ISSN 2047-3338

Implementation and Analysis of Cognitive Radio System using MATLAB

Eeru R. Lavudiya[1], Dr. K.D. Kulat[2] and Jagdish D. Kene[3]
[1]M.Tech Scholar ECE, Department V.N.I.T., Nagpur, India
[2]Professor and Head ECE Department V.N.I.T., Nagpur, India
[3]PhD Research Scholar ECE Department V.N.I.T., Nagpur, India

***Abstract*— The growing demand of wireless applications has put a lot of constraints on the usage of available radio spectrum which is limited and precious resource. If scanning of a radio spectrum including revenue rich urban areas, shows that some frequency bands in the spectrum are largely unoccupied most of the time, some other frequency bands are partially occupied and the remaining frequency bands are heavily used. This leads to an underutilization of radio spectrum. This underutilization of radio spectrum is minimized by the Cognitive Radio. Cognitive Radio is a promising technology which provides a novel way to improve utilization of available electromagnetic spectrum efficiently. Cognitive Radio refers to wireless architectures in which a communication system does not operate in a fixed band, but rather searches and finds an appropriate band in which to operate. Spectrum sensing helps to detect the spectrum holes (underutilized bands of the spectrum) providing high spectral resolution capability. In this paper, we investigated the idea of simulating a cognitive radio system to reuse locally unused spectrum to increase the total system capacity. This work focuses on the practical implementation of a Cognitive radio system. To test the performance of Cognitive radio, simulation has been carried out using MATLAB R2011a.**

***Index Terms*—Cognitive Radio, Spectrum Sensing, Matched Filter, Cyclostationary Feature Detection and Energy Detection**

I. INTRODUCTION

THE available electromagnetic radio spectrum is a limited natural resource and getting crowded day by day due to increase in wireless devices and applications. It has been also found that the allocated spectrum is underutilized because of the static allocation of the spectrum. Also, the conventional approach to spectrum management is very inflexible in the sense that each wireless operator is assigned an exclusive license to operate in a certain frequency band [4]. And, with most of the useful radio spectrum already allocated, it is difficult to find vacant bands to either deploy new services or to enhance existing ones. In order to overcome this situation, we need to come up with a means for improved utilization of the spectrum creating opportunities for dynamic spectrum access. The issue of spectrum underutilization in wireless communication can be solved in a better way using Cognitive Radio (CR) technology [2]. Cognitive radios are designed in order to provide highly reliable communication for all users of the network, wherever and whenever needed and to facilitate effective utilization of the radio spectrum.

Cognitive radios have the potential to jump in and out of un-used spectrum gaps to increase spectrum efficiency and provide wideband services. In some locations and/or at some times of the day, 70 percent of the allocated spectrum may be sitting idle. The FCC has recently recommended that significantly greater spectral efficiency could be realized by deploying wireless devices that can coexist with the licensed users [9].

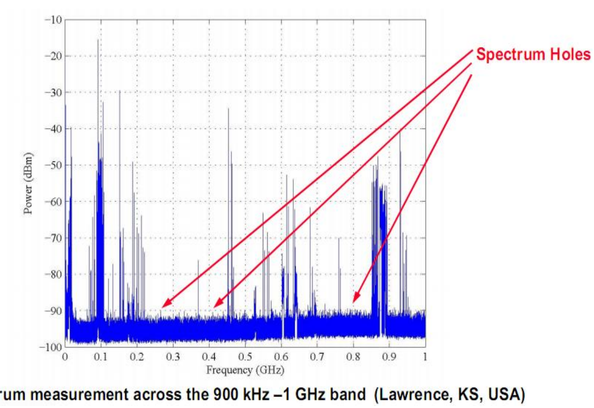

Fig. 1. Occupancy of the spectrum

Cognitive radio is a form of wireless communication in which a transceiver can intelligently detect which RF communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users [3].

In general Cognitive Radio is defined as “Is a technology that provides a promising new way to improve the efficiency of the use of the electromagnetic spectrum that available, by using spectrum sensing for detection of spectrum holes (unused bands), and instantly move into vacant bands while avoiding occupied ones without harmful interference to the Primary User(PU)." The concept of Cognitive Radio is proposed by Joseph Mitola in 1998 [6].

II. COGNITIVE RADIOS

A. There are two types of Cognitive Radios

Full Cognitive Radio: Full cognitive radio takes into account all parameters that a wireless node or network can be aware of [9].

