets, timing errors and phase noise and it requires RF power amplifier with high peak-to-average power ratio. OFDM system is highly sensitive to frequency synchronization problems and this can be overcome efficiently in our proposed work because we are optimizing the hardware program design processes based upon VHDL code for CR encode and decode process and the transceiver functions. The simulink is to arrange the CR-OFDM various blocks and improve the energy efficiency in wireless communication system [21].

The block diagram in figure1 shows that concurrent transmission can be possible using OFDM systems with the help of cognitive radio [30]. This can be useful for other cellular and DTV signals transmission and it can be extended for advanced systems and future wireless communication systems.

III. COGNITIVE RADIO

Cognitive radio (CR) is an adaptive, intelligent radio and network technology that can automatically detect available channels in a wireless spectrum and change transmission parameters enabling more communications. Cognitive radio is a promising paradigm to achieve efficient use of the frequency resource by allowing the coexistence of licensed (primary) and unlicensed (secondary) users in the same bandwidth [4]. Cognitive radio has the potential to increase the efficiency of spectrum usage.

Figure 3. Function of Cognitive Radio

There are four main functionalities of CR in the IEEE definition. The first functionality requires sensing of the radio frequency environment, which includes detection of spectrum holes (unused), estimation of channel state information and primary user traffic statistics [3]. In reality, sensing imperfections occur due to channel impairments and limited observation times. The misdetection leads to interference between the primary user and the secondary user [1]. The second functionality enables the secondary user to access a best available channel for its transmissions based on sensing information. The access modes of the secondary user are classified as interweave, underlay, and overlay concepts. The third functionality highlights the need for spectrum sharing mechanisms to achieve fairness among multiple or dissimilar secondary users. The final functionality is identifying a reconfigurable hardware architecture which will adapt its operating parameters to secondary user in the current radio frequency environment.

A spread spectrum user may only require a very low power signal spread across a wide bandwidth. In the case scenario, a cognitive radio system might test the spectrum in bands much smaller than the wide bandwidth used by the primary user. Unfortunately, the primary user's low power transmission has been designed to look like background noise and may be interpreted by the cognitive radio. In fact the only way to distinguish a spread spectrum transmission from the background is to sample the entire bandwidth, which may be impossible for the cognitive radio, thus leading to false identification of empty spectrum. We propose that the spectrum can be analyzed and used for transmission by CR based OFDM systems [4]. Hence these drawbacks can be overcome because OFDM undergoes digital modulation schemes and use of 5G cellular network.

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We prefer to integrate overlay CR into a 5G cellular network for high data rate, flexible control and low power consumption. In overlay CR, the transmission power distribution of secondary devices is critical to control the interference to the primary network at an acceptable level.

IV. 5G

5G is the upcoming new technology that will provide all the possible applications, by using only one universal device, and interconnecting most of the already existing communication infrastructures. The current generation of mobile networks continues to transform the way of people communication and access of information. 5G will drive the future evolution of the internet by itself. 5G is also known as Tactile Internet which denotes the next major phase of mobile telecommunications standards beyond the current 4G/IMT-Advanced standards [12].

5G will create a new air interface and spectrum together with LTE, 3G, GPRS and Wi-Fi to provide universal high-rate coverage and a seamless user Experience [2]. 5G will allow utilization of any spectrum and any access technology for the best delivery of services [14]. The 5G terminals will have an upgradable multimode and cognitive radio-enabled features [15]. In 5G network, the Spectral efficiency can be significantly enhanced when compared to 4G network.

OFDM has become the dominant signaling format for high-speed wireless communication, forming the basis of all current Wi-Fi standards, LTE and further wireline technologies such as digital subscriber lines, digital TV and commercial radio. Hence it can be employed in 5G communication systems [29].

Cognitive radio is a promising paradigm to achieve efficient use of the frequency resource by allowing the coexistence of licensed (primary) and unlicensed (secondary) users in the same bandwidth [4]. With the use of CR, 5G wireless networks will support global roaming across multiple wireless mobile networks and 5G signal can be used as a secondary signal.

