Minimization of Co-Channel Interference in a Heterogeneous Network Environment

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Abstract:
This paper presented the minimization of interference in a co-channel network environment. Co-channel interference is one of the leading forms of interference in communication systems. This form of interference is very alarming because it doesn't just generate noise in the receiver but also causes heavy jamming by giving you other signals that weren't desired. This research aims to reduce noise and separate identical channels from the primary or desired signals. Communication systems face too many problems, but co-channel interference is one of the major problems. The co-channel interference sends several pieces of information to the receiver because the channels share the same characteristics of signals, at that point noise will be generated and information jamming will occur. The method used in reducing the co-channeling noise is the digital low pass filter, the digital low pass filter in the desired receiver blocks the other frequencies coming to interfere with the desired signal and allows only the desired signal to make it through without any interference. The low pass filter is designed such as to see other interfering signals at a high frequency. The results of this research work show that the bit error rate is low due to the intervention of the filter, interference was reduced, and the noise was reduced from 130dB to 10 dB. The research work evaluated the behaviour of the co-channel interference and the bit error rate and determined the low pass filter response for noise reduction. The research also recommends further improvements in the improvement of bit error rate, improving noise reductions in the channels, and prevention.

Keywords: Co-channel, Interference, Jamming, Filter, Noise reduction

1. Introduction

In networking Co-channel noise is established by one or more noisy signals within the frequency band of the desired signal in a communications system and is a key factor that limits the capacity of co-channel networks. The co-channel noise can arise from communications in the same frequency channel in other cells of the System, or other sources, so its features may be either like or different from those of the desired signal [1].

It is well known that wireless communication uses free space as the communication connection to transmit information (in the form of speech, video, or data) across considerable distances [2] The phrase "Global System for Mobile Communication" (GSM) refers to a kind of wireless communication in which several Mobile Users (MU) collaborate with base stations (BS) to send and receive signal data in real-time. Service providers for Our Network are authorized to use a certain portion of the spectrum to deliver to their customers. On a non-interfering radio transmission, a given spectrum allocation may be split into several disjoints. To separate a radio spectrum into several channels, techniques like frequency division (FD), time division (TD), and code division (CD) may be utilized [1].

However, contemporary social, economic, and political trends are being driven by communications technology. However, the communication network noise is an unwelcome annoyance that is reducing the benefits that may be derived from this significant technology. Noise is a serious issue for service providers on the GSM network since it lowers the quality of their services, which may lead to a decline in income. Self-interference, multiple access interference, co-channel interference (CCI), and neighbouring channel interference are the typical forms of noise (interference) in cellular and co-channel networks. (ACI). Signals sent on a shared transmitter might cause self-interference or noise. Transmission from numerous radios utilizing the same frequency resource results in many access noises. Links that repeatedly utilize the same frequency channel experience co-channel noise. ACI is the interference caused by connections that use nearby frequency bands to communicate in the same place. To reduce noise in cellular and co-channel networks, many strategies have been put forward. Common ways include power management, efficient frequency assignment utilizing clever tricks, and intermodulation fixes [3]. This research work aims to reduce co-channel noise in a co-channel interference system using a low pass filter in a BPSK AWGN Channel's

A. *Review of Related Work*

In reference [4], an analysis of performance is conducted concerning the bit error rate within digital systems affected by co-channel interference. The study aims to assess the impact of interference on system performance and derives expressions for the bit error rate under various scenarios. These scenarios encompass instances involving a single interferer, two interferers, or even a larger number denoted as K, all possessing equal power levels. When K takes on a substantial value, the interference pattern follows a Gaussian distribution, allowing it to be treated akin to additional noise.

The investigation also delves into scenarios involving two interferers, highlighting cases where one holds more influence and where the interference occurs asynchronously in relation to the signal. Despite the convenience of the Gaussian approximation, it falls short as an accurate model for cellular networks. This is primarily because cellular networks typically involve just one or two primary interferers.

The paper introduces an effective methodology for assessing the viability of various strategies proposed to mitigate co-channel interference in cellular networks. This methodology serves as a valuable tool in evaluating the efficiency of these diverse approaches.

