Interference Mitigation In 5G Network Using Frequency Planning And Artificial Neural Network (ANN)

Regina Aniebiet Udoh[1]
Department of Electrical and Electronic Engineering,
Akwa Ibom State University, Ikot Akpaden, Mkpat Enin,
Akwa Ibom State, Nigeria
reginaaniebiet@gamail.com

Ubong S. Ukomm[2]
Department of Electrical and Electronic Engineering,
Akwa Ibom State University, Ikot Akpaden, Mkpat Enin,
Akwa Ibom State, Nigeria.
uukommi@yahoo.com

Emmanuel A. Ubom[3]
Department of Electrical and Electronic Engineering,
Akwa Ibom State University, Ikot Akpaden, Mkpat Enin,
Akwa Ibom State, Nigeria.
emmanuelubom@aksu.edu.ng

***Abstract*— In this work, interference mitigation in 5G network using frequency planning and Artificial Neural Network (ANN) is presented. Specifically, the co-channel and adjacent channel interference are considered. The study utilized SIMULINK to model the clean signal without interference as well as the signal with the co-channel and adjacent channel interference. Furthermore, the interference mitigation techniques are modelled with the SIMULINK and the level of channel interference mitigation using each of the two techniques are determined. The results show that the level of channel interference mitigation with the frequency planning technique is 21.69 %, while that of the ANN is 23.89 %.. In all, the results show that the ANN technique has better level of channel interference mitigation than the frequency planning technique. In addition, the interference with ANN in place would take a higher length of time to re-occur when compared to that of the frequency planning technique.**

Keywords*— *Interference, 5G Network, Frequency Planning, Interference Mitigation, Artificial Neural Network

1. INTRODUCTION

In recent times, communications systems have become the drivers of our economic, social, health and political developments [1,2]. A lot now depends on it, starting from long distance instant voice communication, real time messaging, social media collaboration, news broadcasting, and online shopping to financial transactions are now supported on cellular network platforms making life simpler but dependent on mobile networks as more Apps are being developed and multiple operating cellular networks must coexist in order to support the services [3,4]. These coexistence demands has imposed a lot of pressure on cellular networks systems amongst which is the issues of co-channel and adjacent channel interference which results in increased signal latency, dropped calls, slow data throughput and decrease in coverage capacity [5,6,7,8]. This work therefore aims to analyse methods used by digital cellular networks in combatting the menace caused by channel interference.

Moreover, the introduction of 5G network entails an improved signal utilization and implementation for the communication industries but the constant rise in demand has led to the rise in channel and signal interference [9,10,11]. Therefore, the main essence of this study is to study interference mitigation in 5G network using frequency planning and artificial neural network (ANN) techniques. The channel interference studied includes co-channel interference and adjacent channel interference [12,13].

The 5G signal without interference is modelled in SIMULINK then the co-channel and adjacent channel interferences are separately developed and added to the clean channel signal. The outcome of the effect of the interference is presented with the two channel interference mitigation techniques implemented in this work, namely, Frequency Reuse planning technique and Artificial Neural

Network technique. The performance of the two techniques are compared based on the numerical value of the level of channel interference mitigation using the ANN and the frequency planning techniques.

2. METHODOLOGY

2.1 Signals Modelling in SIMULINK

In this study, first a 5G clean signal input signal generator is modeled, as shown in Equation 1 [14] and then fed into the wireless network channel with and without the existence of a noise (interference) signal. This is used to evaluate the performance of the selected interference mitigation techniques that are considered in this study.

$$NR_{5G} = 10^{-6.5} \times \sum_{i=1}^{n} \left(V \times Q_m \times F \times R_{ma} \times \left(\frac{12N}{T}\right) \times (1 - HO)\right) \quad (1)$$

Where NR_{5G} is used to indicate the 5G clean signal, R_{ma} is used to indicate the maximum number of layers value which are input to the model and V has value range of 1 to R_{ma}, Q_m is used to indicate the maximum value for the modulation order, F is used to indicate the scaling factor which according to [15] must have any of the following values 1 or 0.8 or 0.75 or 0.4 . Notably in this study, F = 1 is adopted because it gives cleaner 5G signal output [16], T is used to indicate the value of the orthogonal frequency division multiplexing (OFDM) which the value of $10^{-3}/28$ is adopted in this study, N is used to indicate the radio block (RB) of the signal and HO is used to indicate the overhead and the frequency range of FR2 to DL (0.18) is adopted in this study.

