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Survey on Various Channel Models for Data Transmission

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Abstract: Several channel models are available in the literature for analyzing the behavior of the channel under observation. Each model used a set of parameters for analyzing the channel. The models used either the conventional or modern approaches for analyzing the channel by using a separate set of parameters. There are several parameters that have to be considered when a model is to be designed. These sets of parameters make the system complex. There is a needed to determine those few parameters that together give the combined effect of all the parameters. In the present paper some advanced channel models are discussed at length and effective channel parameters are identified and tabulated for making the channel simulation design easy.

Keywords: Watterson model, wide band channel model, effective channel parameters.

I. INTRODUCTION

When the information is making a trip from source to destination through the propagating medium, it under goes different changes in view of diverse sorts of disorders, errors brought in as a result of the clamor into the information, delay spread, numerous reflections and so forth. The received information won't be same as the information that has been transmitted by the source [1]. Channel parameters of few channel models that will affect the data that is being communicated to the receiver are considered here. Channel sub-carriers and Time duration in between the transmission of bits are to be handled to mitigate the impairments such as absence of originality in the sub-carriers due to selectivity of time and Inter symbol interference (ISI) which happens due to huge selectivity. The allocated power and signal constellation can be changed at the transmitter side for each of the sub-carrier so that throughput could be maximized. The delay spread is a key parameter which is to be considered for focusing on the phase difference and path delay. If the source or the destination is moving from location to location the Doppler shift will affect the signal phase and thus the data received. The transmission and reception when done simultaneously and several times, spectral efficiency can be further improved. Off-late more advanced models have been invented that considers additional parameters that are required for modelling the channels much more accurately. The models include Watterson model, Wideband Channel Model, and new wideband channel model.

A. The Watterson model

Fig. 1 shows the Watterson model that uses a structure of a tapped delay. A perfect delay line that propagates through a set of taps having distinct delays is considered into a signal that has been transmitted. The signal which is delayed is regulated by amplitude and phase by a tap gain function which is complex. Both the regulated and delayed symbols are added and a noise introduced for forming a output signal. Gi(t) is the tap gain function of the i^{th} tap, S(t) is the baseband transition signal, and n is the quantity of propagation paths and n(t) is the additive noise, r(t) is the received signal, which can be communicated as given by Eqn (1).

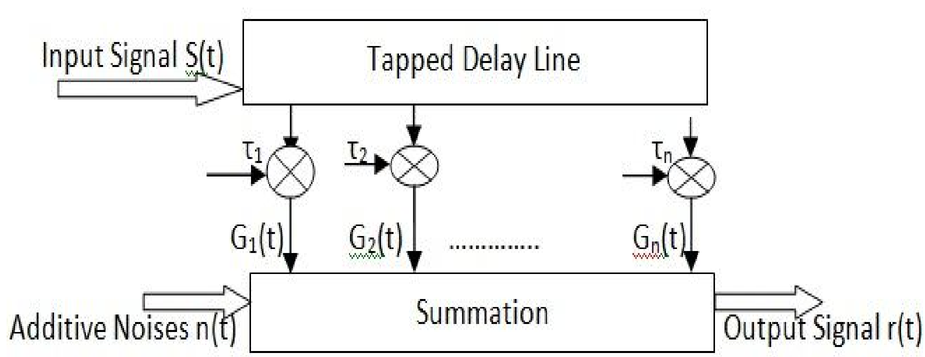

Fig. 1 The Watterson Model

$$r(t) = \Sigma a_i(t)\exp (j (2f_0 (t-\tau_i)+ f_{Di}t)) \qquad (1)$$

where τi is the time delay of i^{th} path, $a_i(t)$ is the amplitude of the signal of i^{th} path, f_{Di} is the corresponding frequency shift. There are many paths in tap delay line which is small corresponding specifically when n is less than 8.

