iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VIII **Month of publication:** August 2017

DOI: http://doi.org/10.22214/ijraset.2017.8176

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

Implementation of Spectrum Detection Techniques in Cognitive Radio

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Abstract: ***This paper is aimed at providing an overview of the implementation of the various types of spectrum sensing or detection techniques used in Cognitive Radio (CR). With the current rate of growth in the demand for available radio spectrum, Cognitive Radio has been found to be highly successful in improving the utilization efficiency of the available frequency spectrum. CR system is basically based on the principle that the spectrum can be efficiently reused by additional secondary users when the primary or licensed users no longer need the spectrum. For achieving this purpose, CR uses different methods for sensing the usage of the spectrum and dynamically allocates it to secondary users whenever it is not used, by causing minimal or no disturbance to the licensed users. So the spectrum sensing forms one of the most important steps in the CR system and hence the choice of method for implementing this technique plays a vital role in the efficiency achieved by the system.***
Keywords: Cognitive Radio, Spectrum Sensing, Energy Detection, Cyclostationary Detection, Matched Filter Detection, Interference Based Detection.

I. INTRODUCTION

The need for wireless communication services and applications is growing exponentially with more and more communication being performed via internet, data, voice communication, control communication, emergency response communication etc. Cognitive Radio (CR) helps to achieve more flexibility, cost efficiency, ease and effectiveness to radio spectrum utilization. CR is a highly intelligent system having its own decision making capabilities by means of monitoring the surrounding radio environment and modifying its own operating parameters, thereby achieving better spectrum utilization. The traditional methods employed for the purpose of managing the available spectrum is not flexible. Every set of frequency band will be solely allocated to a particular user in static spectrum management methods and hence it becomes highly difficult to find vacant bands for deploying new applications and services. Cognitive Radio (CR) gives an efficient solution to the issue by virtue of Dynamic Spectrum Access. For this, the CR network first senses the environment around it to determine the radio activities surrounding it. If the CR detects any vacant or unused frequency bands, it immediately allocates the band to a secondary or unlicensed user. When the primary user again accesses the spectrum, the secondary user's access is revoked. This results in achieving better utilization of available spectrum with minimal or no interference to the primary users. A CR can be defined as a Software Defined Radio (SDR) which also performs the additional tasks of sensing the surrounding environment, tracking the changes and taking appropriate action depending on its findings [1].
The rest of the paper has been organized as follows. Section II shows the different techniques available for spectrum sensing, section III explains the implementation of each of the methods using MATLAB Simulink and Section IV concludes the paper.

II. SPECTRUM SENSING TECHNIQUES

One of the most important steps to be performed by the CR is spectrum sensing. Spectrum sensing can be defined as the process that determines the presence of a primary or licensed user on a particular frequency band. The CR network shares the result of its detection with other CR networks as well [4]. The primary aim of spectrum sensing is to find out the status of the spectrum utilization and activity by periodically sensing the target frequency band. Typically, a cognitive radio transceiver detects the spectrum which is unused (also known as spectrum hole) and also determines method to be used to access the band without interfering with the transmission of licensed user. Since the primary users will not be active all the time, the use of CR networks helps to accommodate additional secondary users as well in the network. These users are dynamically allocated to the specific parts of the spectrum when not occupied by primary users [7].
There are several techniques that can be employed for the implementation of spectrum sensing as shown in Fig. 1. A brief description about the basic principles of operation of these different detection techniques can be given as follows.

A. *Transmitter Detection*

This type of detection technique is also known as Non-cooperative sensing method. This is further classified into three. First is the Energy detection whose advantages are low computational and implementation complexities and is typically used when the

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

receivers do not have any a priori knowledge regarding the signal from the licensed user. Matched filter detection is also referred to as coherent detector. This is an optimal detector in Gaussian noise which maximizes the received signal-to-noise ratio (SNR) and may be preferred in cases where the secondary user has a priori knowledge about the primary user's signal. Cyclostationary feature detection is performed by introducing periodic redundancy into a signal with the help of sampling and modulation. It is highly helpful to differentiate the modulated signal from the additive noise and hence can be used for very low signal to noise detection as well, by making use of the information present in the licensed user's signal but not in the noise part.