The same signal model for the sent 5G signal (as shown in Equation 1) applies to the received 5G signal model except that the 5G data rate at the receiver end is given by Equation 2 [33].

$$DR = NR_{5G} \times DL \quad (2)$$

Where DR is used to indicate the data in the signal receiver, DL is used to indicate the bits in fraction of the sent 5G signal.

The SIMULINK model showing the wanted signal with the co-channel signal interference as well as the adjacent channel interference mixed together is presented in Figure 1. Two different interference mitigation techniques are considered in this study for addressing the challenges of interference signals in the system, The two techniques include frequency planning and Artificial Neural Network (ANN).

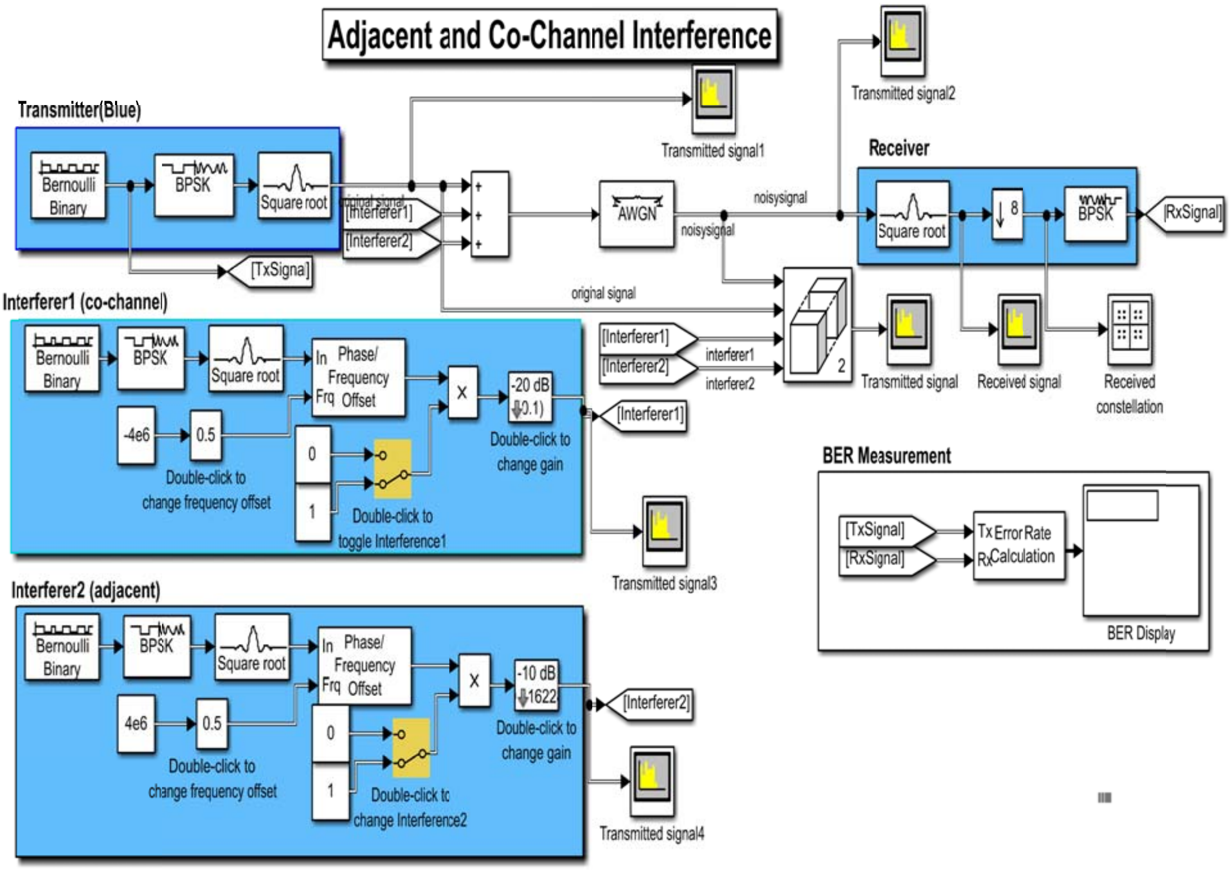

Figure 1: The SIMULINK model showing the wantedsignal with the co-channel signal interference as well as the adjacent channel interference mixed together