The Watterson model is constructed based on three main hypotheses [2] [3] which include the following:

1) A complex Gaussian process effects Gi(t) which is the tap gain function. Every complex Gaussian process produces an action which Rayleigh distributed and phase is distributed by mean.
2) Gain functions stand to be statically absolute to each other
3) The spectrum of Gaussian power considers that each function related to tap-gain is the addition of two Gaussian functions and as a result effects separately magneto ionic components. It has been assumed that power spectrum v_f of the tap gain functions Gi(f) accept Gaussian shape or the shapes having the Gaussian distributions Some of the drawbacks of the Watterson model have limited the use of the model to undertake the modelling of only high frequency channels and also help in simulating the models. The following are some of the constraints of Watterson model.
4) It is assumed that The HF channel must be both stable and stationary.
5) The narrowband Watterson model is just sufficient for data transfer data around 12KHz frequencies.
6) Doppler movement is excluded as the scattering of the delay is not considered in the narrowband.
7) It seems that all HF ionospheric channels are not well represented through Doppler shape variable which Gaussian distributed which is used as a part of a narrowband model. The Lorentzian shape factor can be portrayed more reasonably by the propagation of some specific channels when compared to a component that is Gaussian shaped [4].
8) The wideband applications cannot use the narrowband Watterson model due to its limitations. A wideband HF channel is vital for a propagation that represents configuration and assessment of HF communication systems.

B. The Wideband Channel Model

The impulse reaction of the channel can be utilized for reenactment of the wideband channel. The output signal is the mix of IR (impulse response) and the input signal. Equation (2) shows the relationship.

$$y(t) = \int_0^{\infty} x(t-\tau)h(t,\tau)\,d\tau \qquad (2)$$

where h(t,τ) is the HF Propagation channel (wide band) impulse response function, it is described as per the given below equation:

$$h(t,\tau) = \sum_{n=1}^{N} \mathrm{hn}(t,\tau) \qquad (3)$$

where h(t,τ) is the impulse response of one of different ionospheric propagation paths indexed by n. t, τ are independent variables for time and delay. For each propagation path, the impulse response is given as:

$$\mathrm{hn}(t,\tau) = \sqrt{P_n(\tau)D_n(t,\tau)\psi_n(t,\tau)} \qquad (4)$$

where $P_n(\tau)$ is the delay power profile and its square root $\sqrt{P_n(\tau)}$ describes the shape in delay dimension; $D_n(t, \tau)$ is the deterministic phase function describing the Doppler shift of each path, and $\psi_n(t,\tau)$ is a stochastic modulation function describing the fading of the impulse response.

The delay power profile $P_n(\tau)$ determines how the impulse response behaves as a function of delay τ and can be expressed as

$P_n(\tau) = A \exp (\alpha(\ln z +1 - z))$ (5)where $Z = (\tau-\tau_1) / \sigma_1 > 0$ and A is the power at the expected value of delay τ_c associated with the center frequency, α is the delay spread shape factor. The parameters α and τ_1 are functions of the received signal threshold A_1 the overall delay spread α_τ and α_1.

The deterministic phase function $D_n (t, \tau)$ can be given as:

$$Dn(t,\tau) = e^{i2\pi[f_s+b(\tau-\tau_c)]t} \qquad (6)$$

where f_s is the Doppler shift at τ_c and b is the rate of change of the Doppler shift between τ_L and τ_c.

The stochastic modulating function ψn (t, τ) can be produced as random variables having all autocorrelation capacity with Gaussian shape or Lorentzian shape. The wideband high frequency model must portray the impacts of delay time spread, Doppler frequency shift, Doppler spread and variety of Doppler movements with delay. The channel scattering function relates the 4 parameters and gives a graphical technique to show the signal energy distribution [5] [6]. The scattering function S(τ, fp) is the Fourier transform of the autocorrelation capacity of the IR shown by:

$$S(\tau, f) = \int_{-\infty}^{\infty} R(\tau, \Delta t) e^{-i2\pi f D \Delta t} d\delta t \quad (7)$$

where fD is the Doppler shift, δ t is the autocorrelation time lag, and R(τ, δt) is the autocorrelation function of the impulse response.

C. The New Wideband Channel model

The simulation models can also be used for modelling the channels. The simulation models that are quite frequently employed include the Wideband channel simulator model, single propagation included simulation models, multiple propagation simulation models etc. The wideband HF channel model beforehand depicted is an augmentation of the narrowband Watterson model. The HF propagation channel is a time varying scattering channel. Under the motivation by the structure of tapped delay line which is utilized as a part of the simulation of the narrowband Watterson model, another wideband channel software is proposed by Yang Guo, Ke Wang [7]. In this channel model test system, the aggregate channel reaction is partitioned into 'n' paths, comparing to the 'n' propagation paths demonstrated in Fig. 2. At that point, every propagation path is made out of 'm' sub paths, which is not the same as the tapped delay line structure of the Watterson model, appeared as Fig. 3. The signals in a solitary sub-path are firstly delayed by τ_i, i=1, 2, … m. At that point the signal is multiplied by a time delay amplitude $\sqrt{P(\tau_i)}$, which is tested from the time delay profile $\sqrt{P(\tau)}$.

