OFDM based Transceiver for a Cognitive Radio

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Abstract: **Cognitive radio is the heir of next generation wireless communication. This will be the next big leap in the process of making wireless communication efficient. In this paper, we present the implementation and benefits of orthogonal frequency division multiplexing commonly known as OFDM in the transceiver (transmitter and receiver) of a cognitive radio. The transmitter part of the OFDM transceiver is implemented as a model in LabVIEW and dumped in a NI based FPGA. This papers aims to show how OFDM falls in place with the other components of a typical cognitive radio also the challenges faced while adopting OFDM.**

Keywords: Cognitive radio, OFDM.

A. INTRODUCTION:

Electromagnetic spectrum is considered as a precious resource due to its increase in use in different applications across the world which makes the spectrum scarcity. Hence efficient use of spectrum is necessary under perfect channel conditions to increase the system capacity. Cognitive radio is introduced as a novel technology which to solve the problem of efficient utilization of spectrum. At the same time this technology has to be reliable, secure and accurate.

Cognitive radio is an intelligent wireless communication system that is aware of its surrounding environment (i.e. outside world) and uses the methodology of understanding by-building to learn from the environment and adapt its internal states to statistical variations in the incoming radio frequency stimuli by making corresponding changes in certain operating parameters (like transmit-power, carrier frequency, and modulation strategy) dynamically in real time, with two primary objectives in mind [1]:

- Highly reliable communications whenever and wherever needed;
- Efficient utilization of radio spectrum.

Cognitive radio which is so important and yet has not made its debut in the industry is due to various challenges imposed in design, intelligence, security, flexible hardware design as defined by the radio, cross-layer design, decision making, accurate identification of empty spectrum ask for efficient spectrum sensing algorithms etc. This attracts a large number of research activities across the world.

Orthogonal frequency division multiplexing (OFDM) is the technique proposed in this paper to be used in the transceiver of a cognitive radio. OFDM is a digital multi-carrier modulation technique. OFDM is widely is used across various fields in wireless transmission. The flexibility and features offered by OFDM makes it so popular in the field of wireless communication. The transceiver which is studied in this paper employs OFDM and we shall see the features and challenges it offers in the upcoming sections of this paper.

The main goal of this paper is to integrate OFDM in the transceiver of a typical cognitive radio model thus naming the title. We shall see the features and advantages OFDM offers in the design. At the same time, challenges faced while implementation shall also be studied.

The article is arranged as follows. In section B OFDM is studied and in Section C explains about how CR is integrated with OFDM and followed by conclusions.

B. OFDM:

Orthogonal Frequency Division Multiplexing (OFDM) is a digital modulation technique in which a signal is divided into several narrow band channels at different carrier frequencies. As the name suggests, OFDM is another form of FDM (Frequency division multiplexing) specialized in such a way that the divided narrow band channels are orthogonal to each other. OFDM uses the spectrum more efficiently by spacing the channels more closely [2]. As the sub-carrier channels are orthogonal to each other talk between them, preventing Inter carrier interference (wiki) which the traditional FDM lacks.

In a traditional OFDM receiver Inverse Fast Fourier Transform (IFFT) is performed in the transmitter side and Fast Fourier Transform (FFT) is performed at the receiver's end. IFFT and FFT are employed in an OFDM transceiver is because it provides an efficient solution to ensure that the sub-carrier channels produced are orthogonal to each other. At the same IFFT and FFT can be implemented very efficiently with least complexity in hardware [3].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

