Evaluation Of Modified Artificial Neural Network-Based Interference Mitigation In 5G Network

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***Abstract*— In this work, evaluation of modified Artificial Neural Network-based interference mitigation in 5G network is presented. The primary essence of this study is to implement and evaluate a Modified Artificial Neural Network (M-ANN) means of mitigating co-channel and adjacent channel interference in 5G networks. To achieve this, the model of the desired signal was done in SIMULINK, followed by the implementation of the interferences (both co-channel and adjacent channel interference) models. Then, the M-ANN method of interference reduction was introduced to the model to view the interference improvement performance based on the bit error rate (BER) performance. The performance of the M-ANN interference mitigation is then compared with those of intermodulation technique and the Artificial Neural Networks (ANN) technique. The results showed that the modified ANN had the highest signal interference mitigation reduction impact of 36.74% followed by the intermodulation technique with a value of 28.63% and then the Artificial Neural Networks (ANN) technique with a value of 23.89%. In all, the M-ANN technique was the most effective in minimizing the level of impact of the channel interference on the clean 5G signal. This simply implies that the pattern of M-ANN technique should be utilized in the signal interference minimization process in 5G networks.**

Keywords— Adjacent Channel Interference, Modified Artificial Neural Network, Interference Mitigation, 5G Network, Co-Channel Interference

1. INTRODUCTION

Over the years, the telecommunications industry has grown increasingly important to socioeconomic and technological development of any nation [1,2,3]. It has been a major driver in the rapid growth of Nigeria's information technology, music, film, arts and entertainment, and financial services sectors which employ approximately 53% of the country's workforce [4,5]. Such growth of, and contributions by, the Nigerian telecommunications industry has been facilitated by the increased access to telecommunications services by the citizens and residents, following the introduction of General System for Mobile (GSM) services in 2001 [6,7]. Eleven years later, telecommunications services have become ubiquitous in Nigeria, with an internet subscriber base of 154.3 million [8], and a telephone subscriber base of 195.4 million [9], as at December 2021. The majority of these subscribers access the telecommunications services using mobile telephones connected to cellular networks.

A cellular network is a wireless telecommunications network that is distributed over land areas called cells, each of which is served by at least one fixed-location transceiver known as the cell site or base station [10]. As each base station covers a limited land area, lower power transceivers may be used. Cells are typically equilateral triangular, square or hexagonal, since circular shapes would result either in interleaving gaps or greater cell intersection [11]. Concatenation of multiple such cells provides network coverage over a wide geographical area. Also, with each cell using a different set of frequencies from its neighbouring cells in order to avoid interference and improve service quality within the cell, it is possible to reuse the same frequency a few cells away, thereby enabling the coverage of a large area with a limited set of frequencies.

Although frequency reuse within the cellular network provides for more efficient use of the limited radio frequency spectrum, it sometimes leads to co-channel and adjacent channel interference issues. Co-channel interference occurs when two or more coinciding signals are of the same frequency, resulting in cross-talk [12], while adjacent channel interference occurs when the information on a coinciding adjacent signal of close centre frequency seeps into the pass band of the signal being transmitted, thereby degrading the channel performance [13,14]. Such interference issues typically not only limit the extent to which the available frequencies can be reused, but also ultimately have negative impact on quality of service, as well as increasing the complexity, and perhaps also the cost, of network equipment. Accordingly, the the aim of this work is to carry out details analysis of co-channel and adjacent channel interference mitigation in 5g network based on modified artificial neural network (M-ANN) approach. The performance of the M-ANN interference mitigation is then compared with those of intermodulation technique and the Artificial Neural Networks (ANN) technique.

2. METHOD

The primary essence of this study is to implement and evaluate a Modified Artificial Neural Network (M-ANN) means of mitigating co-channel and adjacent channel interference in 5G networks. This study was carried out in SIMULINK/MATLAB environment. To achieve this, the model of the desired signal was done in SIMULINK, followed by the implementation of the interferences (both co-channel and adjacent channel interference). The M-ANN method of interference reduction was introduced to the model to view the interference improvement performance based on the bit error rate (BER) performance. Also, similar simulated experiments were conducted comparative evaluation with two other interference mitigation techniques, namely, the intermodulation technique and the Artificial Neural Networks (ANN) technique. The summary of the research procedure is presented in the steps shown in Figure 1.