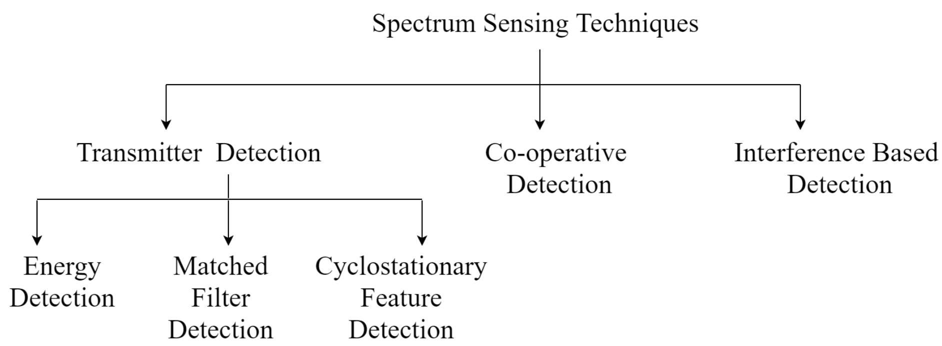

Fig.1 Spectrum Sensing Techniques

B. *Co-operative Detection*

The sensing will be accomplished by a number of different radios within a cognitive radio network in a cooperative cognitive radio spectrum sensing system. Typically reports of signals from different radios in the network are received by a central station which concludes their combined decision by some particular fusion rule. Cooperative detection is typically useful to solve the issues that typically occur due to fading, noise uncertainty, shadowing etc. [8].

C. *Interference Based Detection*

Interference at the transmitter side is controlled by controlling the radiated power which causes the interference. But the same task is accomplished at the receiver side by imposing interference temperature limits, which is the additional amount of interference that can be tolerated by the receiver. But the major drawback associated with this model is that it considers the case with only a single secondary user.

III. IMPLEMENTATION

Spectrum sensing in cognitive radio networks have been implemented using Simulink models. The detection of spectrum activity in each method makes use of different basic principles and hence the efficiency of each method also varies. The choice of the detection method to be used depends on the application or the type of network that is being used. The following section explains the Simulink models that were used for the implementation of each of the detection techniques.

A. *Energy Detection*

Energy detection method is one of the fastest and simplest means used by the CR for sensing the radio spectrum around it and is commonly used to detect whether or not unknown signals exist [3]. The most important advantage of this method is that the receiver is not required to have any a priori knowledge about the signal from the primary user. Fig. 2 shows a Simulink model of Energy Detection.

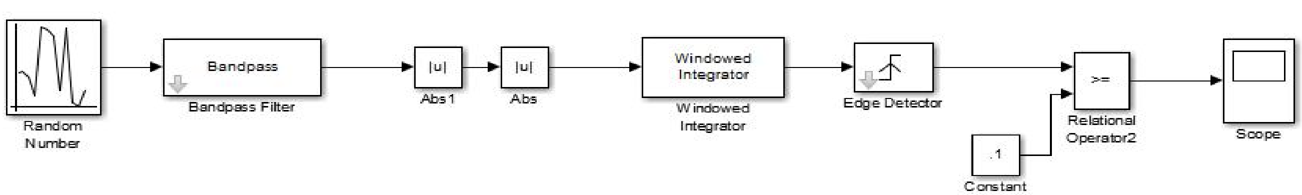

Fig 2. Energy Detection

Here a band pass filter is used to filter the input signal, which would allow only the selected range of frequencies to pass and blocks all the other frequencies. In the next step, it computes the magnitude of the received input signal and is then squared using the absolute math function. A window integrator then integrates the received signal, followed by which a rising edge detection is performed. An Edge detector is used for this purpose and then a relational operator is used to perform the comparison of the input signal and a constant threshold signal and the detector's output is plotted by a Scope.

B. Cyclostationary Feature Detection

Cyclostationary Feature Detection (CFD) method makes use of the cyclostationary characteristics associated with the radio signal under consideration [1]. This method can help to differentiate the desired signal from additive noise. The mean and autocorrelation of a cyclostationary signal are periodic. CFD method is used to distinguish the primary user's signal from noise [6]. CFD method possesses greater noise protection as compared with other types of spectrum sensing methods. Fig. 3 depicts the CFD method implementation model [1]. CFD method is performed by introducing periodic redundancy into a signal with the help of sampling and modulation [4]. A discrete sine wave is applied as the input to the system followed by which, Additive White Gaussian Noise (AWGN) is added. The Peak Notch filter typically rejects very few range of frequencies. ADC quantizer performs the quantization of the input signal into a stair step function. Next step involves an Encoder which converts the quantizer's output in the form of integers. An FFT (Fast Fourier Transform) block is used to convert the signal from time domain to frequency domain. Window function used here is the Kaiser window. Data type conversion block converts any signal in the form of user specified signal [1]. In the last section, a constant block is used to generate a threshold value which is compared with the input signal by a relational operator and the output is plotted using scope.