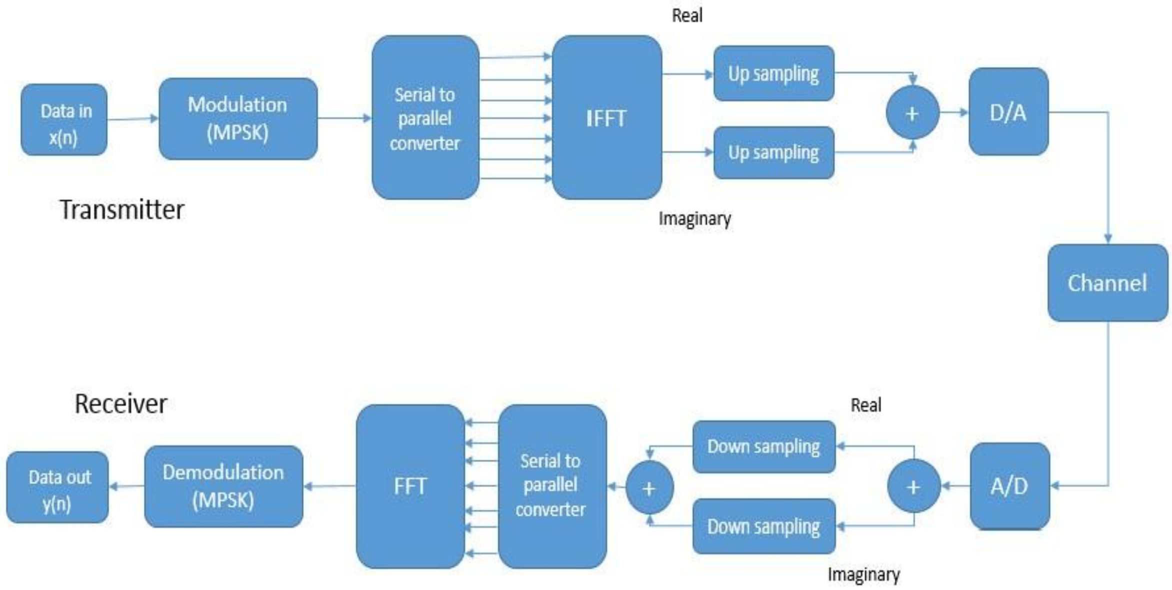

Fig. 1. Block diagram of an OFDM transceiver

The above picture Fig.1. depicts the flow diagram of an OFDM transceiver. The channel is an Additive white Gaussian noise channel with fading. Data in $x\ (n)$ is taken in the form of binary numbers. BPSK or any MPSK modulation scheme is performed on the serial data input. Then this data input is passed into the serial to parallel converter. The number of parallel outputs represents the number of orthogonal sub carrier channels. The orthogonal condition is ensured by IFFT. Then this sequence is split into real and imaginary and then up sampled to meet the required condition as per design requirements. Finally, it passes through digital to analog (DAC) converter and transmitted on the wireless channel.

The transmission wireless channel is an Additive White Gaussian Noise (AWGN) channel. This white noise adds independent Gaussian noise samples to the transmitted signal. It is named additive because it could destroy the signal in an additive manner, Gaussian because of the Gaussian distribution, which is to have zero mean at all values. AWGN is a model for thermal noise generated by random electron movement in the receiver [5]. Multipath Fading is a common phenomenon in wireless signal transmission [4]. When a signal is transmitted over a radio channel, it is subject to reflection, refraction and diffraction [5]. Especially in the urban and suburban areas where cellular phones are most often used [5].

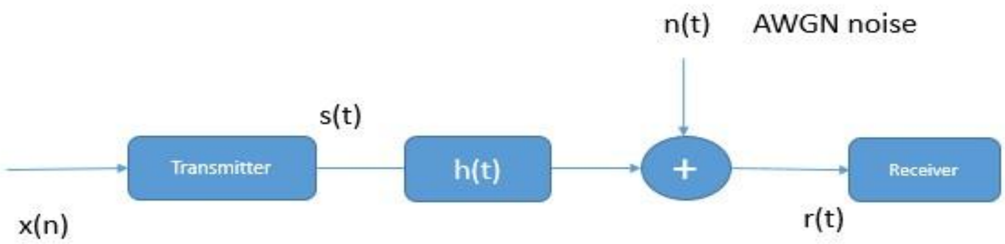

Fig. 2. Effect of AWGN and fading

$$\boldsymbol{r(t)} = \boldsymbol{s(t)} * \boldsymbol{h(t)} + \boldsymbol{n(t)}$$

Fig. 2. Represents a wireless transmission channel where (n) in the input data input, $s\ (t)$ is the transmitter output, $h(t)$ Denotes frequency flat channel fading, $n\ (t)$ is the AWGN and $r\ (t)$ is the received signal which is distorted from the fading and noise.