Spectrum Sensing Cognitive Radio: Spectrum sensing cognitive radio is used to detect channels in the radio frequency spectrum. Spectrum sensing is a fundamental requirement in cognitive radio network. Many signal detection techniques can be used in spectrum sensing so as to enhance the detection probability [8].

B. The two main important characteristics of Cognitive Radio

Cognitive Capability: Cognitive capability refers to the ability of the cognitive radio technology to capture or sense the information from its radio environment.

Reconfigurability: Reconfigurability enables the cognitive radio to be programmed dynamically according to the radio environment [5]**.** Basic cognitive cycle is shown in the Fig. 2.

C. Cognitive Radio mainly does four functions

Spectrum Sensing: Cognitive Radio continuously looks for the unused spectrum which is known as the spectrum hole or white space as shown in the Figure. This property of cognitive radio is termed as spectrum sensing.

Spectrum Management: Once the spectrum holes or white spaces are found, cognitive radio selects the available white space or channel. This property of cognitive radio is termed as spectrum management.

Spectrum Sharing: Cognitive Radio allocates the unused spectrum (spectrum hole) to the secondary (cognitive) user as long as primary user does not need it. This property of cognitive radio is termed as spectrum sharing.

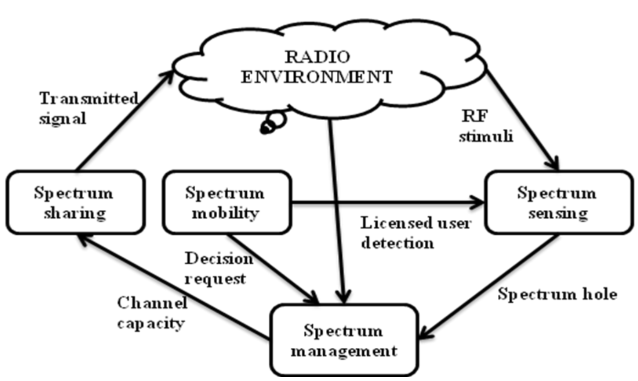

Fig. 2. Basic Cognitive Cycle

Spectrum Mobility: Cognitive Radio vacates the channel when a licensed (Primary) user is detected. This property of cognitive radio is termed as the spectrum mobility [1].

In these four functions Spectrum sensing is an important and a sensitive task in Cognitive Radio since interfering with other users is illegal. Spectrum sensing (also known as spectrum detection technique) is the main task in cognitive cycle and the main challenge to the Cognitive Radio users. In spectrum sensing studying the spectrum and find the unused bands and sharing it while avoiding the spectrum that is occupied by Primary user. It can be defined as "action of a radio measuring signal feature".

III. PROBLEM FORMULATION

A. Spectrum Sensing Techniques

To enhance the detection probability many spectrum detection techniques can be used. These spectrum detection techniques are described as:

Transmitter detection (Non-cooperative Detection): In transmitter detection each Cognitive radio (CR) must independently have the ability to determine the presence or absence of the Primary user (PU) in a specified spectrum. A hypothesized model for transmitter detection is defined as that is, the signal detected by the Secondary user (SU) is:

$$H0: y(t)=w(t) \quad \text{(Primary user is Absent)}$$
$$H1: y(t)=h*x(t)+w(t) \quad \text{(Primary user is Present)}$$

Where H0 represents the hypothesis corresponding to "no signal transmitted", and H1 to "signal transmitted", y(t) is received signal, x(t) is transmitted signal, w(t) is an Additive White Gaussian Noise (AWGN) with zero mean and variance σ^2, and 'h' is the amplitude of channel gain (channel coefficient). Several methods have been proposed, such as, matched filter detection, energy detection, and Cyclostationary feature detection [10].

1) Matched Filter Detection

The matched filter detector that can use as CR has been first proposed. The matched filter (also referred to as coherent detector), it can consider as a best sensing technique if CR has knowledge of PU waveform. It is very accurate since it maximizes the received signal-to-noise ratio (SNR). Matched filter correlates the signal with time shifted version and compares between the final output of matched filter and predetermined threshold will determine the PU presence. Hence, if this information is not accurate, then the matched filter operates weakly.

2) Cyclostationary Feature Detection

Implementation of a Cyclostationary feature detector is a spectrum sensing which can differentiate the modulated signal from the additive noise. A signal is said to be Cyclostationary if its mean and autocorrelation are a periodic function. Feature detection denotes to extracting features from the received signal and performing the detection based on the extracted features. Cyclostationary feature detection can distinguish PU signal from noise, and used at very low Signal to Noise Ratio (SNR) detection by using the information embedded in the PU signal that are not present in the noise.