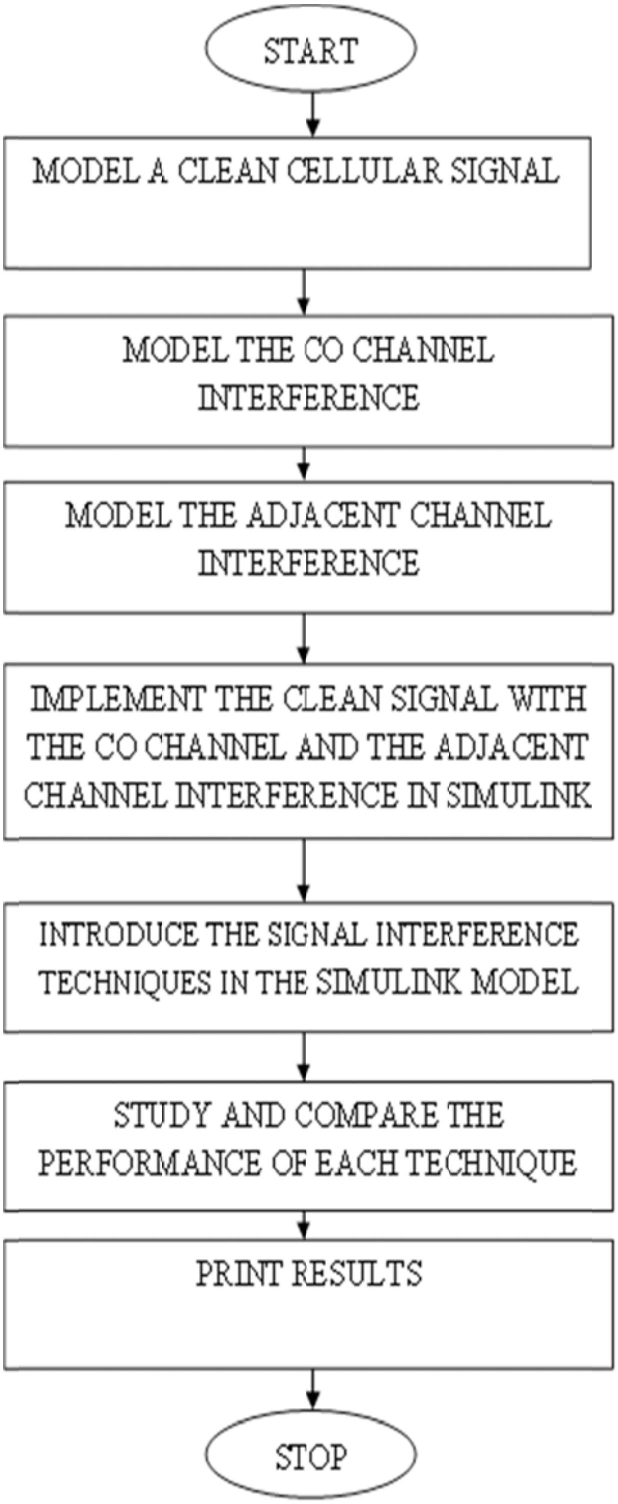


Figure 1: Flow diagram for the research process

2.1 The SIMULINK model for the clean signal, the co-channel interference signal and the adjacent channel interference signal

The SIMULINK model for the clean signal, the co-channel interference signal and the adjacent channel interference signal are presented in Figure 2, Figure 3 and Figure 3 respectively.