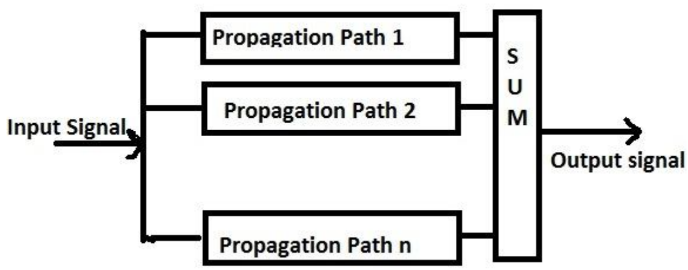

Fig. 2 New Channel simulator Design Diagram

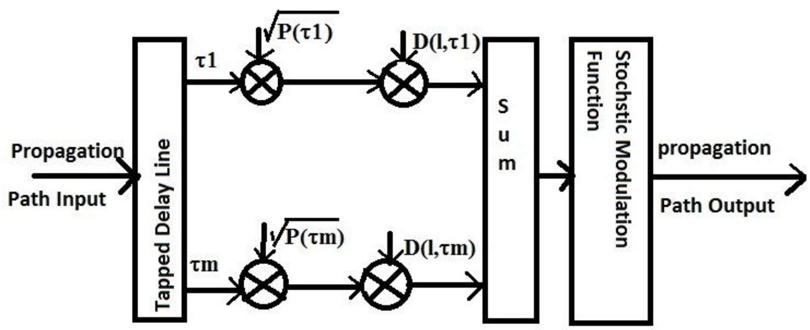

Fig. 3 Model of Single Propagation Path

Every sub path signal is duplicated by a deterministic phase function Dn(t, τ) confirming to the Doppler shift of the sub path. inally, the sub path signals are modulated by a stochastic modulation function, representing the Doppler spread of the sub path. All the sub path signals are added to frame the output signal. Another approach to execute the Doppler spread is to first sum up the sub path signals and after that, tweaks the output signal with an aggregate stochastic modulation function. In this model, the delay power profile is inspected and every propagating path is discretized into numerous sub-paths (Fig. 4). Thus, the convolution can be supplanted by the summation of 'n' sub-paths after the deterministic phase function reliant on time delay is included. The proposed structure can be effectively utilized as a part of real time simulations and it is difficult to change the parameters of the HF channel. It is sure that when the quantity of sub-paths in each propagation path is adequately substantial, the channel response call is sufficiently adequate for the exact channel reaction.

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Fig. 4 Samples of single propagation path

The Consultative Committee for International Radio (CCIR) Recommendation 520–1 [8] has been listed in a number of high frequency Channel conditions. This document is well-known. CCIR has defined Good, Moderate, and Poor channels. The table 1 shows the details of these channels. This table also defines the CCIR Flutter Fading channel, which is defined as a dual path 0.5 ms differential time delay with each path having a Doppler spread of 10 Hz. No mention of HF channel simulator specifics, other than time spread and frequency spread are mentioned in this document. The frequencies and time delays that can be affected at different channel conditions are tabulated in Table 1.

Table 1: Channel conditions at different frequency spreads and time delays

S.No	Condition	Frequency Spread (Hz)	Delay (ms)
1	Flat Fading	0.2	0.0
2	Flat Fading (Extreme)	1.0	0.0
3	Good	0.1	0.5
4	Moderate	0.5	1.0
5	Poor	1.0	2.0