As stated in reference [5], the scarcity of available spectrum coupled with the rise of diverse wireless applications has led to a pressing concern: the coexistence and sharing of resources between IMT-Advanced and Fixed Wireless Access (FWA) systems. This issue has gained significant importance recently. In the WRC-07, ITU-R addressed this by designating the 3400-3600 MHz band for the upcoming fourth generation (4G) or IMT-Advanced, to be shared on an equal basis with existing FWA systems. Consequently, it has become imperative to establish protocols for coexistence and sharing, encompassing factors such as separation distance and frequency coordination for both co-channel and adjacent channel scenarios.

The study delves into scenarios involving the co-siting of the two base station antennas and those where they are non-co-sited. This differentiation depends on a standard coexistence criterion set at an interference to noise ratio of -6 dB. The analysis considers interference models such as the Adjacent Channel Interference Ratio (ACIR) and the Spectral Emission Mask (SEM) within the specified frequency band. These models aid in determining the additional isolation required to safeguard against adjacent channel interference.

Ultimately, the paper suggests potential techniques for mitigating interference between these two systems. These techniques hold the promise of alleviating intersystem interference effectively.

In reference [6], an exploration is undertaken into the cellular aspects of a novel concept that introduces a fresh element known as the forwarding mobile terminal (FMT) within the context of the Hipper LAN/2 (H/2) framework. The core objective of the FMT is to expand the coverage area of an H/2 access point, thereby granting users situated in areas lacking coverage access to the fixed Internet through an intermediary hop. Essentially, the FMT is a modified version of an H/2 mobile terminal, requiring solely a different software configuration without the need for an additional transceiver. This contribution illustrates the behavior of this concept across various cellular environments, focusing on interference dynamics and their effects on users. This concept proves particularly advantageous in scenarios where substantial attenuation by walls is anticipated. For urban settings, the forwarding concept facilitates rapid system deployment, curbing cabling expenses, and providing a reasonable user experience across an expansive service area.

In accordance with reference [7], the escalation of co-channel interference (CCI) in wireless local area networks (WLANs) is posing significant challenges within contemporary, densely populated wireless environments. CCI within IEEE 802.11-based networks is inevitable due to the inherent carrier sensing mechanism but can be mitigated through resource optimization strategies. Hence, the analysis of CCI holds fundamental importance for efficient resource management. This article introduces an innovative CCI analysis approach grounded in queuing theory, which accounts for the variability in end users' behaviors and the intricate and irregular nature of network traffic in high-density WLANs. The approach adopts the M/M/c queuing model to analyze CCI, with a focus on scenarios where multiple networks overlap and trigger channel contentions. To assess CCI impacts in densely overlapped WLANs, the analysis incorporates a probabilistic factor into the queuing model, utilizing the ratio of signal-overlapped areas to signal coverage. Through simulations employing the queuing model, the study examines how CCI influences the quality of service (QoS) in high-density WLAN environments.

According to references [1] and [8], the fundamental performance measures of a cellular system are defined by Coverage and Capacity. However, these metrics are constrained by interference within the system. Among the significant sources of interference, Co-Channel Interference (CCI) stands out, primarily originating from the concept of frequency reuse. In CDMA-based systems, the impact of CCI is more pronounced due to their employment of a unity frequency reuse ratio. This study introduces a novel approach to estimate the capacity and coverage of a 3G WCDMA system while considering the influence of CCI.

The ramifications of CCI are elucidated through the concept of CCI probability. This research investigates the conditional probability of encountering CCI, specifically when signals follow a Rayleigh distribution. The paper incorporates the COST 231 Hata model to compute the coverage area. The evaluation of capacity and coverage encompasses variables like the number of Co-Channel interferers, the ratio of antenna gain, voice activity factor, Eb/No (energy per bit to noise power spectral density), and diverse data rates.