The main drawback of this method is the complexity of calculation. Also, it must deal with all the frequencies in order to generate the spectral correlation function, which makes it a very large calculation. The benefit of feature detection compared to energy detection is that it typically allows different among dissimilar signals or waveforms.

3) Energy Detection

Energy detection (also denoted as non-coherent detection), is the signal detection mechanism using an energy detector (also known as radiometer) to specify the presence or absence of signal in the band. The most often used approaches in the energy detection are based on the Neyman-Pearson (NP) lemma. The NP lemma criterion increases the probability of detection (Pd) for a given probability of false alarm (Pfa). It is an essential and a common approach to spectrum sensing since it has moderate computational complexities, and can be implemented in both time domain and frequency domain. To adjust the threshold of detection, energy detector requires knowledge of the power of noise in the band to be sensed.

Compared with energy detection, matched filter detection and Cyclostationary detection require a priori information of the PU's to operate efficiently, which is hard to realize practically since PU's differ in different situation. Energy detection is not optimal but simple to implement, so it is widely adopted. The signal is detected by comparing the output of energy detector with threshold which depends on the noise floor [7].

IV. METHODOLOGY FOR IMPLEMENTATION OF COGNITIVE RADIO SYSTEM USING MATLAB

Digital implementations offer more flexibility by using FFT-based spectral estimates. Fig. 3 shows the architecture for digital implementation of an energy detector [4].

Energy detector based approach is the most common wayof spectrum sensing because of its low computational and implementation complexities. When the primary user signal is unknown or the reciever cannot gather sufficient information about the primary user signal, the energy detection method is used. About the primary user signal, the energy detection method is used. This method is optimal for detecting any unknown zero-mean constellation signals and can be applied to cognitive radios (CRs) [1].

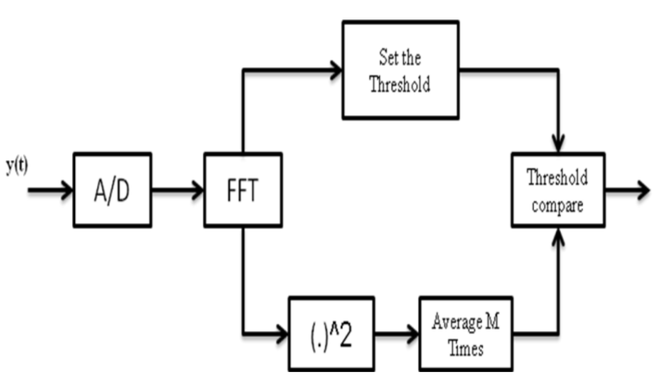

Fig. 3. Digital implementation of an energy detector

The process flow of the energy detector is, the received signal is passed throug the ADC then calculate the FFT coefficient values then squared those values and average over the observation interval. Then the output of the detector is compared to a pre defined threshold value to decide whether the primary user is present or not.

A. Cognitive Radio Applications

Cognitive Radio techniques which allow spectrum sharing with other spectrum users are ideal for non-time critical applications. Four applications were considered to be the most promising.

1) Mobile multimedia downloads (for example, download of music/video files to portable players) which require moderate data rates and near-ubiquitous coverage.
2) Emergency communications services that require a moderate data rate and localized coverage (for example, video transmission from firemen's helmets).
3) Broadband wireless networking (for example, using nomadic laptops), which needs high data rates, but where users may be satisfied with localized "hot spot" services.
4) Multimedia wireless networking services (e.g., audio/video distribution within homes) requiring high data rates.

V. SIMULATION RESULTS AND DISCUSSIONS

This paper presents the cognitive radio system using MATLAB (R2011a) v.7.12.0.635. We have used the digital implementation of energy detector using FFT. It is assumed that there are 5 primary users in the spectrum.

The cognitive radio system continuously looks for the spectrum hole where primary user is not present which is determined by the energy detection method and as soon as it finds out the spectrum hole, it allots it immediately to the Secondary user and whenever primary user wants to occupy the slot, secondary user immediately vacates it.

The carrier frequencies used for 5 signals are 1MHz, 2MHz, 3MHz, 4MHz, 5MHz and sampling frequency is 12MHz. Power spectrum density of signal is calculated and it is compared with the predefined threshold value to determine the presence of primary user signal [1].