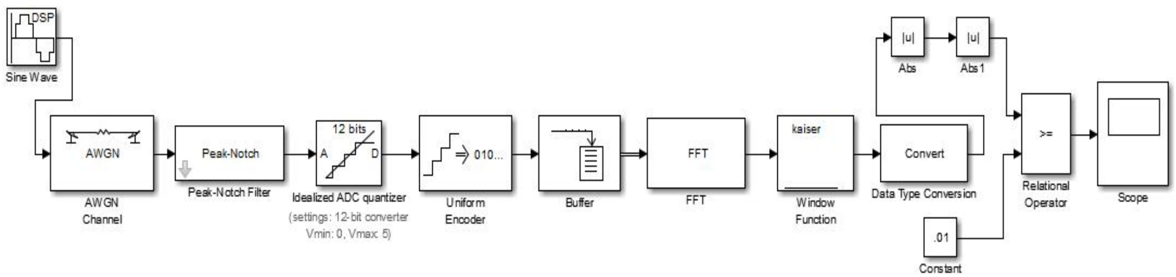

Fig 3. Cyclostationary Feature Detection

C. Matched Filter Detection

In order to achieve an efficient SNR, a matched filter is most commonly used at the front end of the receiver [2]. Matched filter is basically a linear filter which is designed so as to achieve maximum output signal to noise ratio for a given input signal. Matched filter detection method is usually used when the secondary or unlicensed user has a priori knowledge about the primary user's signal. The presence of a primary user is determined by the matched filter by correlating the signal with a time sifted version and then comparing the output with a predetermined threshold [4]. There are two different types of receivers typically used. They are coherent or non-coherent.

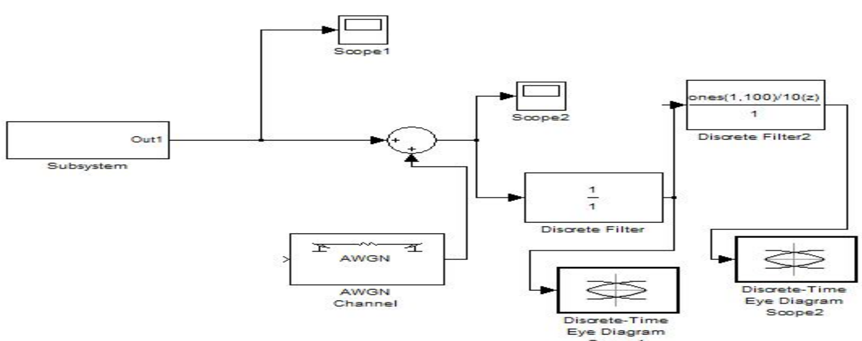

Fig 4. Matched Filter Detection

Coherent receivers are used when the amplitude and phase of the received signal are known and hence it helps in achieving a perfect match between the matched filter coefficients and the input signal. The noncoherent receiver models the received signal as a replica of the original signal with a random phase error [2]. Fig. 4 and 5 give the Simulink model used for the implementation of Matched Filter Detection method. There are two major drawbacks associated with Matched Filter Detection method. Firstly, the a priori knowledge about the primary user's signal is required for its operation. Otherwise the system performs very poorly. The second drawback is that a dedicated receiver is needed for every type of cognitive primary user.