Findings indicate that capacity tends to rise when there are fewer active Co-Channel interferers and lower data rates. Additionally, enhancing the height of base station antennas improves the cellular coverage area of the WCDMA system. The methodology proposed in this paper can also be effectively adapted to assess capacity and coverage within 3GPP LTE and

LTE Advanced systems. Keywords: Co-Channel Interference (CCI), WCDMA, CCI Probability, COST 231 Hata model, LTE, LTE Advanced.

II MATERIALS AND METHOD

B. Materials

The materials used in this work are:

i. BPSK Modulator
ii. BPSK Demodulator
iii. Constellation Tool
iv. Display
v. Additive White Gaussian Noise

C. Method

The binary phase shift key technique was adopted in this research work to analyze signal interference in a co-channel network environment.

D. Co-Channel Cell Noise Interference Evaluation

Inside a prison Reusing frequency suggests that several cells may utilize the same set of frequencies within a given coverage region. Co-channel interference is the name for the conflict between transmissions from this cell. The co-channel interference ratio is dependent on the radius of the cell (R) and the separation between the centres of the closest co-channel cells when each cell is about the same size and the base stations broadcast the same amount of power. (D). The spatial distance between co-channel cells in relation to a cell's coverage distance increases as the D/R ratio increases. Improved RF energy separation from the co-channel cell thereby reduces interference. The cluster size and the parameter Q, often known as the co-channel reuse ratio, are connected. Considering a hexagonal geometry [9]:

$$Q = \frac{D}{R} = \sqrt{3}N \quad (1)$$

Where D is the distance between co-channel cells, R is the cell radius, and N is the number of co-channel interfering cells.

Using N as the number of co-channel interfering cells, the following equation may be used to represent the co-channel interference power for a mobile receiver [10]:

$$\sum_{i=1}^{N} I_i$$

Where I_i For the same mobile, the following formula yields the signal-to-interference ratio S/I. is the signal intensity of the interference caused by the ith co-channel cell base station [10]:

$$\frac{S}{i} = S / \sum_{i=1}^{N} I_i \quad (2)$$

S stands for the intended base station's desired signal power. The average received signal intensity at any given location in a mobile radio channel exhibits a power law relationship with the separation distance between a transmitter and a receiver, according to propagation measurements. a typical received power p_r at a location that is about d from the transmitting antenna [10]:

$$p_r = p_0(d/d_0)^{-a} \quad (3)$$

Where a is the exponent of the route loss and P_0 is the power received at a close-in reference point in the antenna's far-field region at a relatively short distance d0 from the transmitting antenna. This latter parameter is typically between 2 and 4 in cellular networks. If D_i is the distance between the ith interferer and the mobile (D_i), then the received power from the ith interfering cell at a given mobile is proportional to D_i. If the transmit power of each base station is the same and the route loss exponent is uniform throughout the coverage region, then we can approximately compute the S/I for mobile devices as follows [11]:

$$\frac{S}{i} = R^{-a} / \sum_{i=1}^{N}(Di)^{-a} \quad (4)$$

So, (4) simplifies to:

$$\frac{S}{i} = R^{-a}/\sum_{i=1}^{N}(D)^{a} = (\frac{\frac{D}{R)^{a}}}{N}) = (\sqrt{3N})^{a}/N \quad (5)$$

The Bernoulli binary is the digital input signal of 1 and 0's into the transmitters. This signal goes through the binary phase shift keying modulators. For the co-channel interference, multiple same signals are sent into the BPSK modulators, these signals are multiplexed to AWGN before being sent to the receiver. The receiver receives multiple channels, thereby generating noise in the receiver and signal jamming. But when a low-pass digital filter is introduced to the primary transmitted signal and the receiver, the receiver only accepts the signal from the primary transmitted channel due to the signal matching and filters interference 1 and interference 2 because it sees them as high signals and they are unwanted. This signal is then displayed on the spectrum analyzer as shown in Figures 1 and 2.