2.2. Frequency planning or frequency reuse interference mitigation technique

The frequency model used in the frequency planning or frequency reuse technique is as shown in Equation 3.

$$N = i^2 + j^2 + ij \quad (3)$$

Where N represents the number of channels, i and j represent integers that are required for the tuning of the model in equation 3.2.

The essence of adjusting i and j parameters was to improve the number of available channels as the higher the number of channels, the higher the prevention of interferences. Therefore, it became essential that during the frequency planning modeling, the channel of used cell to be re-used must be apt so as to ensure high amount of channel interference mitigation process. The systematic process of selecting and allocating the frequency sub-band for the cellular base station in a system way is known as frequency planning or frequency re-use. This is necessary because the spectrum allocated for cellular transmission is limited and at the same time and the demand is ever increasing. Increase in demand increases the frequency interference as guard bands are no more feasible and transmit to receive frequency separation (Tx-Rx) are now very narrow. Hence to ensure proper bandwidth allocation process, a frequency response estimator block (discrete transfer estimator block) was inserted in the channel interference SIMULINK model to estimate the frequency-domain transfer function and buffer the input data into overlapping segments. The model block is as shown in Figure 2.

Figure 2: Frequency Estimator Block

Ensuring that the frequency band allocation in the network is maintained mitigates signal interference and can be measured with the SIMULINK block model shown in Figure 3.9.

2.3 Artificial Neural Network (ANN) interference mitigation technique

Artificial neural network interference mitigation technique was deployed in mitigating the effect of the interference on the clean signal. The ANN architecture displayed in achieving this outcome is shown in Figure 3.

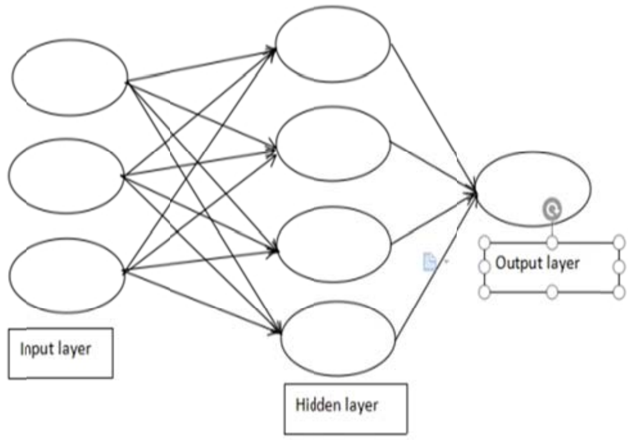

Figure 3: The architecture of the Artificial Neural Network (ANN) interference mitigation technique

The input layer in Figure 3 has three input neurons (namely: the clean signal, the co-channel interference and the adjacent interference) the clean signal was the target (which was why it was the output). The ANN model was around four hidden neurons with each neuron having a log sigmoid model. The output layer has one output neuron which was the clean signal. Hence, ANN main function was to reduce the effect of the signal interference.

The mitigation procedures adopted in this study was implemented in MatLab 2015a. The flow diagram of the process of modeling signal interference reduction using the ANN interference mitigation is as shown in Figure4.