CCIR Report 549-2 [9] gives a more top to bottom discussion of high frequency Ionospheric channel simulators. This record gives a percentage of the propagation hypothesis foundation to bolster a various propagation mode model. It examines Gaussian-disseminate HF Channel display, the test approval of this model, and a usage of a channel simulator system in view of this model. This record characterizes the relationship between Doppler spread and the standard deviation of the Gaussian channel spectrum. This archive likewise expresses that the Gaussian range of the fading taps has been accepted over other channel spectra. The most recent form of this record, ITU-R F.1487 [10] gives some extra channel models to HF in view of scope and presents a method for similar testing of HF modems, yet does not cover the points of interest of HF Channel simulator implementations. At the point when Harris Corporation started executing the high data rate waveforms of STANAG 5066 Annex G (the ancestor to US MIL-STD-188-110B and STANAG 4539), two distinctive programming channel test systems were accessible. The primary waveform that had been produced in the mid 90 depends on STANAG 4285 rules. It used a two-pole Butterworth filter for the fading procedure, redesigned at a rate of 600 times each second. The second was produced particularly for STANAG 4415 which is tested subsequent to the NATO working group and chose to fix the channel simulator system so that various waveform developers could look at hopeful waveforms. This simulator used a Gaussian shaped channel, redesigned at a rate no less than 32 times the coveted Doppler spread. The channel simulator details have been excluded in the standard for reference purposes. At the point, when Harris Corporation chose to institutionalize its channel simulator to the one produced for STANAG 4415, a huge distinction in execution was seen between the two channel simulators when the 9600 bps waveform was tried on a CCIR's poor rated channel. It was noticed that there was close understanding in measured execution under single path, non-fading channel conditions and not under fading channel conditions. This highlighted the fading tap era process as the presumable guilty party in charge of the distinctions in execution. Further examination exhibited that the filter shape, the redesign rate of the taps, and the interpolation strategy, or lacking thereof, all added to the watched contrasts in execution. What takes after is a progression of execution and spectrum plots that highlight modem execution estimation varieties as a function of spectral shape, interpolation scheme, and redesign rate. Fig. 5 is a plot of the deliberate execution on a CCIR's poor rated channel for 2400 bps in long inters leaver waveform (2400L). Fig. 6 is a plot of the deliberate execution on a CCIR's poor rated channel for the 9600 bps in long interleaves waveform (9600VL). Measured execution is exhibited for two distinctive filter usages, Butterworth and Gaussian, both with and without test based interjection. Looking at Figures 5 and 6 uncovers that the 9600VL waveform considerably more delicate to varieties in the execution of the HF channel simulator than the 2400L waveform. The 2400L waveform demonstrates a most extreme contrast in execution of around 1/2 dB at a BER of 10-5 contrasted and a deviation of more than 2.3 dB for the 9600VL waveform for the same BER of 10-5.

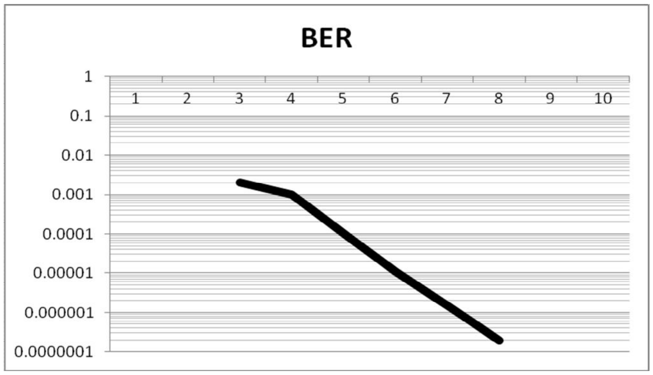

Fig. 5 Performance of U.S. MII-STD-188-110B 2400L bps

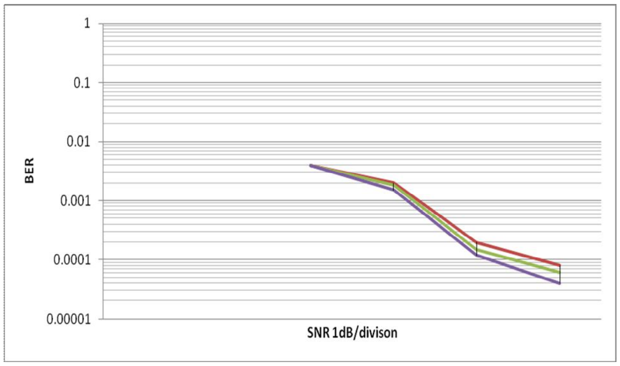

Fig. 6 Performance of US MIL-STD-188-110B 9600VL bps

Figure 7 contrasts the perfect Gaussian channel spectrum and that is accomplished by the new Harris model, using the accompanying particulars recorded underneath the figure 7. It ought to be noticed that the deviation of the range beginning at –30 dB is likely because of the range estimation procedure utilized. These determinations are an endeavor to give a more tightly meaning of a Watterson model based channel simulator that will bring about a great deal less usage to execution deviations.