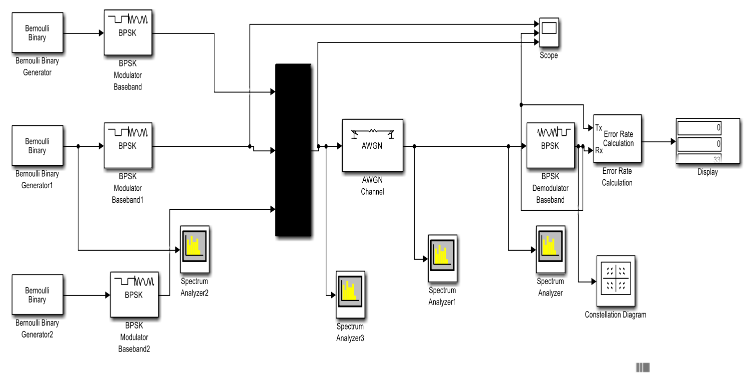

Figure 1: Co-channel interference Simulink Model without Digital Filter

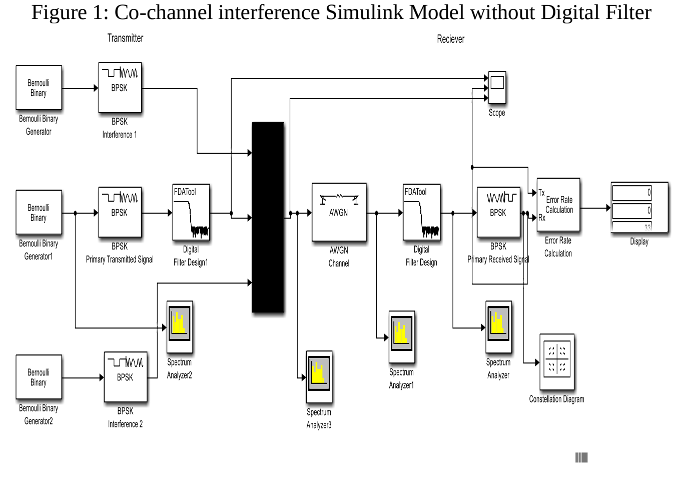

Figure 2: Co-channel Interference Simulink Model with Digital Filter

in the border cell It can be shown for a seven-cell cluster using an accurate cell geometry configuration that the mobile unit is precisely D from the two closest co-channel interfering cells and DR from the other six cells the two other co-channel cells and D+R from the other interfering cells in the first tier, The signal-to-interference ratio in the worst case can be approximated as [11]:

$$\frac{S}{I} = R^{a}/[2(D-R)^{-a} + 2D^{-a} + 2(D+R)^{-a} \quad (6)$$

If the co-channel reuse ratio Q is used, (6) may be rewritten as follows:

$$\frac{S}{I} = 1/[2Q-1)^{-a} + 2D^{-a} + 2(D+R)^{-a} \text{ s} \quad (7)$$

E. BER Analysis

The BER for a BPSK modulation without interference can be given as [12]:

$$p_b = Q\left(\sqrt{2\frac{E_b}{N_0}}\right) \quad (8)$$

Where the BER expression for a wide variety of interference conditions. It was also said that while thinking about BER along the channel, the scenario with just one co-channel interference is the most important to consider AWGN channel, the BER is given as [12]:

$$p_b = \frac{1}{2}Q\left((1+\propto)\sqrt{2\frac{E_b}{N_0}}\right) + \frac{1}{2}Q\left((1-\propto)\sqrt{2\frac{E_b}{N_0}}\right) \quad (9)$$

The BER upper limit was stated in terms of the bit weight enumerating function for convolutional codes. This is expressed as:

$$p_b < \sum_{d=d_{free}}^{\infty} B_d Q\left(\sqrt{\frac{2dRE_b}{N_0}}\right) \quad (10)$$

Where d_{free} is the unconstrained distance, B_d the coefficients for the non-zero information multiplied by d, and R the coding rate. Using the same approach to generate (9) and (10), we estimate an upper limit on the bit error rate (BER) for binary BPSK in the presence of co-channel interference, which is given as:

$$p_b < \sum_{d=d_{free}}^{\infty} B_d \left[\frac{1}{2}Q\left((1+\propto)\sqrt{\frac{2dRE_b}{N_0}}\right) + \frac{1}{2}Q\left((1-\propto)\sqrt{\frac{2dRE_b}{N_0}}\right)\right] \quad (11)$$

The input parameters of the Co-channel interference modulation are shown in Table 1.