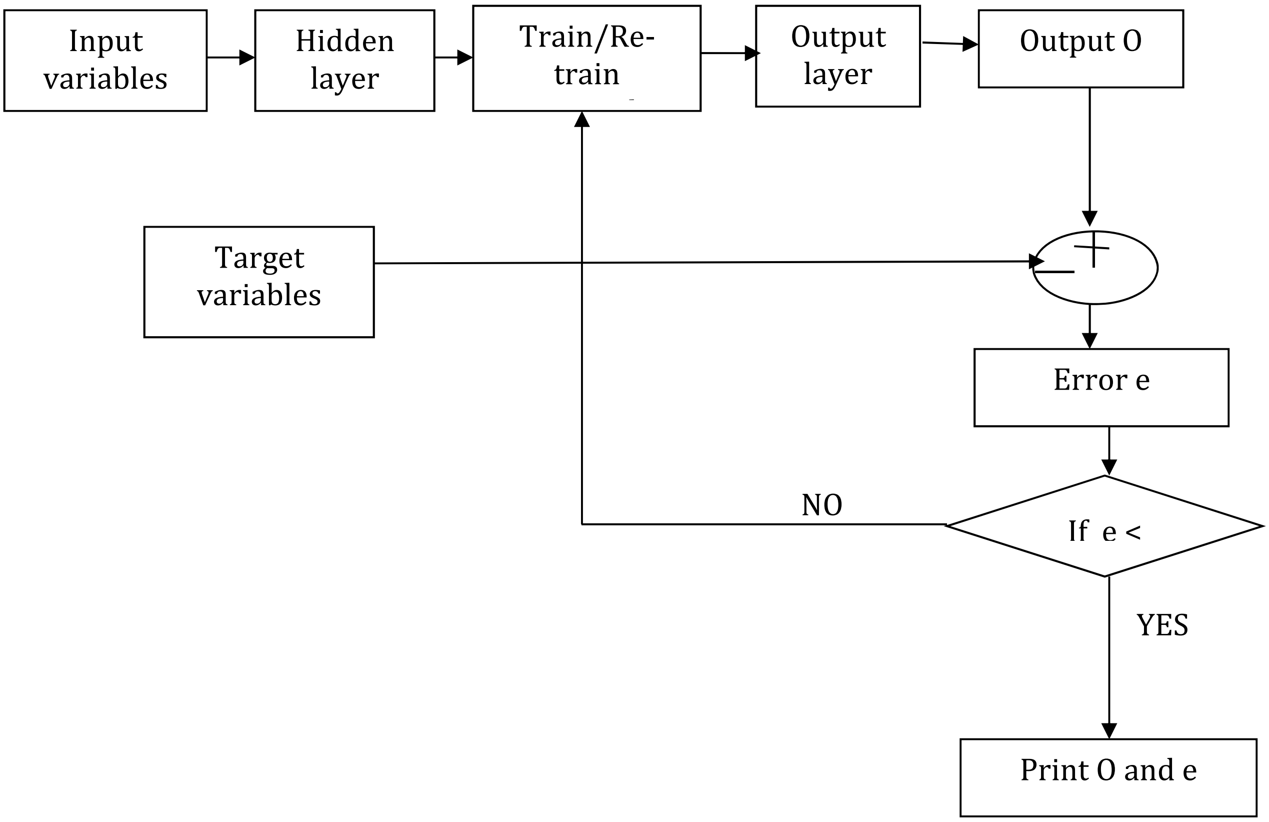

Figure 4: ANN modeling flow diagram for interference mitigation

In Figure 4, the input signal variables were sent to the hidden layer, the output layer was where the network model was trained and output variable generated. The output which was the signal with mitigated interference was compared to the target variable and error values were obtained and the set error value was $1.0x10^{-4}$. When the signal error was less than the set error value, the system was re-trained until the condition was met.

3. RESULTS AND DISCUSSION

3.1 The results of the interference mitigation using Frequency Planning and Re-use

A frequency planning interference mitigation model simulator block was inserted in the SIMULINK model to ensure that the channel signal interference was reduced by well estimated frequency estimation and segmentation. The result obtained from the frequency planning interference mitigation is shown in Figure 5.