Here, we have assumed that 1st, 4th primary users are present and 2nd, 3rd and 5th primary users are not present. Further 5th primary user leaves the slot. Here, Signal to noise ratio (SNR) is taken as 10dB. Then, the following results are obtained which are shown in the Fig. 4. (a), Fig. 4. (b), Fig. 4. (c) and Fig. 4. (d).

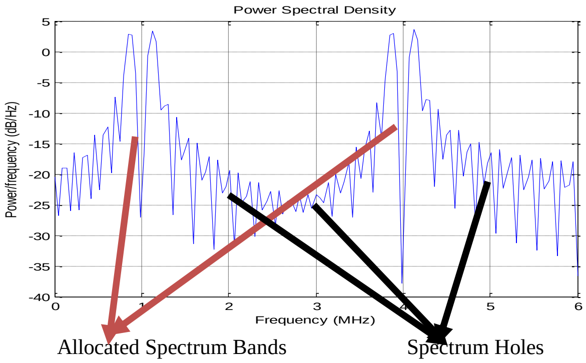

Fig. 4. (a) used bands (1st and 4th), unused bands (2nd, 3rd and 5th)

Now the Cognitive Radio system will search the first available gap (Spectrum hole) in the spectrum and automatically assign it to the secondary user. As the first available gap was occupied by the secondary user1 it is shown in the Fig. 4. (b).

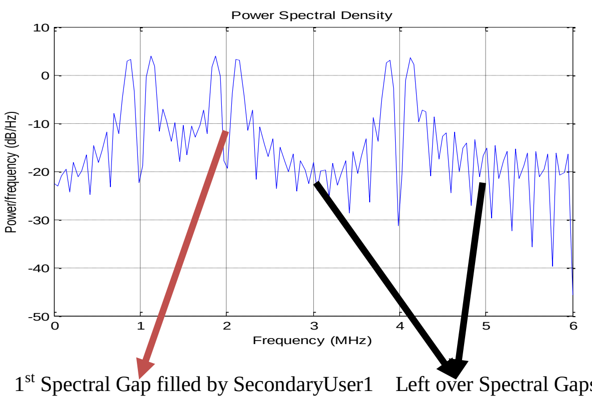

Fig. 4. (b) 1st unused band assigned to Secondary user1

Now the Cognitive Radio system will search the next available gap in the spectrum and automatically assign it to the secondary user. As the next available gap was occupied by the secondary user2 it is shown in the Fig. 4. (c).

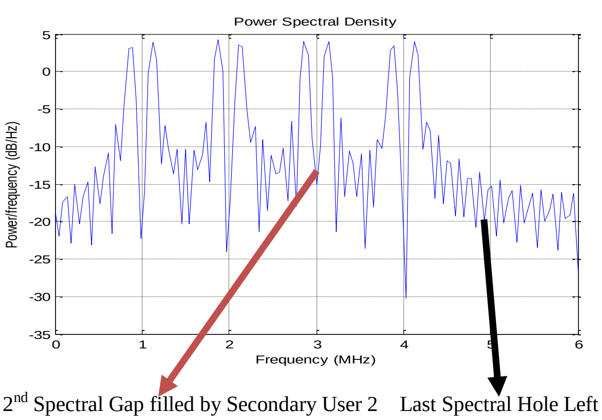

Fig. 4. (c) 2nd unused band assigned to Secondary user2

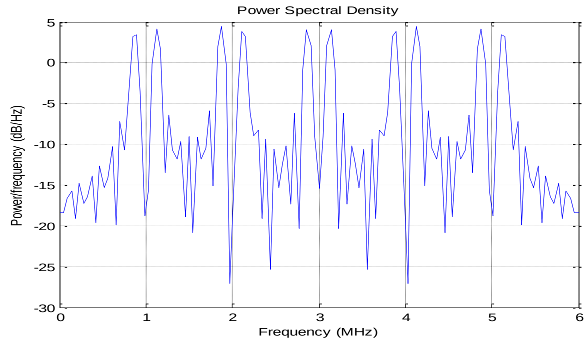

Fig . 4. (d) All of the Spectrum bands are in use

Now we have just one empty slot left which will get filled by addition of another Secondary user as shown in Fig. 4. (d). It shows that all of the frequency bands are efficiently in use after the last spectrum hole is occupied by secondary user3.