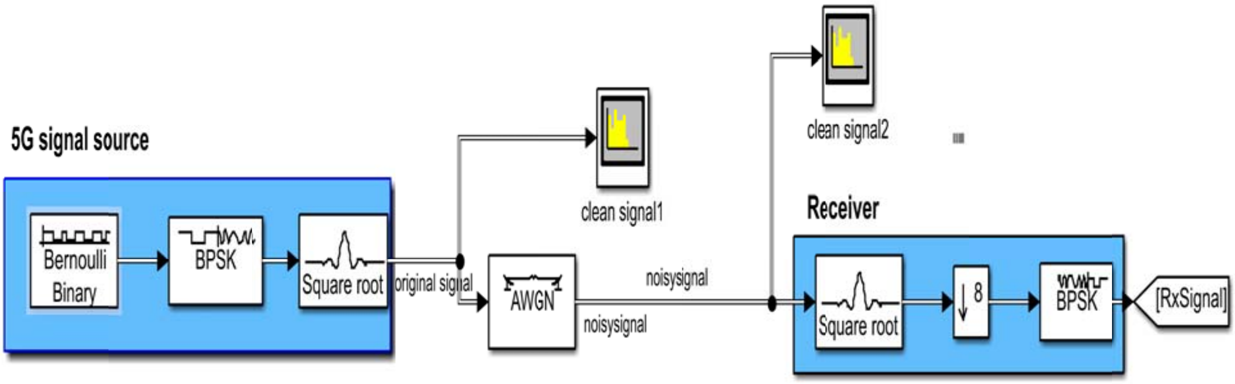


Figure 2: The SIMULINK Model used to characterize the Clean Signal

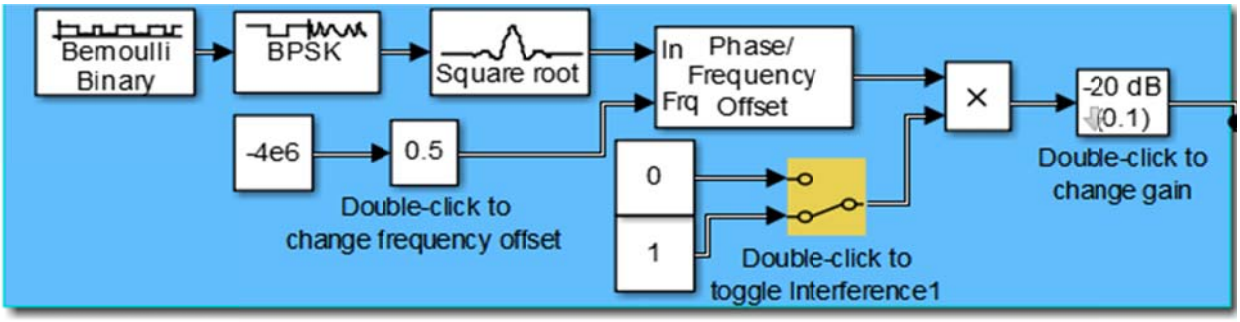


Figure 3: The SIMULINK Model used to characterize the co-channel interference signal

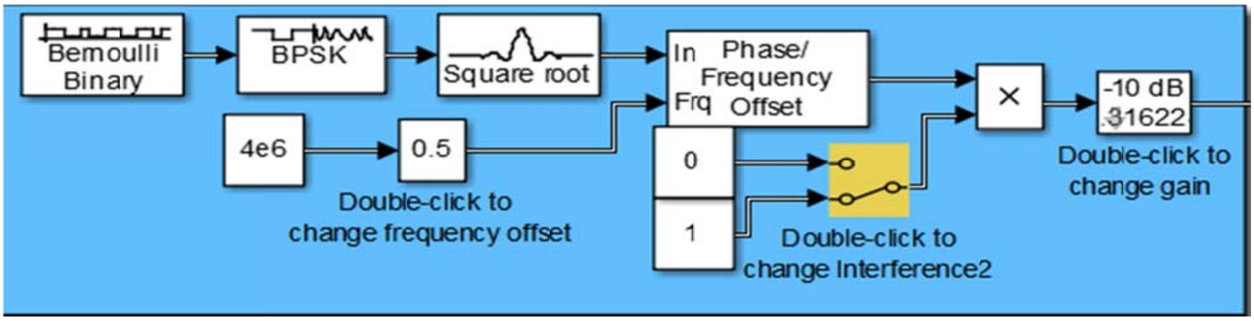


Figure 4: The SIMULINK Model used to characterize the Adjacent Interference Signal

2.2 The Modified Artificial Neural Network (M-ANN) model for interference mitigation

The ANN model in Figure 5 is modified by the introduction of fuzzy logic model. The flow diagram of the Modified Artificial Neural Network (M-ANN) model is shown in Figure 6.