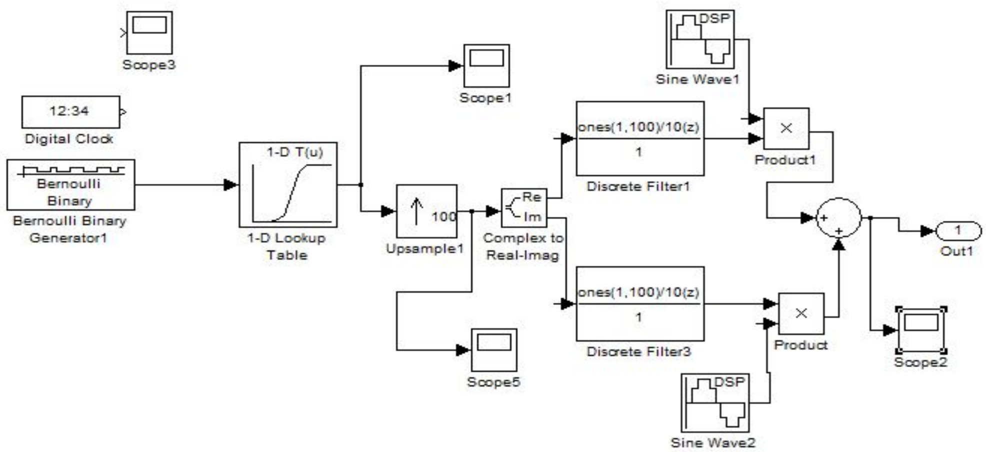

Fig 5. Subsystem design for Matched Filter Detection

D. Interference Based Detection

Interference at the transmitter side is basically regulated and controlled by minimizing the necessary radiated power, which in turn would help to reduce the interference. But interference actually occurs at the receiver side as well and hence a new technique for measuring same has been developed, which is termed as interference temperature. Interference temperature model operates by imposing interference temperature limits at the receiver, which is the maximum amount of additional interference that can be tolerated by the receiver.

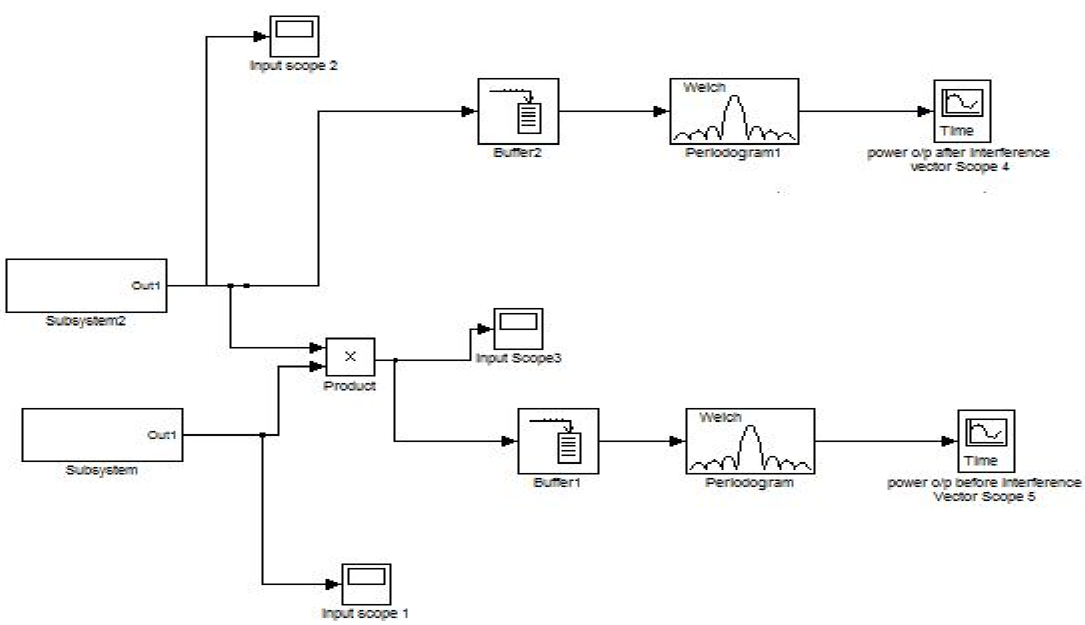

Fig 5. Interference Based Detection

The most important thing to be taken care of in this model is that any unlicensed transmission should not violate the interference temperature limit at the licensed receivers to use the spectrum band. But there are certain drawbacks associated with this model. First one is that it considers the interference caused by single secondary user alone and cannot be used in cases where there are multiple secondary users. Second major setback is that it is not suitable when secondary user does not have the information regarding the position of nearby primary users.

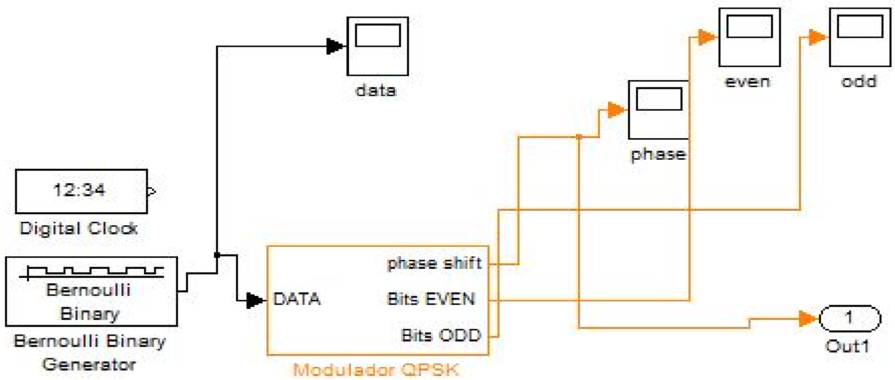

Fig 6. Subsystem for Interference Based Detection

IV. CONCLUSIONS

The Cognitive Radio is a highly successful technology that has been helpful in utilizing the available radio spectrum in a much more efficient and effective way. The under-utilization as well as the over-utilization of certain frequency bands in the spectrum has been taken care of well using CR technology. The key factor or step that helps in achieving the high efficiency has been the spectrum sensing step. The different methods employed by CR networks for sensing the activity of surrounding radio spectrum has been discussed and the implementation of the same using Simulink models have been illustrated. The advantages as well as the drawbacks associated with each method has been discussed. The choice of the spectrum detection method depends on the type of intended application or service and this in turn decides the efficiency that can be achieved by the CR network.