TABLE 1:
THE INPUT PARAMETERS OF THE CO-CHANNEL INTERFERENCE MODULATION

S/NO	**Primary Transmitted Signal**	**Interference 1**	**Interference 2**
Probability of zero	[0.1 0.5]	[0.1 0.5]	[0.1 0.5]
Initial seed	[12345]	[12345]	[12345]
Sample time	1	1	1
Frame-Based output	10	10	10

For a significant change to be made in the co-channel interference, a filter must be introduced. However, in this research work, a low-pass filter was introduced to reduce co-channel interference. By blocking the presence of interference 1 and 2 as the co-channel to the primary transmitted signal in the region.

F. Evaluation of Co-Channel Noise Interference using FIR Low Pass Filter

Designing Windowed FIR Filters Given the ideal system's frequency response Hd(ej) and impulse response Hd[n], we want to approximate the infinitely long HD[n] with a finite sequence h[n], where h[n] = 0 except for 0 n M. This is done by using the Fourier transform, which transforms the frequency response into an impulse response. Consider an ideal low pass filter whose frequency response is finite and rectangular [13]. Possible criteria for approximation errors include:

$$E = \frac{1}{2\pi}\int_{-\pi}^{\pi} |H_d(e^{j\omega}) - (e^{j\omega}|^2 d\omega) \quad (12)$$

To minimize E, use Parseval's theorem:

$$E = \frac{1}{2\pi}\int_{-\pi}^{\pi} |H_d(e^{j\omega}) - (e^{j\omega}|^2 d\omega) \quad (13)$$

From [14], the error E is equal to the frequency response Hd (ejω). To minimize the error of the co channel noise interference, the impulse responds of the filter ideal system can be expressed in form of the Parseval's theorem considering the impulse response $h_d[n]$ and the with the finite sequence of the filter $h[n]$. And the minimized error of the system can be expressed as the summation of the of the impulse response minus the finite sequence of the filter plus the summation of the filter order of the squared impulse responds and finite sequence response of the filter, this equation is expressed as follows:

$$E = \sum_{n=-\infty}^{\infty} |h_d[n] - h[n]|^2 = \sum_{n=0}^{M} |h_d[n] - h[n]|^2 + \sum_{n=z[0,M]} |h_d[n] - h[n]|^2 \quad (14)$$

$$h[n] = \begin{cases} H_d[n] & 0 \le n \le M \\ 0 & otherwise \end{cases} \quad (15)$$

The truncation of the ideal impulse response is found by finding the FIR approximation that minimizes the mean square error. H[n] may be written as the product of the ideal impulse response with a rectangular window of limited time w[m]:

$$h[n] = h_d[n]\omega[n] \quad (16)$$

$$\omega[n] = \begin{cases} 1 & 0 \le n \le M \\ 0 & otherwise \end{cases} \quad (17)$$

$$H_{(e^{j\omega}) = \frac{1}{2\pi}\int_{-\pi}^{\pi} H_d(e^{j\theta}) W(e^{j(\omega-\theta)} d\theta} \quad (18)$$

The ideal impulse response is truncated, implying a convolution process. As the sine pulse W (ej()) approaches the optimal frequency response Hd(ej()), an estimate of its amplitude is produced. Transition bands form and ripples form on both sides when W (ej()) crosses the Hd(ej) discontinuity. The transition bandwidth 2 (2/ (M + 1)) is determined by the major lobe of the window frequency response. The primary lobe is the area that extends from the origin to the first zero crossings on each side. W (ej) should have as high a frequency concentration as feasible. Pass band and stop band ripples are modulated by the side lobes. The greater the region beneath the side lobes, the larger the waves. Ripples in the passband and the stopband are roughly equivalent across a broad frequency range [13].