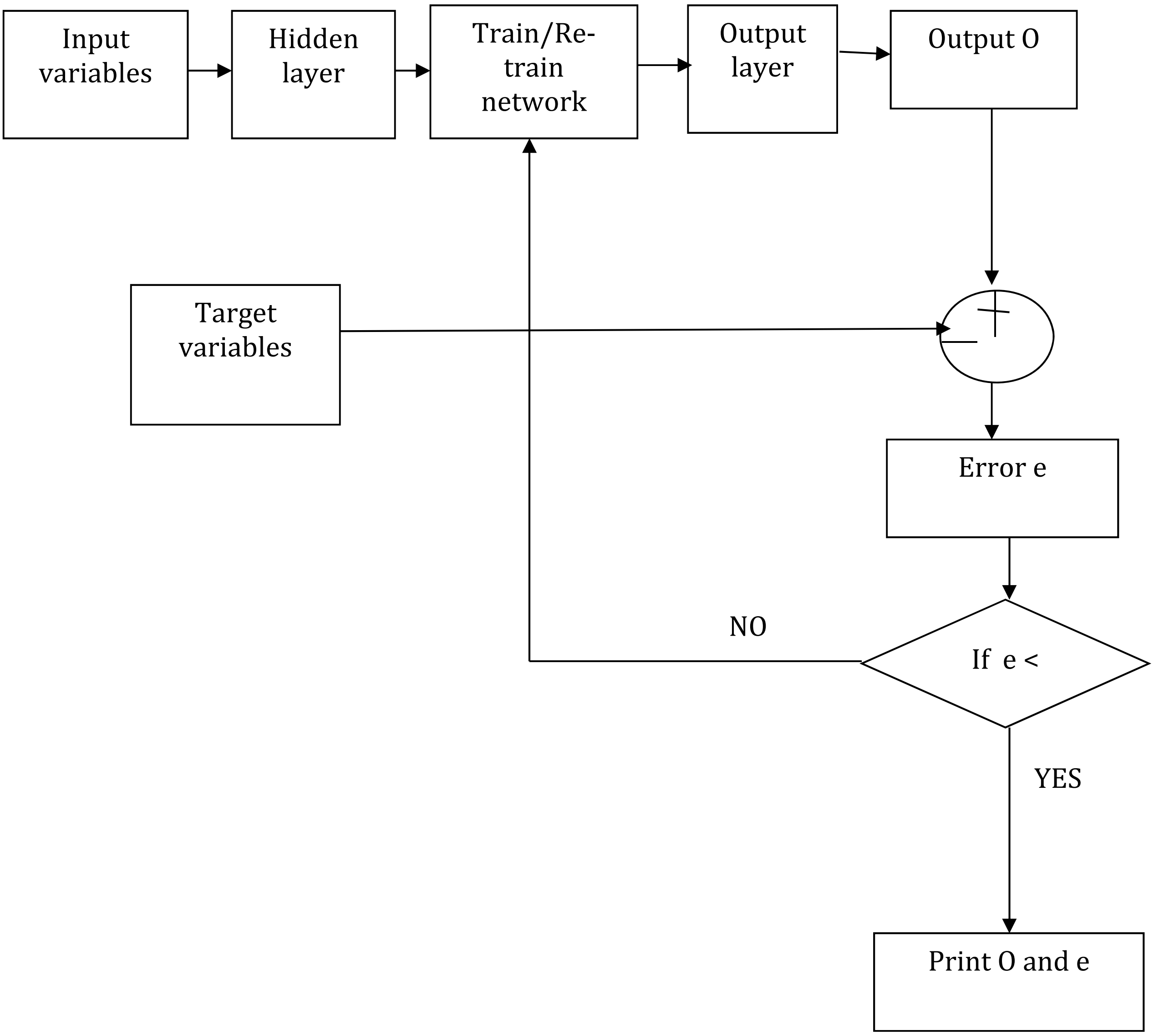


Figure 5: ANN modeling flow diagram for interference mitigation

The type of membership function utilized for the input variable is triangular member function (three membership functions for each input variable) and linear membership function was used for the output variable (27 membership functions). Hence the input layer had nine input neurons (3 input variables multiplied by three membership function for each input variable) while the hidden layer had 27 neurons which represented 27 inference rules, output layer had 27 neurons and output variable was one.