Receiver also follows a similar method as that of the transmitter. OFDM requires very accurate time, frequency synchronization between transmitter and receiver which plays a vital role in the accuracy and reliability of the transceiver. For example, if 1kbps of random binary data input with BPSK modulation and creating 64 orthogonal sub-carrier channel is up sampled by 10000 to create 10MHz wave which is it to be transmitted. This example is done as model in LabVIEW which is shown in Fig. 3.

International Journal of Engineering Research & Technology (IJERT)
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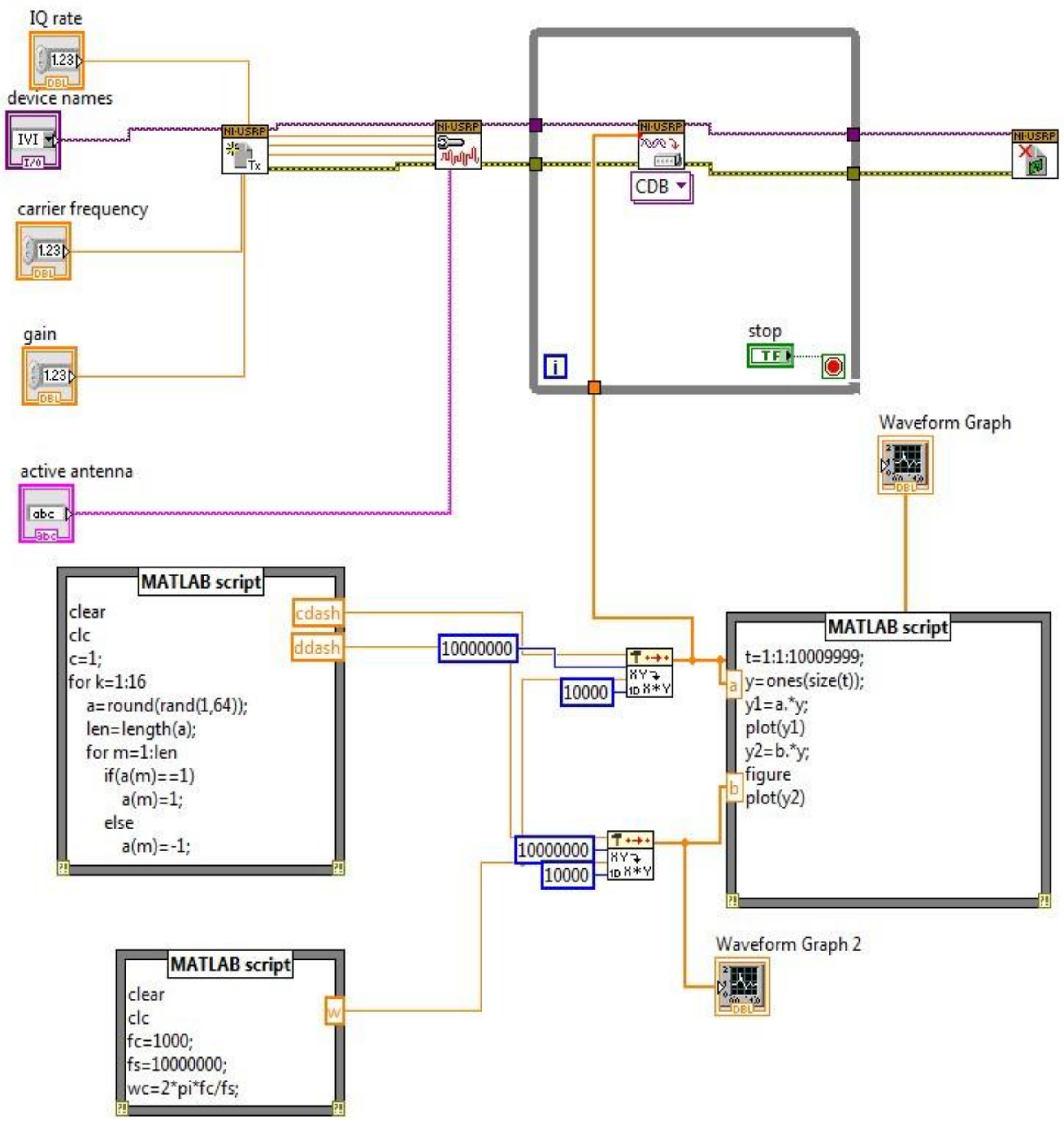