II. RESULTS AND DISCUSSION

F. Co-Channel Interference Signal Characteristics

The primary transmitted signal as shown in the figure is said to be a co-channel to several signals within a specific region. This is because they share the same bandwidth, same frequencies, and same signal strength. They are all identical to each other, that's why they are co-channels. This characteristic makes these channels have interference due to channel overlapping. Overlapping of the signals implies that the same characteristics, same traits of the channels are being shared amongst the channels. By this definition, it will result in poor signal quality, noise, jamming, and attenuation as shown in Figure 3.

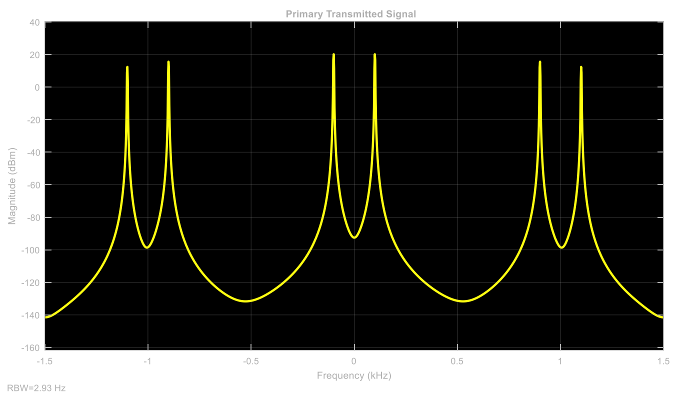

Figure 3: Primary Transmitted signal

G. Interfered Channels Vs Received Filtered Signal

The major issue most times in communication systems is multiple co-channeling communication systems in a particular region. This brings instability, poor signals, and noise due to interference. Haven knows that interference affects communication negatively by reducing signal quality and increasing noise to signal ratio. The interfered channels of the BPSK along the AWGN channel as seen in figure 4 has an interaction or interference due to the same bandwidths, same frequency, and same phases. This made them co-channels within that region. The signal is digital because the communication system is a digital system at different bits of 1 and 0's from the magnitude of the signal is shown alongside the oscillating time of the binary phase shift keying modulation techniques.

The filtered received signal of the BPSK shows a filtered digital signal of the primary transmitted signal, without interference. For the primary transmitted signal to be distinctive from its co-channels, a filter was employed to suppress the existence of the co-channels in the AWGN channel. By the employment of the filter in the co-channel transmission channel, the primary transmitted signal was received without interference as shown in figure 4.

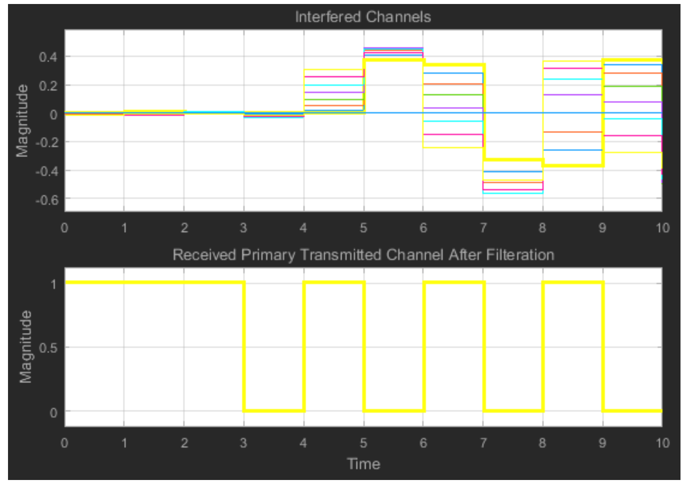

Figure 4: Interfered Channels

H. Low Pass Filter Response

The low pass filter function in this design is to block all forms of unwanted signals that want to cause the noise of interference from getting access to the receiver. The response of the filter is shown in figure 5.