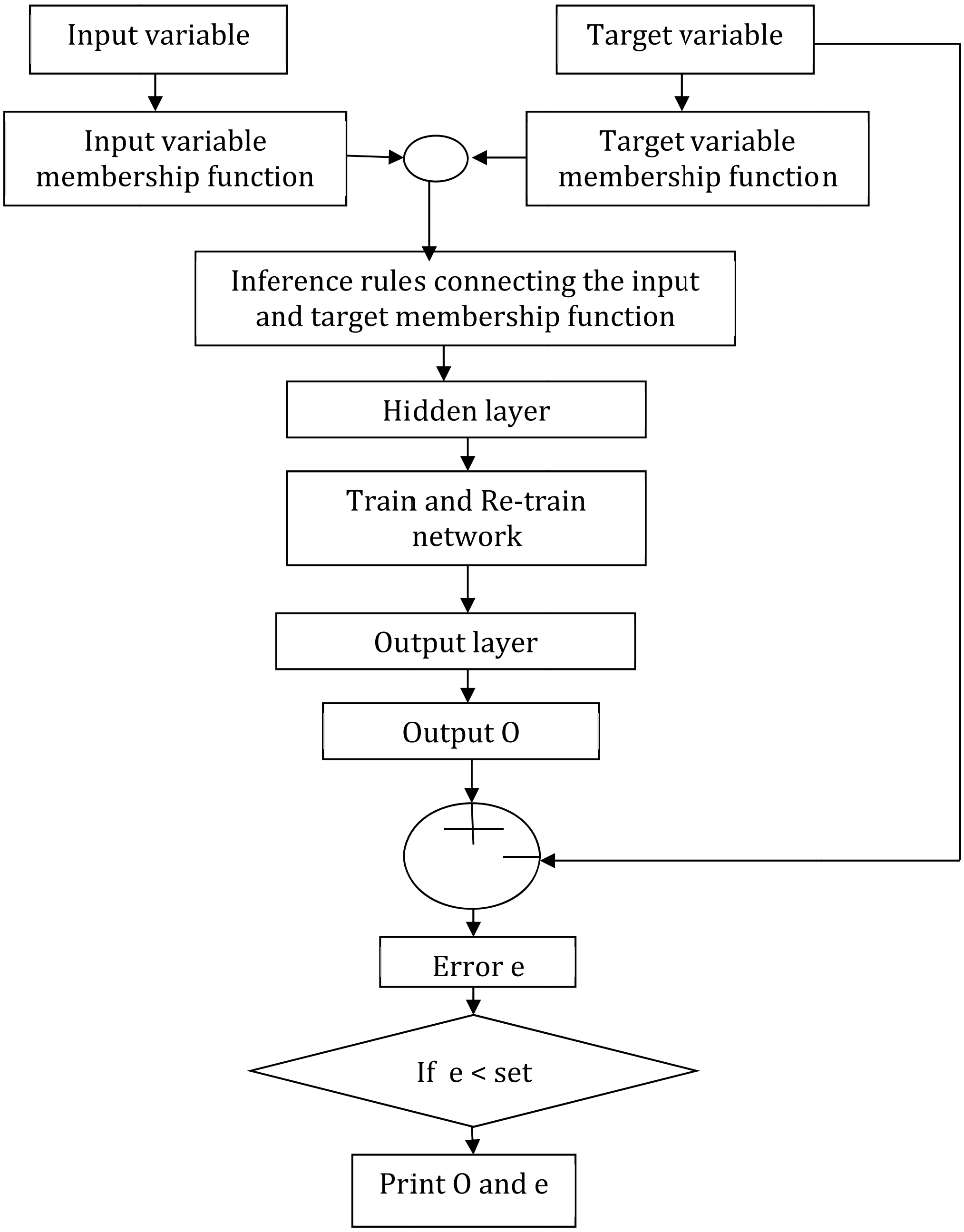


Figure 6: Flow diagram for the Modified Artificial Neural Network (M-ANN) model

2.3 The Intermodulation technique for interference mitigation

In the intermodulation technique, the parameters of normal signal (5G signal), the co-channel interference signal and the adjacent channel interference signal were interchanged with changes in mathematical operations (mainly addition and subtraction) and the best 12 combinations of the operations were selected. These intermodulation variations were modelled in the Simulink model shown in Figure 7.

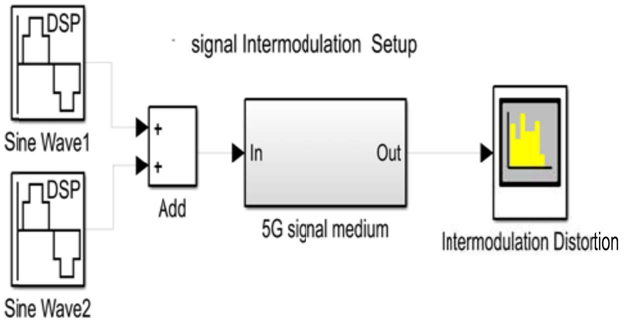


Figure 7: Signal Inter-modulation Setup

In the Simulink model of the inter modulation of the signal shown in Figure 7, the add block represented the mathematical operation utilized for the intermodulation variation. The transmission and interference that occur in the signals is highly non-linear (the source devices of the sender and the receiver devices are made of active non-linear components) as such the devices generate intermodulation distortion effects as the signals propagates through them. Although there are many factors that leads to inter-modulation distortion, such as; the use of nonlinear devices (diodes and amplifiers in transmitters and receivers), operating devices in non-linear range, using poor devices and low quality circuit components and not shielding transmitters. In this study, only the reduction of non-linearity range in signal transmission was implemented as the characterization of the other causes could be very random in nature.

2.4 Determination of the level of channel interferences on the clean signal

The sample plot of the signal interference is shown in Figure 8. The model for the determination of level of channel interferences on the clean signal was shown in equation 1.

$$CI = \frac{A_c + A_a}{A_T} \times 100\% \qquad (1)$$

Where A_c and A_a represents the distance line of the interferences and the clean signals and A_T represents the total signal occupied by the clean and the channel interferences. The addition of the channel distances and division with the total distance covered by the signal lengths gives the level of impact of the interference on the clean signal.