Fig. 3. LabVIEW model for an OFDM transmitter

This LabVIEW model which is done in form of blocks can be directly be dumped into the NI based FPGA for transmission. LabVIEW and the LabVIEW FPGA module deliver graphical development for FPGA chips on NI reconfigurable I/O (RIO) hardware targets. With the LabVIEW FPGA Module, you can develop FPGA VIs on a host computer running Windows, and LabVIEW compiles and implements the code in hardware. The MATLAB simulation results of the same example considered above is depicted in Fig. 4.

Fig. 5. Depicts the simulation result when the signal reaches the receiver for decoding after passing through the wireless transmission channel with AWGN and fading.

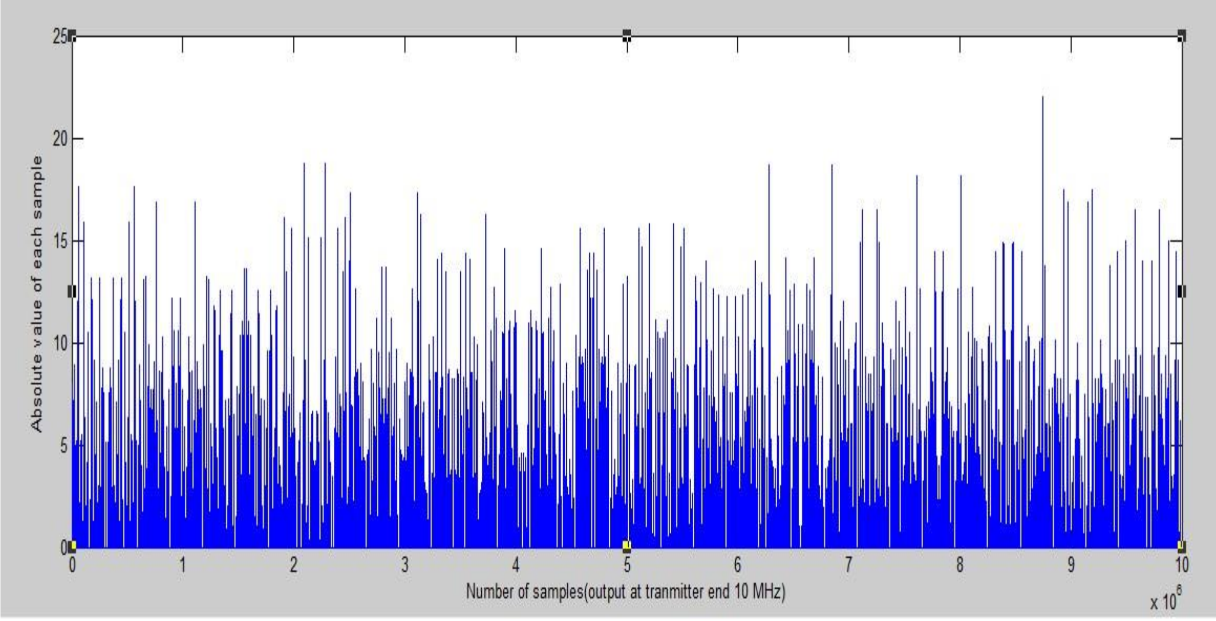