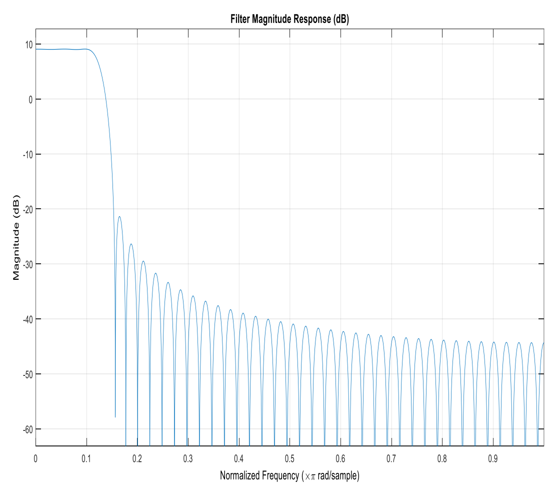

Figure 5: Low Pass Filter Response

I. Bit Error Rate of the Modulated Signal

For the primary transmitted signal, the result to be improved from the interference of the co-channel situations, then the bit error rate must be reduced, this will indicate that massive reception on the actual signal from the BPSK channel has been received without interference. And this also implies that as the unwanted co-channels have been filtered, disturbance and co-channel interference have been reduced. In the AWGN channel, BPSK has a low bit error rate (BER), and its low noise helps it achieve a high signal-to-noise ratio and high output quality as shown in Figure 6.

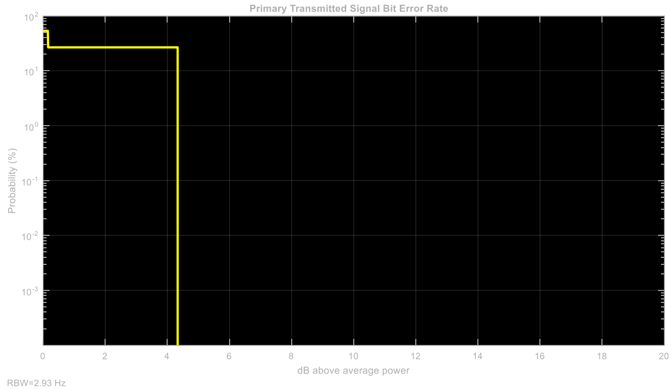

Figure 6: Bit error rates

J. Constellation of the Received Signal

A digital modulation system, such as phase shift keying, may be seen using a constellation diagram of the principal broadcast signal in a BPSK channel. This shows (Figure 7) the signal as a scatter diagram in the complex plane in two dimensions, between symbol sampling instants. The carrier wave's deviation from a reference phase is shown by the angle of a point measured anticlockwise from the horizontal axis. The BPSK has 4 constellations in its diagram illustrating that the amplitude or strength of a signal may be quantified by the distance of a point from the signal's theoretical center.

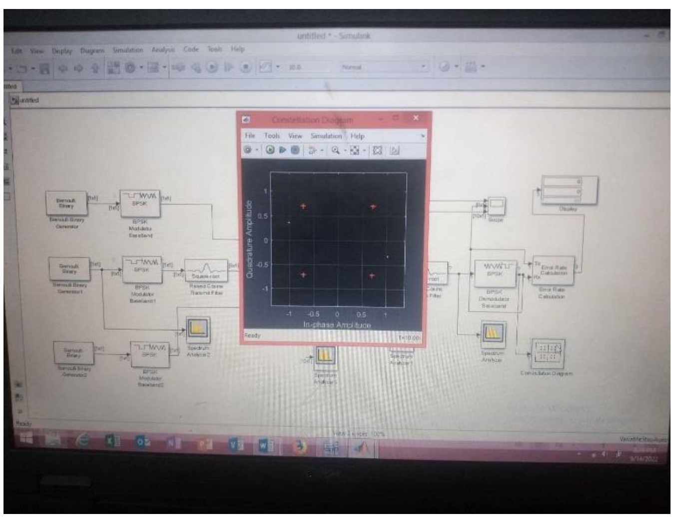

Figure 7: Constellation Diagram

K. Co-Channel Interference Noise

Co-channel interference is quite one of the most disturbing parts of communication systems. The problems majorly occur within the receivers of the communication systems. That is to say that as many channels share the same characteristics within a given location so the possibility for co-channel interference increases. The noise generated by the co-channel interference is shown in Figure 8.