Here, low peaks in Fig. 4. (a) are for 2nd, 3rd and 5th primary users who are not present and high peaks for the present ones. In Fig. 4. (b), you can see that after allocating the 2nd slot to secondary user1, there is an increase in the peak of 2nd slot. Similarly in Fig. 4. (c), there is an increase in the peak of 3rd slot allocating it to the secondary user2. Now at this instant 5th primary user leaves the slot.

So, finally, Fig. 4. (d) shows the allotment of 5th slot to secondary user3 by the cognitive radio network.

Now we have to take Signal to noise ratio (SNR) is 5dB, 14dB. Then, the following results are shown in the Fig. 4. (e) and Fig. 4. (f).

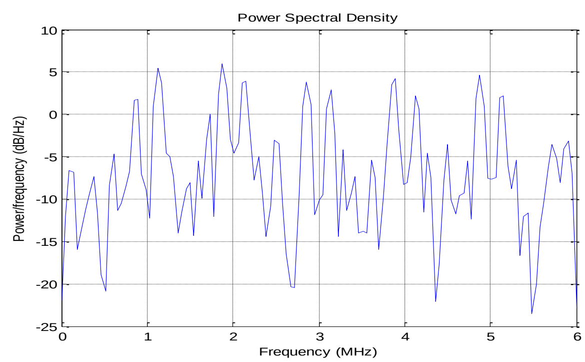

Fig. 4. (e) SNR=5dB

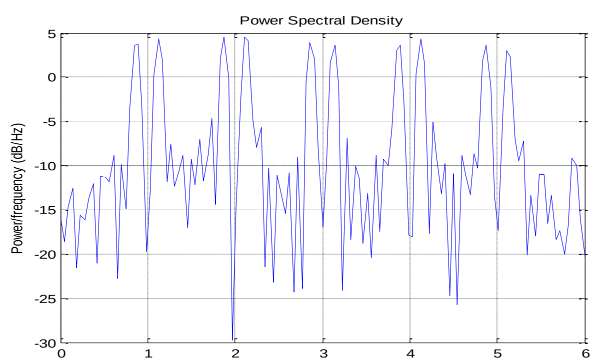

Fig. 4. (f) SNR=14dB

Now we have to attenuate the received signal with attenuation percentage values 10% and 15%. Then, the following results are shown in the Fig. 4. (g) and Fig. 4. (h).

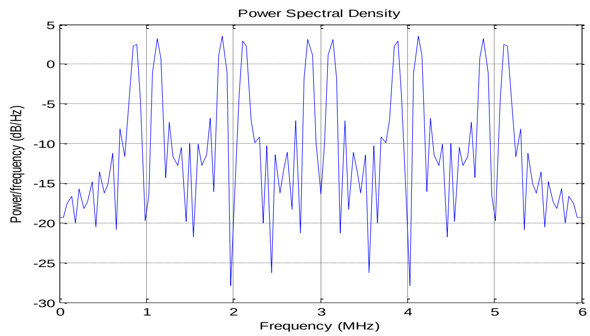

Fig. 4. (g) Attenuation=10%

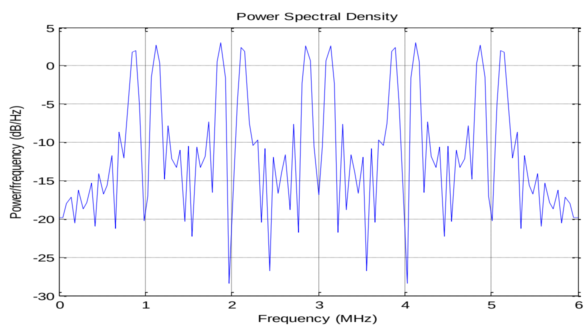

Fig. 4. (h) Attenuation=15%

VI. CONCLUSION

Cognitive Radio is an innovative technology proposed to increase spectrum usage by allowing dynamic allocation of the unused spectrum in changing environment. Cognitive users monitor the spectrum and are allowed to use it as long as it does not interfere with primary users to whom it has been licensed. In this paper we have performed the energy detection spectrum sensing using FFT within the specified frequency band. The simulation result it has been shown that how the cognitive radio works with changing the frequency band from one to another and successfully demonstrated. In this simulation we are used the Additive White Gaussian noise with the Signal to noise ratio (SNR) values are taken as 5dB, 14dB and Attenuation percentages are 10 and 15.That is the Cognitive Radio demonstrated successfully without interfering with the other frequency bands which are used by the primary user and it is implemented in MAT LAB.