V. 4G vs 5G

- 4G is the fourth generation of mobile communication but 5G is a revolution to 4G. 5G will be more advanced that will interconnect the entire world by providing perfect real wireless world called worldwide wireless web (WWWW).
- 5G includes all advance features and it is an un-imaginable technology. It will be more demanding in future. It allows data transfer in Gbps and the uploading speed is much higher than 4G.
- 4G provides dynamic information access and wearable devices whereas in case of 5G, it provides dynamic information access and wearable devices with AI capabilities.
- 4G supports data band width in Mbps and 5G supports data band width in Gbps. Band width per frequency channel is up to 28 GHz but 4G supports only 100 MHz.
- 4G supports CDMA and 5G support both CDMA and BDMA.
- 5G technology will be the most and the fastest technology of the wireless communication world. For example, a movie can be downloaded within a seconds. It is a real wireless world with no more limitations of access and zone issues.
- 5G includes large phone memory, dialing speed, and much more and also we can hookup 5G cell phones with laptop to get broadband internet access which is not present in 4G.

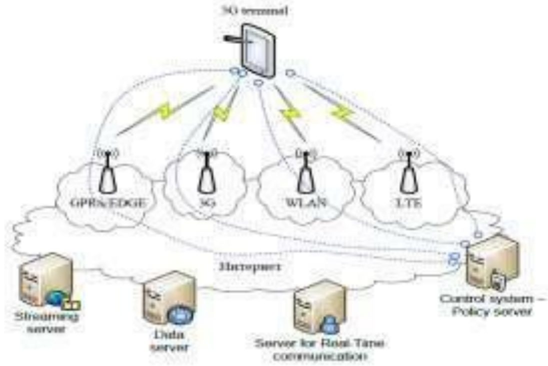


Figure 4. Functional Architecture of 5G Networks

TABLE I. 4G Vs 5G

Features	4G	5G
Years	2010s	2020s
Technology	LAN, WAN, PAN, WLAN & WWW	LAN, WAN, PAN, WLAN & WWWW
Frequency Band	2-8 GHz	> 8 GHz
Bandwidth	100 MHz	28 GHz
Data rate	100 Mbps	Several tens of Gbps
Access	OFDM	CR-OFDM

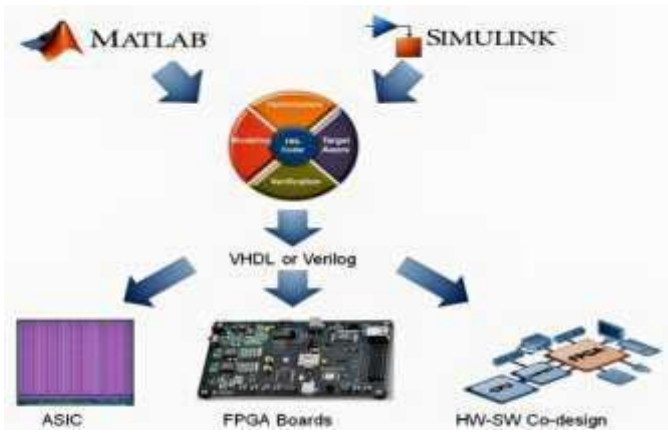


Figure 5. Designing procedure

VI. PROPOSED WORK

Our system is to design CR-MIMO OFDM architecture designs for Matlab-simulink software combined with hardware FPGA board using Xilinx system generator. The communication process is mainly used for the data transmission and reception process only. In real time data transmission process, the data are transmitted in a bit wise manner. This type of process reduces the hardware complexity and the power & energy consumption level. Our proposed work is to modify 5G based cellular network architecture using simulink with Xilinx block design for processing of 5G and DTV signals.

Cognitive radio can be computationally intensive wireless systems that implement highly demanding digital signal processing algorithms, on different platforms. General Purpose Processors (GPPs) are the most programmable and flexible platforms, though is reflected in their relatively poor performance. On the other hand, Application Specific Integrated Circuits (ASICs) provide high performance at the cost of reduced flexibility. FPGAs are an enticing alternative since they provide some measure of the flexibility afforded by GPPs along with performance and power efficiency closer to that of ASICs [7].