Fig. 4. Simulation result at the start of the channel

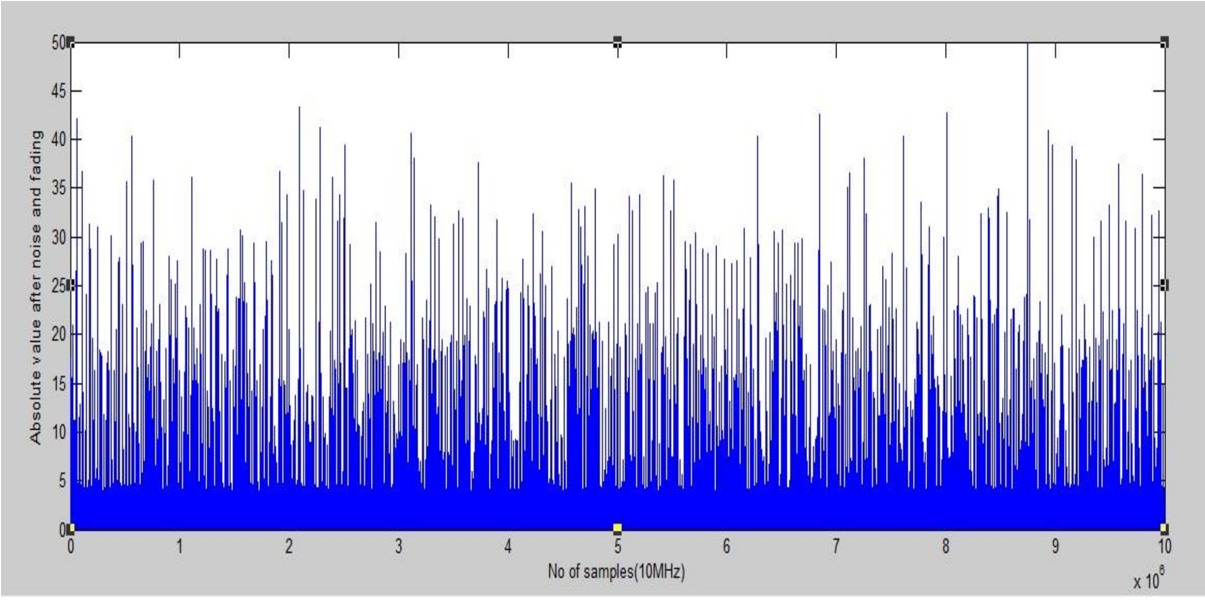

Fig. 5. Simulation result after passing through wireless channel

The OFDM transceiver is thought to be integrated with a cognitive radio as explained below, but due to lack of time the integration of OFDM with cognitive radio is not been made.

C. Integration of OFDM with a traditional Cognitive Radio

Cognitive radio is combined with the OFDM transceiver. Cognitive radio has ability to change the parameters of the OFDM transceiver based on information from a spectrum sensing. Cognitive radio is an intelligent system which is trained and programed to take the right decisions from the data available in the spectrum which is fed into the cognitive radio.