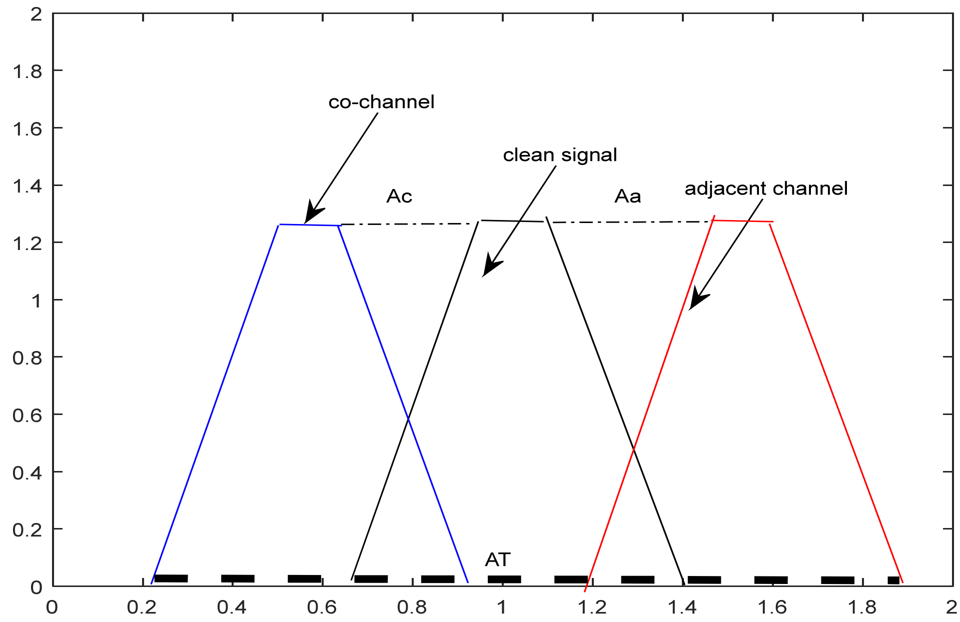


Figure 8; Schematic plot of signal interferences on the clean signal

3. RESULT AND DISCUSSION

3.1 Inter-Modulation Distortion

The effect of inter modulation is common. Majority of the transmitter, analyzer and receiver electronic components are non-linear, leading to significant interference effects caused by the generation of the harmonics and sums and differences signals especially as increase in wireless services demand and cellular activities increases the interfered signals in a network. Inter-modulation abnormally is shown in Figure 9.

The distortion rate presented in Figure 9 was high leading to its significant effect on signal interference. The frequencies determined for the distortions were shown in Figure 10.