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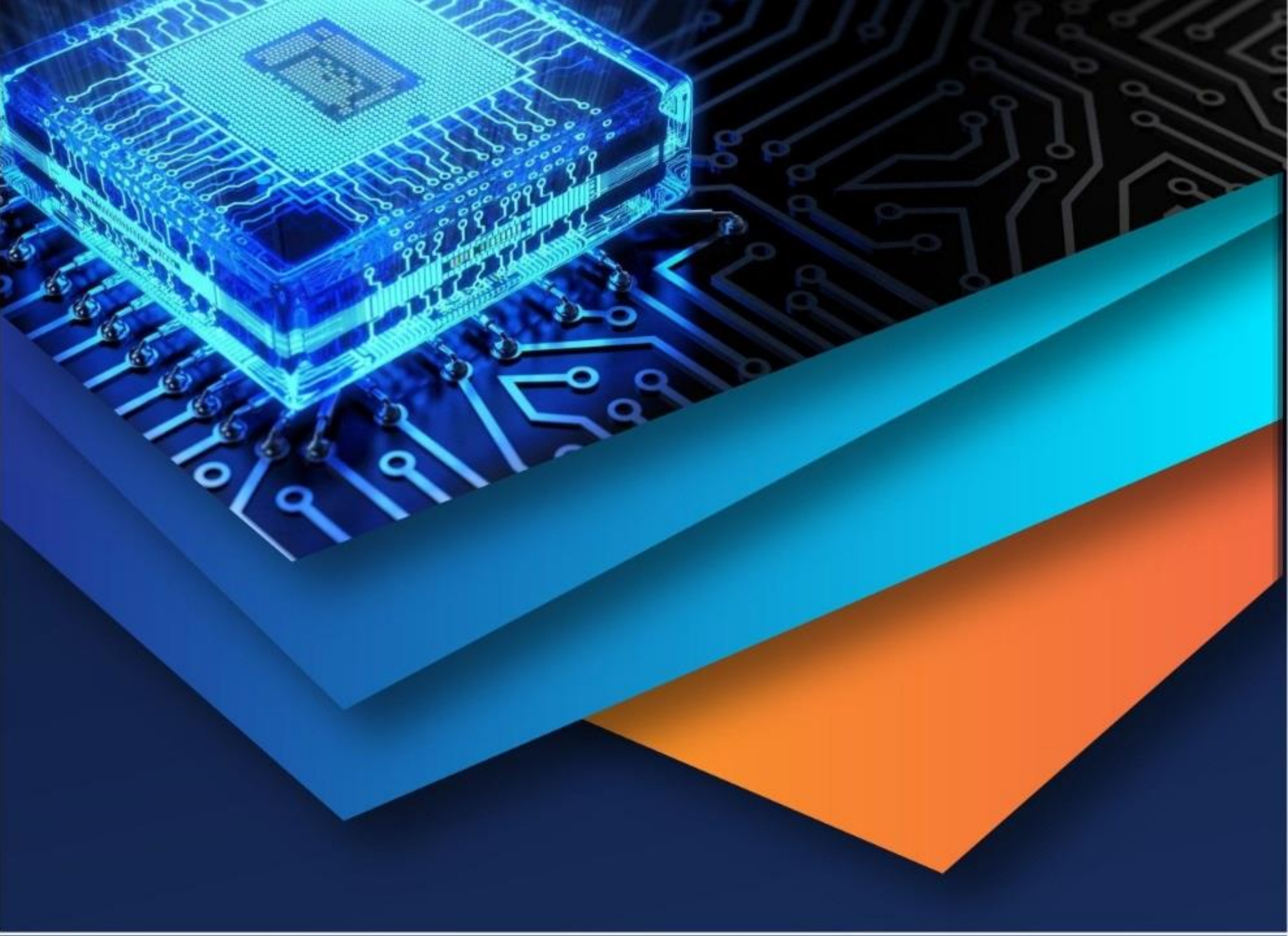

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