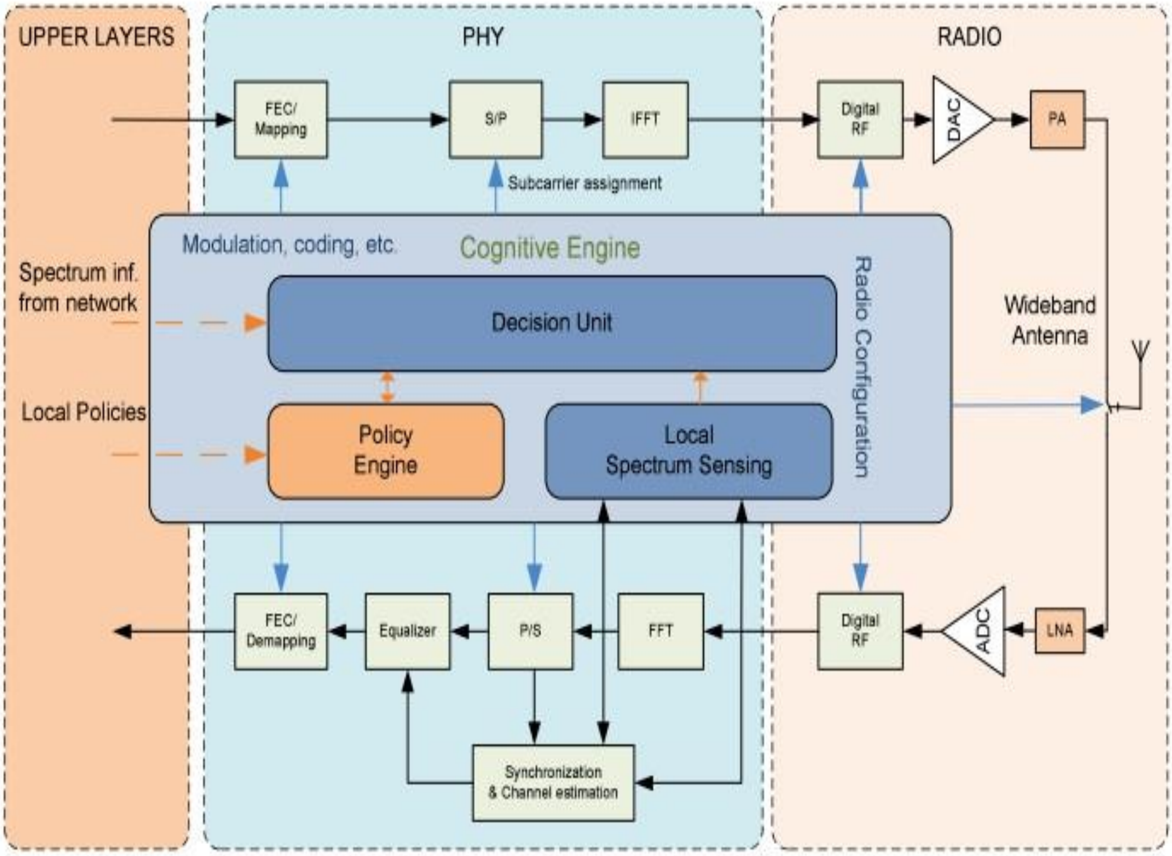

Fig. 6. Integration of OFDM with Cognitive radio from Mahmoud [6].

Cognitive radio modifies the parameters in the OFDM transceiver as per requirements. It should be able to make use of unused spectrum in a fast and efficient manner. Spectrum sensing and interpretation of availability of spectrum and other operating conditions makes the vital part of a cognitive radio. FFT operation performed in the receiver which converts time domain to frequency domain makes spectrum sensing easier. Spectrum sensing information is fed into the cognitive radio while spectrum analysis and spectrum decision making is done by the cognitive radio.

Spectrum Sensing:

Spectrum sensing information is obtained from time, frequency analysis of the data after FFT in the receiver's end. Sometimes it may even extend to a geographical place.

Spectrum Analysis:

Spectrum analysis is done based on spectrum sensing analysing all the factors required for communication.

Spectrum Decision making:

Reconfiguration of transceiver adapting to the real time changing environments and alteration of transmission parameters.

OFDM provides a flexibility of using the spectrum efficiently with the help of spectrum shaping. Shaping plays an important role allowing cognitive users, use the unoccupied part of the spectrum. Shaping is done with by simply turning off a few subcarriers [6]. OFDM is robust against inter-channel interference due to its orthogonal condition. OFDM can adapt easily to several channel conditions. This change can be optimized to meet various goals. OFDM is sensitive to the Doppler Effect. It requires accurate frequency synchronization between transmitter and receiver or else it would lead to deviation in the sub-carriers which are orthogonal to each other. If accurate synchronization is not ensured it may lead to intercarrier interference.

D. CONCLUSION

In this paper, we have briefly discussed OFDM which is used in many wireless systems today. OFDM transmitter was implemented in LabVIEW model and MATLAB simulations were observed. Cognitive radio, though it has not made its debut in the market it has a potential to provide us with innovative solutions for spectrum crowding. With these two working together, it has the potential to touch great heights in wireless communication.

ACKNOWLEDGEMENTS:

I would like to express my deepest gratitude to my faculty supervisor Prof. Vijay Kumar Chakka for his valuable guidance and constant support. He always helped with my problems and gave us time in spite of his busy schedules, more importantly motivating me for to improve my research skills and better understanding.

I also thank Shiv Nadar University and the Dean of Research for this wonderful opportunity.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

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