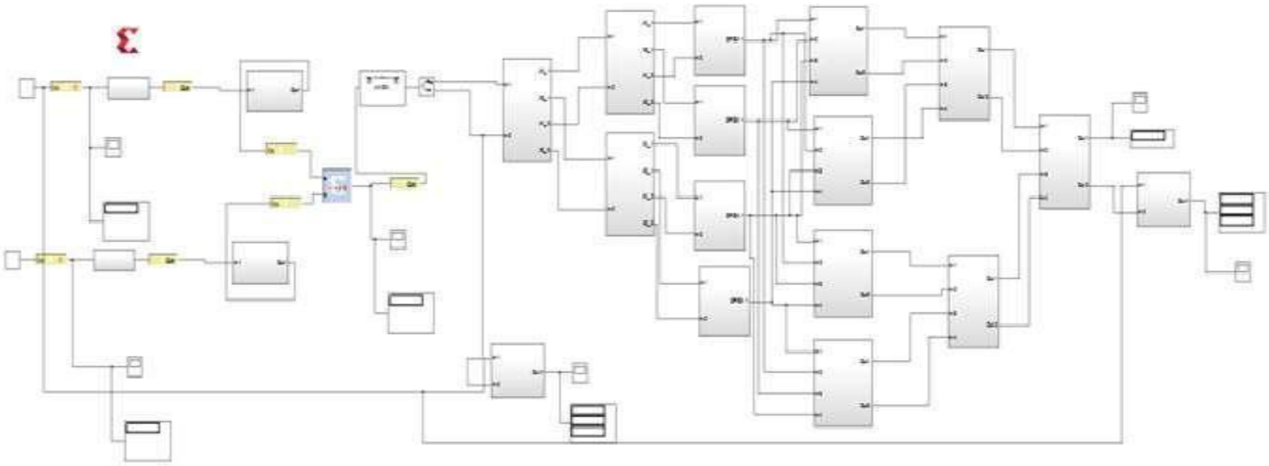
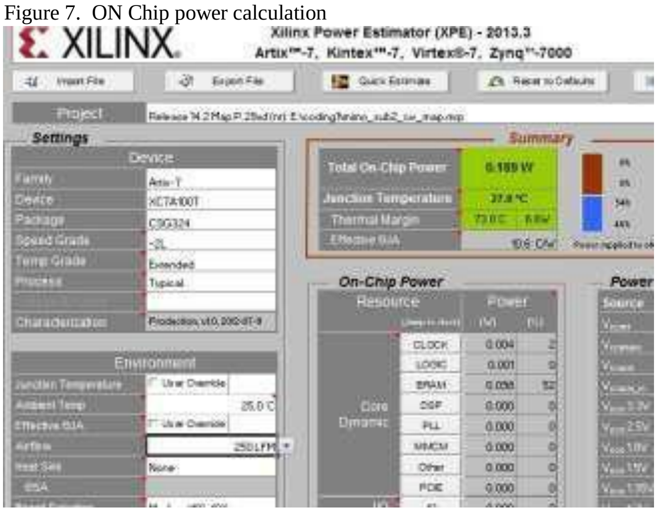


Figure 6. Matlab-simulink block design for processing of 5G signals

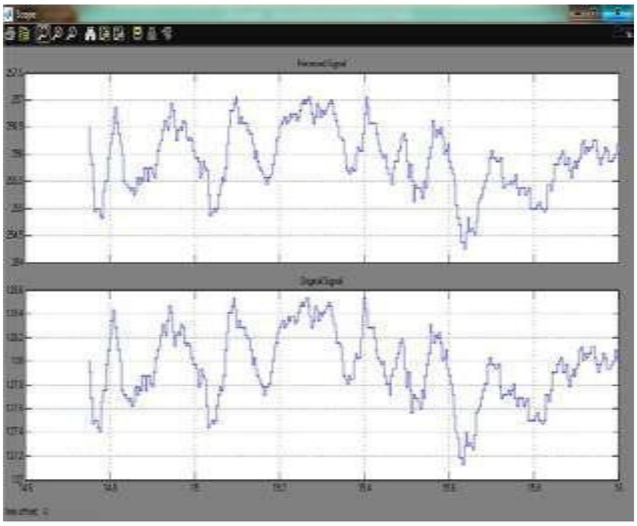
Our design is to convert the matlab-simulink blocks into VHDL code and RTL schematic and TECHNOLOGY diagram are generated as result. First we have to design the 5G based MIMO-OFDM transceiver blocks using the Xilinx digital blocks and run the transceiver design. Then we generate the VHDL codes for the corresponding blocks and synthesize the VHDL code. Finally, the RTL and TECHNOLOGY diagram are generated for the codings using ISE modelsim Xilinx tool [26]. The RTL diagram is used to display internal gate design for the MIMO-OFDM architecture. The TECHNOLOGY diagram is used to display the FPGA placement for the required transceiver architecture.