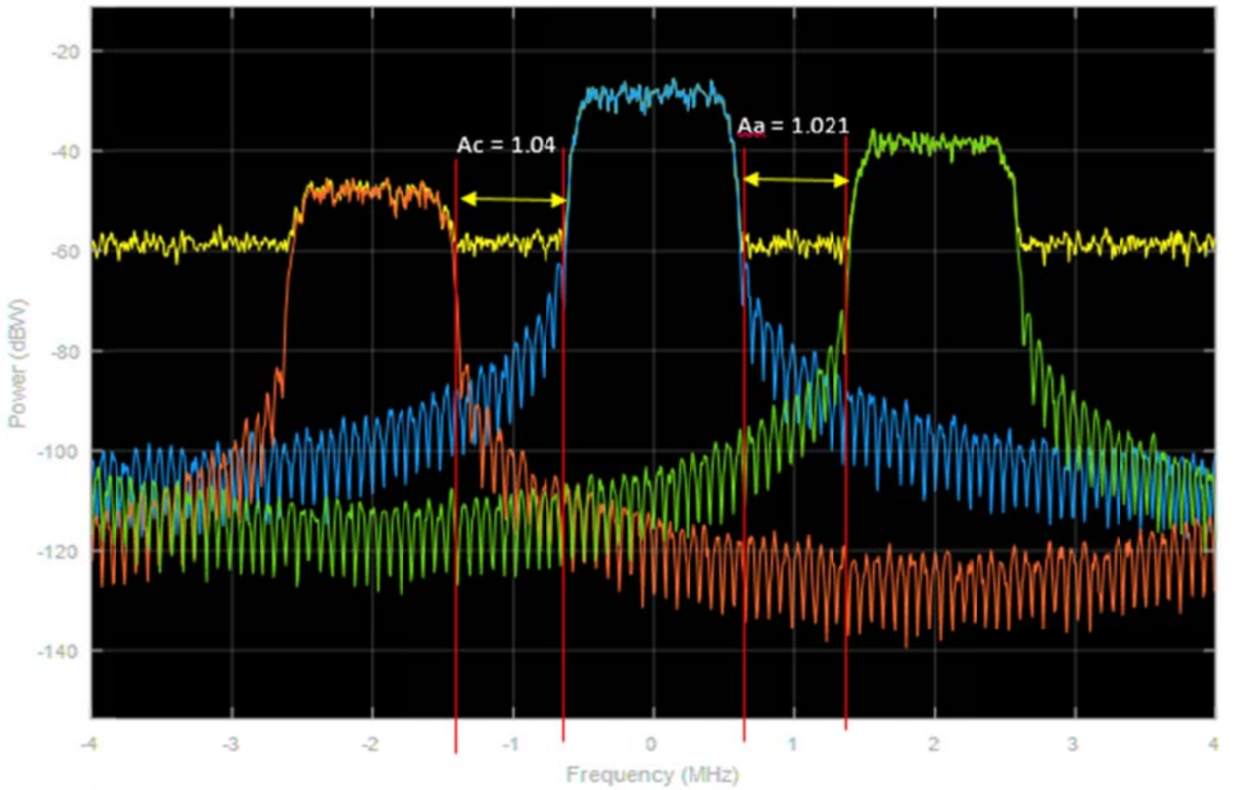

Figure 5: Effect of Frequency Re-use on Interference Reduction

Notably, according to the results shown in the graph of Figure 5 for the frequency re-use interference mitigation, the level of channel interference mitigation, CIL on the clean signal is obtained from Equation 4 as 21.69 %, where A_T = 9.5.

$$CIL = \frac{A_c + A_a}{A_T} \times 100\% \quad (4)$$

Hence, for A_T = 9, A_C = 9. = 1.04 and A_a= 1.021

$$CIL = \frac{1.04 + 1.021}{9.5} \times 100\% = 21.69\ \%$$

Furthermore, the simulation outcome shows that the interference reduces at an instant when the same number of users was maintained but increases (slowly) as the number of users increases. Hence, it is recommended that bandwidths should be created (once the frequency bandwidths are used up after planning) and frequency planning should also be done so as to reduce the amount of bandwidth required because the absence of proper frequency planning leads to wrong introduction of channels which increases channel interference.

3.2 The results of the interference mitigation using Artificial Neural Networks

In the ANN model implemented, the clean signal devoid of interference was used as the target while the signal with the interference was the input to the model. The result obtained from the interference reduction with ANN is shown in Figure 6.