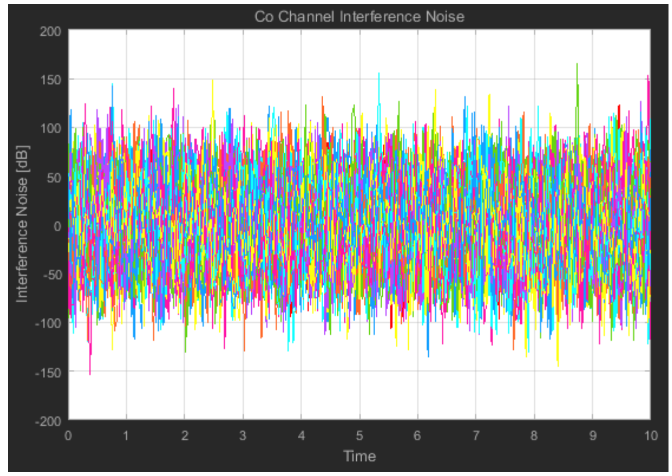

Figure 8: Co-channel interference noise

L. Reduced Interference Noise

By introducing a digital filter system, the noise in the interference system was reduced to 10 dB. From the noise interference, it can easily be compared how the noise was reduced to get a good signal from the primary transmitted signal. The filter was a low pass filter, that filters higher lever noises, so by this definition, the interference noise was reduced drastically as shown in Figure 9.

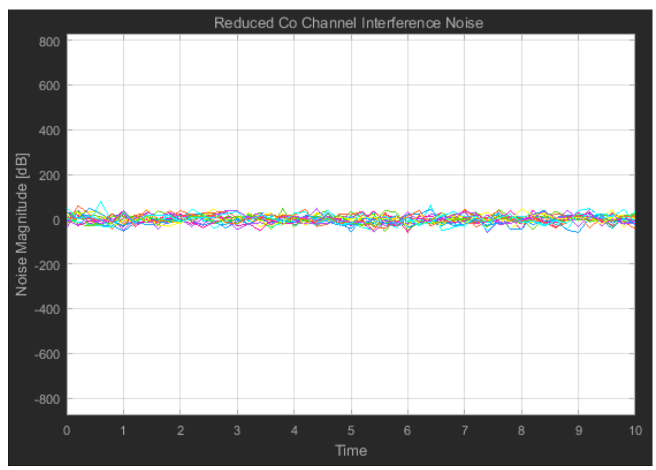

Figure 9: Reduced Interference Noise

III. Conclusion and Recommendations

The major challenge with co channel interference network is noise. Sometimes the degree of noise will also determine the strength of the signal loss due to co channel interference or the strength of signal gained. This research work determined the amount of noise in a co channel network and how it affects the co channel interference network. The following conclusions were drawn from the study:

The bit error rate of the BPSK Primary transmitted signal along the AWGN channel was also evaluated to ensure lesser losses along the channel. However, it was shown that the bit error rate of the system is low and has a high-performance system when compared to when the filter was not introduced.

To reduce the noise in the co channel interference network, the low pass digital filter was introduced in both the transmitter and receiver of the primary signal of the BPSK channel. This helps the BPSK receiver antenna when the desired signal is present. By so doing when multiple channels are being transmitted it sees other signals at high frequency then resists them hence allowing the primary transmitted signal to be received without any interference. The noise within the channels was also reduced drastically.

In this research work, three different channels were designed using MATLAB Simulink to illustrate the behavior of the co channel interference system. The system illustrates the how different channels interfere with each other based on the sharing of same signal characteristics. BPSK modulators were introduced to observe the performance of the multi co channels.

In this research work, noise in the channel has been reduced and interference has also been reduced by the introduction of a digital low-pass filter. Haven designed and illustrated the co-channel systems using the BPSK and AWGN channels respectively a higher recommendation should also be made in the following areas:

i. Continuous noise reduction in the receiver of the channel
ii. Advance means of co-channelling separations
iii. Improvement of bit error rates.

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