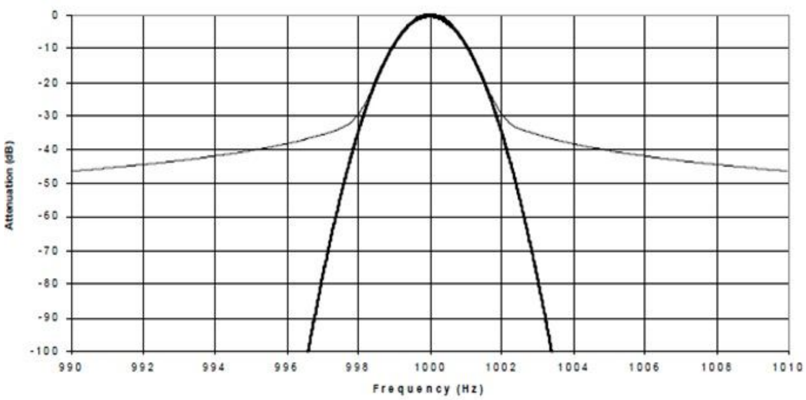

Fig. 7 Achieved Gaussian Filter spectrum Vs Ideal Spectrum

Specification of an improved model that models a HF channel (Multipath modeled by tap-delay line).

1) All paths ought to be standardized by summing the fancied powers for every path and setting aggregate power equivalent to 1.0 (for appropriate SNR esteem).
2) Fading taps for tap-delay line acquired by dithering complex white Gaussian noise tests. Readers new to WGN can locate a fabulous portrayal in [11].
3) Filters utilized for fading procedure ought to have a Gaussian shaped power spectrum (frequency domain) with Doppler spread of power spectrum equivalent to double the standard deviation (2σ). $f_j(t) = \sqrt{2}e^{-\pi^2 t^2 d_j^2}$, $-\infty < t < \infty$ should be utilized to register the channel taps taking into account the sampling rate of the channel simulator. The length of the channel ought to be set to at any length where the registered tap is 0.01 little than the maximum tap. Channel ought to be symmetrical about max tap (tap for time 0). Channel ought to then be power standardized to 1.0 and scaled by gain processed in (ii) above for given path.
4) Fading taps must be figured no less than 32 times speedier than the coveted fade rate.
5) Fading taps must be interjected to in any event the symbol rate of the waveform (2400 examples a second) to abstain from presenting expansive discontinuities in the yield of the simulator. (Harris channel test system interjects to 9600 specimens for each second). In a perfect world, the fading taps ought to be inserted to the sample rate of the channel simulator.
6) No simulated radio filters or AGC ought to be utilized. Additionally, since information to channel simulator is a genuine audio signal, a Hilbert transform [11] ought to be utilized to make an complex signal.
7) SNR ought to be the average signal to noise ratio of a waveform measured in a 3 kHz bandwidth. Consideration ought to be taken to measure average signal power of the input waveform.
8) Additive White Gaussian Noise [11] ought to be utilized as noise source.
9) In request to create a fading procedure that is inside 0.1% of the craved Doppler spread, the crystal used to produce the specimen rate for the channel simulator ought not surpass 500 Parts Per Million (PPM).

II. COMPARATIVE ANALYSIS OF ADVANCED CHANNELS MODELS

The presentation of various types of models described in the previous section reveal the consideration of a set of model parameters for effective and efficient modeling of a channel. Table 2 shows the list of parameters and a mopping of the same to the models presented in the previous sections. It can be seen from Table 2 that the way a particular parameter is introduced into the model has been different. Some of the parameters however have been used in similar manner by all the three models presented in previous section. Thus it becomes necessary to find the best effective manner of implementation of the parameters that should be used in the designing a channel model.

Table 2 Parametric Identification of the models used in the advanced models

Parameter Serial	Name of the parameter	Watterson Model	Wide Band Channel Model	New Wideband Channel Model
1	Single versus Double Scattering	Multiple Bounce scattering	Multiple Bounce scattering	Multiple Bounce scattering
2	Delay dispersion	Neglected	Considered	Considered
3	Power Spectrum	Power range of the tap addition capacities are expected to have a Gaussian shape	Postponement force profile decides the drive reaction	Deferral force profile is inspected and every engendering pat is discretized into numerous sub-ways.
4	Band of operation	For frequencies no more than 12 KHz.	Useful for wide band models	Useful for wide band models
	Wave Propagation	Assumes that	Expect that the	Expect that the

5		channel is both stationary and stable	transmitter and beneficiary are powerfully moving	transmitter and beneficiary are powerfully moving
6	Diffuse Multipath Components	Radio channel is a superposition of limited number of engendering ways.	Radio channel is a superposition of limited number of engendering ways.	Radio channel is a superposition of limited number of engendering ways.
7	Multiple Reflection/hop paths	Multiple propagation paths are considered.	Multiple propagation paths are considered.	Multiple propagation paths are considered.