REFERENCES

[1] A. Bansal, Ms. R. Mahajan, "Building Cognitive Radio System Using Matlab", *IJECSE*, Vol.1, Number 3, 2012.

[2] F. Khozeimeh and S. Haykin, "Self-Organizing dynamic spectrum management for cognitive radio networks", In *Proc. of 8th Annual Conference on Communication Networks and Services, 2010.*

[3] J. Mitola, "Cognitive Radio for Flexible Multimedia Communications," IEEE International Workshop on *Mobile Multimedia Communications*, 1999, pp 3-10.

[4] James O'Donnell Neel, 2006, "Analysis and Design of Cognitive Radio Networks and Distributed Radio Resource Management Algorithms," *PhD Dissertation, Virginia Polytechnic Institute and State University*, Blacksburg, VA.

[5] F.I. Akyildiz, W.Y. Lee, M.C. Vuran and S. Mohanty, "A Survey on Spectrum Management in Cognitive Radio Networks," in *IEEE Communications Magazine*, 2008, pp. 40-48.

[6] J. Mitola III, May, 2000. "Cognitive Radio: An Integrated Agent Architecture for Software Defined Radio," *PhD Dissertation Royal Institute of Technology*, Stockholm, Sweden.

[7] K.Cheng Chen and R. Prasad, "Cognitive Radio Networks," *John Wiley & Sons Ltd*, 2009.

[8] S. Haykin, "Cognitive radio: Brain-empowered wireless communications," *IEEE J. Select. Areas Commun*. vol. 23, no. 2, 2005, pp. 201-220,

[9] FCC, (Nov. 2002), "Spectrum policy task force," Tech. Report.

[10] A. Sahai and D. Cabric, "Spectrum sensing: fundamental limits and practical challenges," *IEEE Proc. of International Symposium on New Frontiers in Dynamic Spectrum Access Networks(DySPAN*), Baltimore, MD, 2005.

Mr. Eeru Ramdas Lavudiya completed his bachelor degree in Electronics and Communication Engineering in 2009, from Gokaraju Rangaraju Institute of Engineering and Technology, JawaharLal Nehru Technological University, Hyderabad, A.P. India. He is currently pursuing the Master degree in Electronics and Communication Engineering under the supervision of Dr. Kishor D. Kulat at Visvervaraya National Institute of Technology (VNIT), Nagpur, M.S., India. His project work is related to Study and implementation of Cognitive Radio using various Spectrum Sensing Techniques. He believes that Hard work is the secrets of success.

Mr. Jagdish Deorao Kene completed his bachelor degree in Electronics Engineering in 2001, from Manoharbhai Patel Institute of Engineering and Technology, Nagpur University, Nagpur and Master degree in Electronics Engineering in 2005, from Yashavantrao Chowan College of Engineering, Nagpur Universyty, Nagpur, M. S. India. He is currently associated with U. C. O. E. Nagpur, as Assistant Professor in Electronics Engineering Department having total experience of 11 years. He is currently pursuing P-hd in the field of wireless communication under the supervision of Dr. Kishor D. Kulat at Visvervaraya National Institute of Technology (VNIT), Nagpur, M.S., India. His research work is related to Performance evaluation and optimization solution of physical layer by implementing various error correction coding techniques in mobile Wi-Max environment. He has published 1 Journal Paper in Elsevier, 3 papers in International Conferences in his research area. He also published 1 paper in International Conference and more than 8 have been published in National Conferences in his academic carrier. He is member of Professional societies like ISTE. He believes that Trust and Honesty is the secrets of success.

Dr. Kishor D. Kulat completed his degree in Electrical Engineering, BE in 1980, from VRCE (at present VNIT) Nagpur and ME degree in 1984 from VJTI, Mumbai, India. He completed his Ph.D. degree in Electronics Engineering, in the year 2003 from VNIT, Nagpur. Having a total experience of more than 25 years, he is currently associated with VNIT, as Professor and Head in the Electronics & Computer Science Department. With his profound knowledge & experience in his field he is guiding around 18 research scholars for their doctoral degree, 11 have been awarded the Ph. D. degree. He has published around 81 Journal Papers, more than 75 papers in International Conferences & more than 100 have been published in National Conferences. He has worked as Reviewer for many National & International Conferences. He is a member of Board of Studies for Electronics Engineering, Nagpur University for last 12 years. He is member of Professional societies like IETE, IEI and ISTE. With all his faith in God, Dr. K. D. Kulat believes in achieving excellence through the process of continuous up gradation.