The higher the frequency of the inter-modulation distortion, the higher the channel signal interference. The higher the presence of non-linear devices cumulates to increases in the signal inter-modulation (as shown in the frequency values of the distorted peak in the left side of Figure 10). Hence, the effect of inter modulation reduction on signal interference was considered.

3.2 results for the Inter-modulation interference mitigation technique

The inter-modulation technique applied was the reduction of non-linear devices (diodes, transistors and so on) used in the design of the receiver, transmitter and analyzer and other communication devices of the communication channel equipment. The effect was as shown in Figure 11.

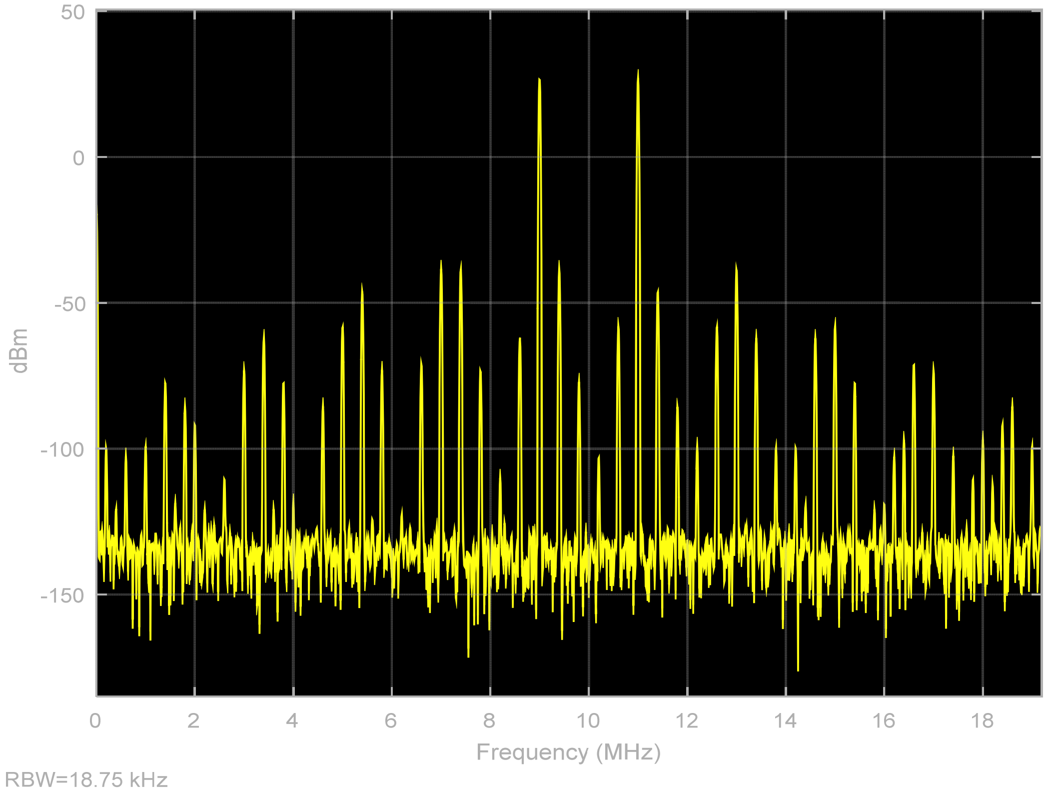
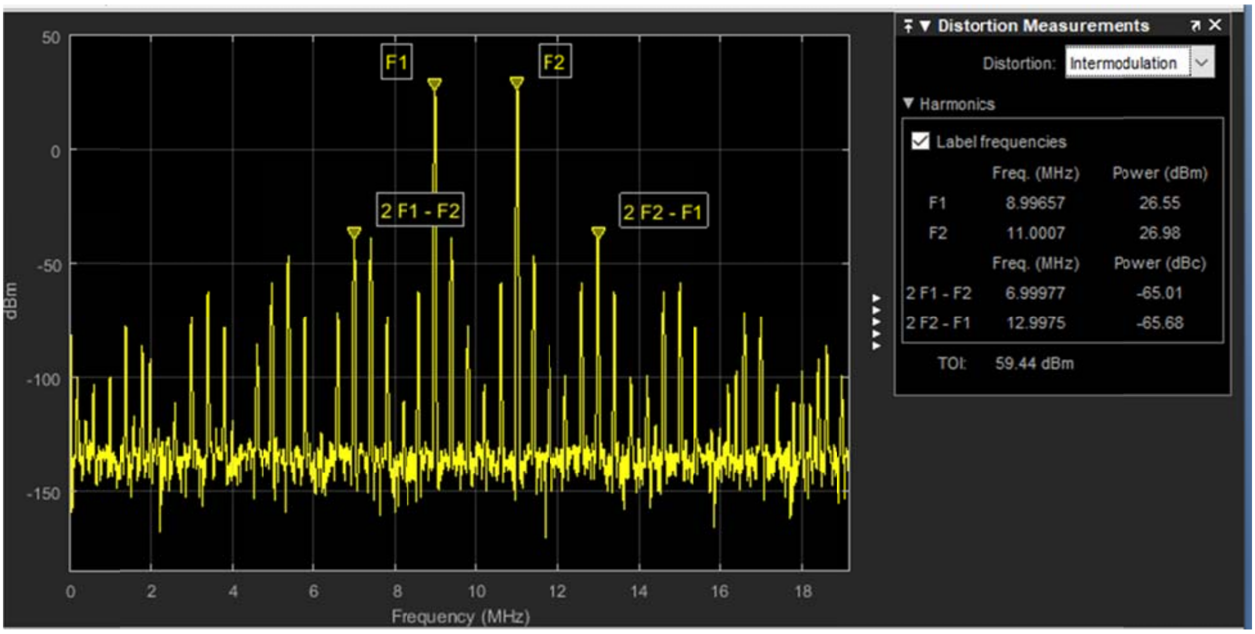