Figure 7. ON Chip power calculation



The proposed system is to increase the system performance, reduces the circuit complexity level and also used to remove the noise effectively. Path delay has reduced and system speed also increased because it is a digital based transceiver design. The bit stream is to be transmitted by mapping QAM symbols followed by a 64-point IFFT,

The Transceiver block is shown in the fig.(6) and it has been designed by Matlab-simulink configured by Xilinx. If Xilinx is configured with matlab then the Xilinx blocks are included in the matlab and transceiver is finally designed. DTV signal with frequency range above 50MHz is applied as primary layer signal and 5G cellular signal with frequency range above 50GHz is applied as secondary signal [14]. After simulation, the VHDL codings are generated using Xilinx system generator.Fig.7 shows the output Signal which comprises of both DTV and 5G Cellular signals. Fig 8 shows



the estimation of the transceiver power of 5G

Figure 8. Processing Signal

parallel-to-serial conversion and extension of the resulting time-domain sequence by a cyclic prefix of length 16. Since IEEE 802.11a is a frequency division duplex (FDD) system, the same hardware can be reused to perform the FFT [18].

At the system clock frequency of 80 MHz, a single-butterfly radix-4 I/FFT was found to provide sufficient performance. Data bits are given as a inputs to the transmitter. In order to scatter the input sequence to avoid the dependence of input signals power spectrum on the actual transmitted data these bits passed through the scrambler. The mapper is used for mapping and puncturing of data bits and puncturing removes some of the parity bits.

TABLE II.COMPARISION BETWEEN EXISTING & PROPOSED SYSTEM

SPECIFICATIONS	EXISTING SYSTEM	PROPOSED SYSTEM
SLICES	166	109
LUT'S	142	108
BIO'S	187	162
POWER(MW)	591	118
DELAY(NS)	9.43	1.245
SPEED (MHZ)	106.0	1180

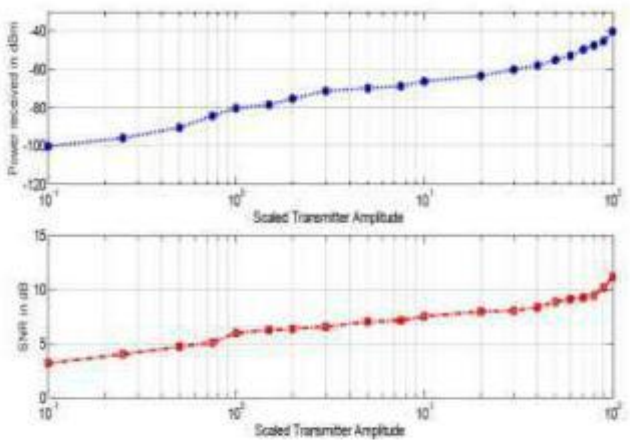


Figure 9. SNR and power of the received signal for various amplitude levels of the transmitted signal

We propose a framework to allow radio designers to benefit from FPGAs without the need of hardware design experience by abstracting the radio design process from the FPGA implementation details and these implementations are moving from traditional fixed hardware architectures towards software, allowing more efficient development. Today, field- programmable gate arrays (FPGAs) and regular desktop computers are fast enough to handle complete baseband processing chains, and there are several platforms for both open source and commercial [6].

VII. RESULTS & CONCLUSION

Here we design transceiver for processing of 5G cellular signals and DTV signals with the characteristics of cognitive radio and MMO-OFDM. The system is designed and implemented on a high level mathematical modeling of Simulink. The reason for selecting Matlab-Simulink is given that it resembles the real time transceiver design with spatially multiplexed 4x4 MIMO OFDM using 16 QAM and it is implemented on a Spartan Vitex-6 FPGA board with help of Matlab-Simulink, Xilinx System Generator. Thus MIMO transmits four data streams through a single channel, thereby can deliver four or more times the data rate per channel without additional bandwidth or transmit power. Power consumption is very less and complexity levels have been reduced in a great manner. 5G will rule the world in 2020 and future research on 5G will also discussed in our paper.

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