III. CONCLUSION

It has been seen while comparing various models that many parameters are involved and the way a parameter is used in the model has been differing. An elaborate study of each parameter has to be undertaken to find the importance of the same and also to find the way the parameters must be introduced into the model. Every parameter can be introduced in different style and manner. It is necessary to find the most effective way of implementing a parameter within a design model. The detailed description of each of the parameter, the methods that can be used for introducing the parameters and the most effective way of implementing the parameters are shown in Table 2.

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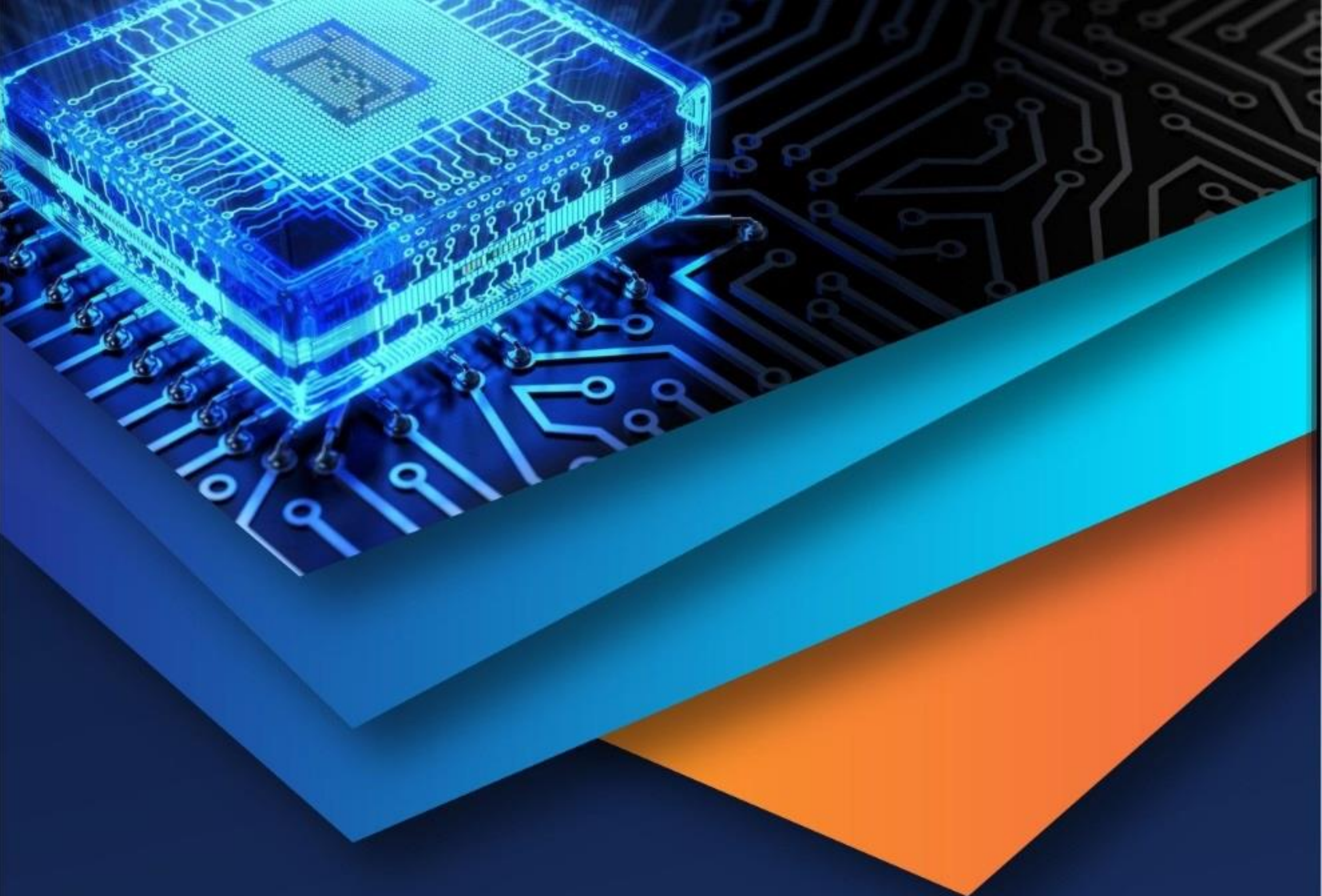

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