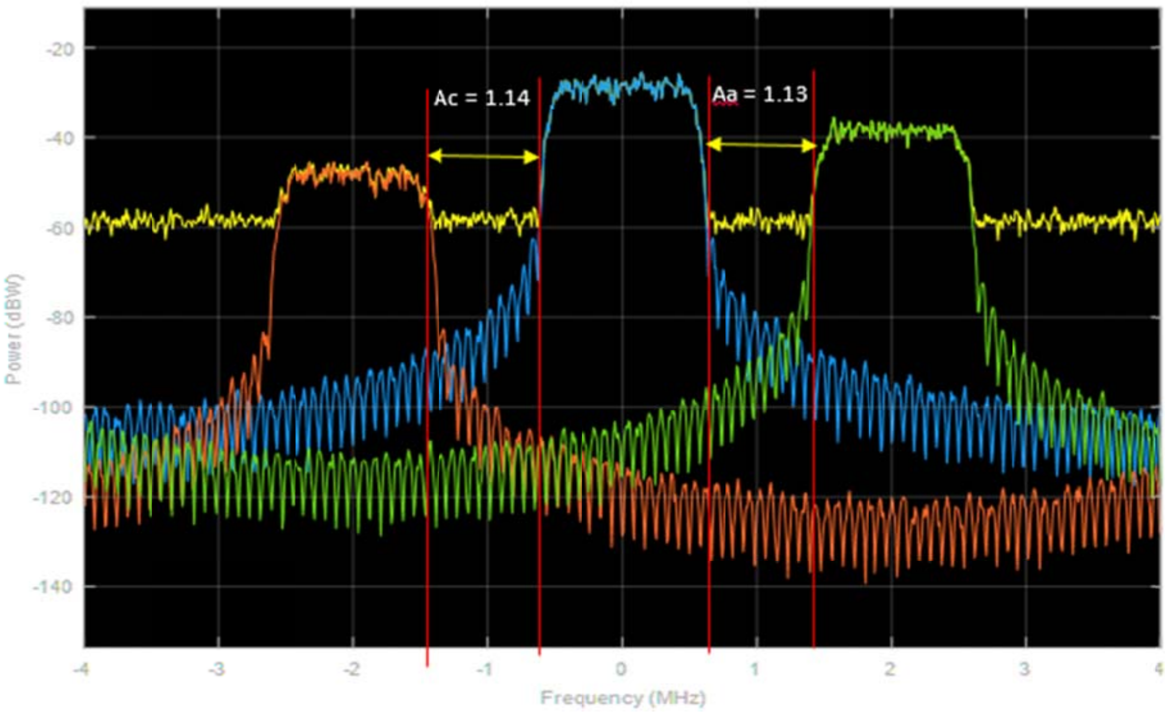

Figure 6: Signal Interference Reduction with ANN

Again, according to the results shown in the graph of Figure 6 for the ANN-based interference mitigation, the level of channel interference mitigation, ClL on the clean signal is obtained from Equation 4 as 23.89 %, where A_T = 9.5, A_C = 9. = 1.04 and A_a= 1.021.

$$CIL = \frac{1.04 + 1.021}{9.5} \times 100\% = 23.89\ \%$$

Using a signal without interference as a target showed a good improvement when the ANN model was implemented on the clean signal with interference. However, the issue is as the demand increases, interference increases which would occur when the demand would be high. The interference would take a higher length of time to re-occur when compared to that of the other technique. In all, the ANN technique has better level of channel interference mitigation as shown in Table 1.

Table 1: Comparison of the level of channel interference mitigation using ANN and frequency planning techniques.

S/N	CHANNEL INTERFERENCE MITIGATION TECHNIQUES	AC	AA	AT	MITIGATION LEVEL (%)
1	Frequency planning	1.04	1.021	9.5	21.69
2	ANN	1.14	1.13	9.5	23.89

4. CONCLUSION

This work presented two interference mitigation techniques in 5G network. The two techniques are frequency planning and Artificial Neural Network (ANN). Specifically, the co-channel and adjacent channel interference are considered. The study utilized SIMULINK to model the clean signal without interference as well as the signal with the co-channel and adjacent channel interference. Furthermore, the interference mitigation techniques are modelled with the SIMULINK and the level of channel interference mitigation using each of the two techniques are determined. In all, the results show that the ANN technique has better level of channel interference mitigation than the frequency planning technique.

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