Figure 9: Inter-modulation Distortion of the Generated Signal



Distortion: Intermodulation

☑ Label frequencies

	Freq. (MHz)	Power (dBm)
F1	8.99657	26.55
F2	11.0007	26.98
	Freq. (MHz)	Power (dBc)
2 F1 - F2	6.99977	-65.01
2 F2 - F1	12.9975	-65.68

TOI: 59.44 dBm

Figure 10: Frequencies of the Intermodulation Distortion Effect

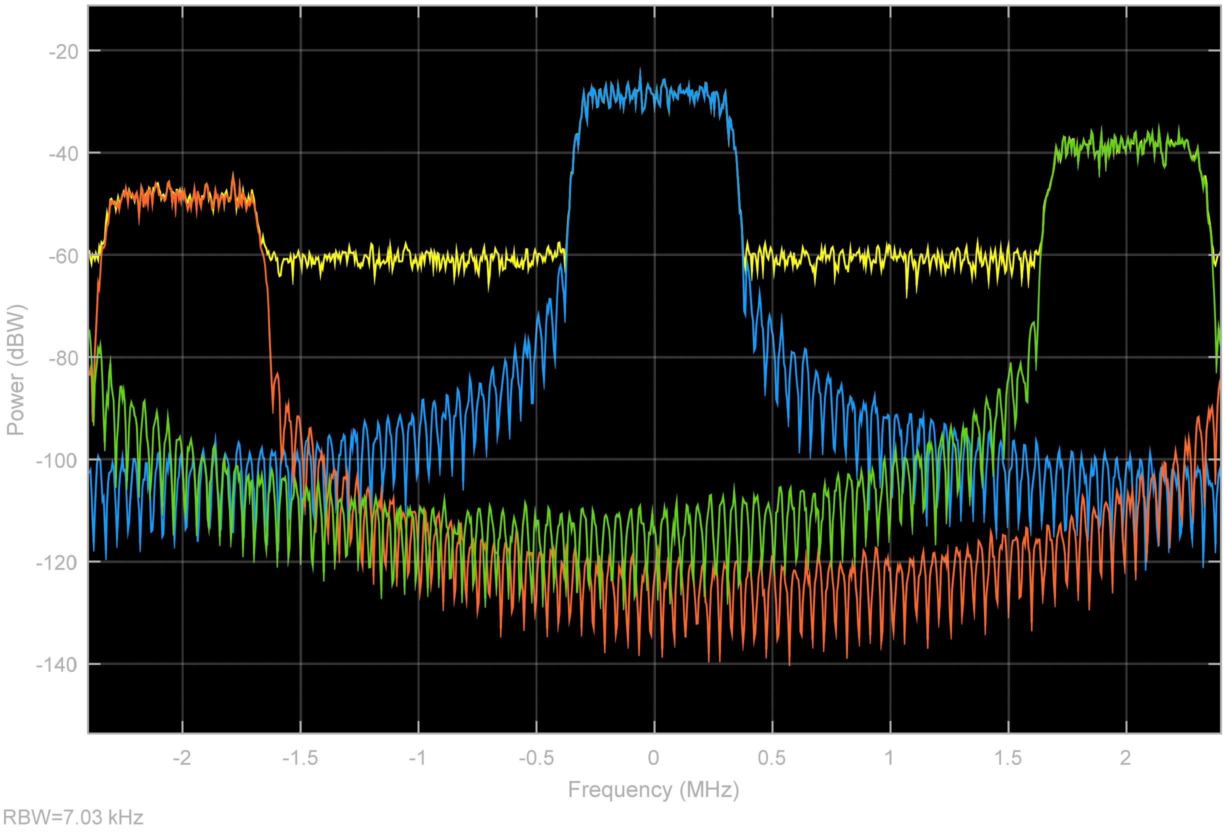


Figure 11: Implementation of the solution of Intermodulation

When the intermodulation peaks were reduced (reduction in intermodulation frequency), it had a significant effect on the reduction of signal interference. However, it should be noted that reduction of the amount of non-linear devices installed weakens the wanted signal transmission. Hence, the result in Figure 11 was the optimal amount of non-linear devices removed to ensure significant channel reduction outcome and the same ensures strong strength of signal transmission.

3.3 Interference rreduction with Artificial Neural Networks and with the Modified Artificial Neural Network (M-ANN) techniques

The outcome of signal reduction with ANN is shown in Figure 12 while the outcome of the modified ANN model was shown in Figure 13.

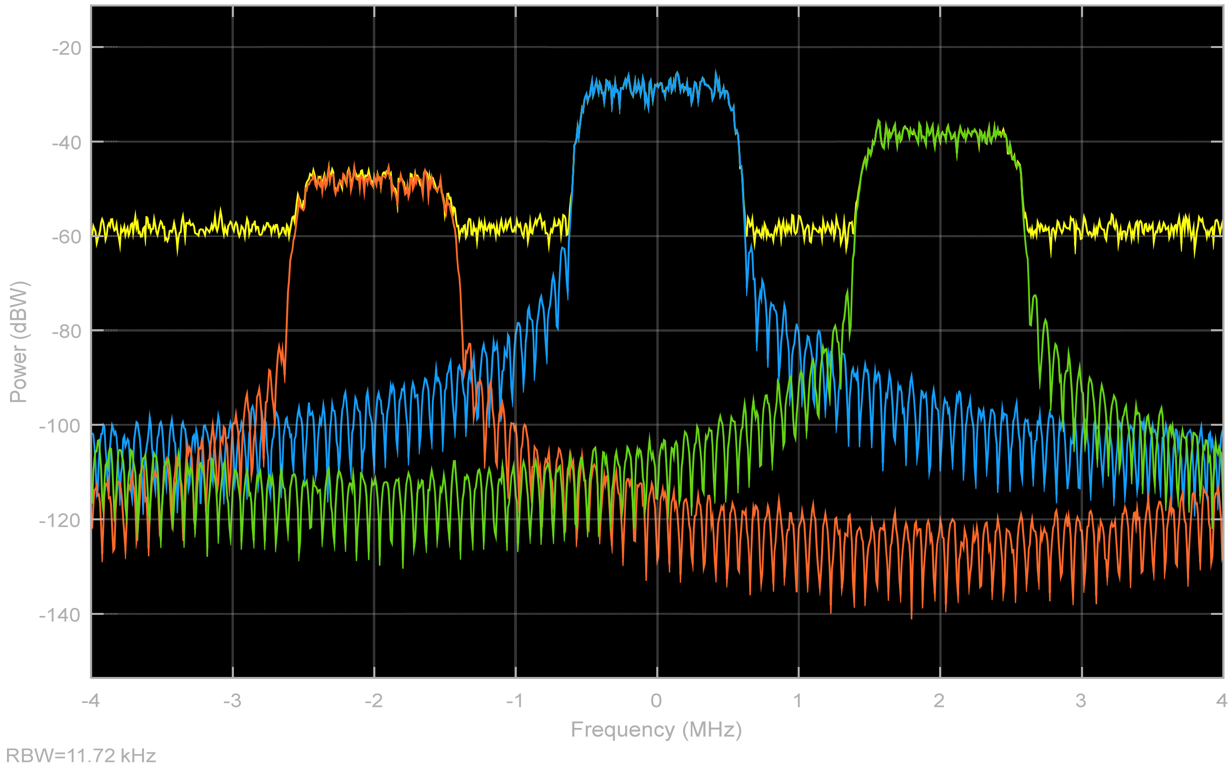


Figure 12: Signal Interference reduction with the ANN technique

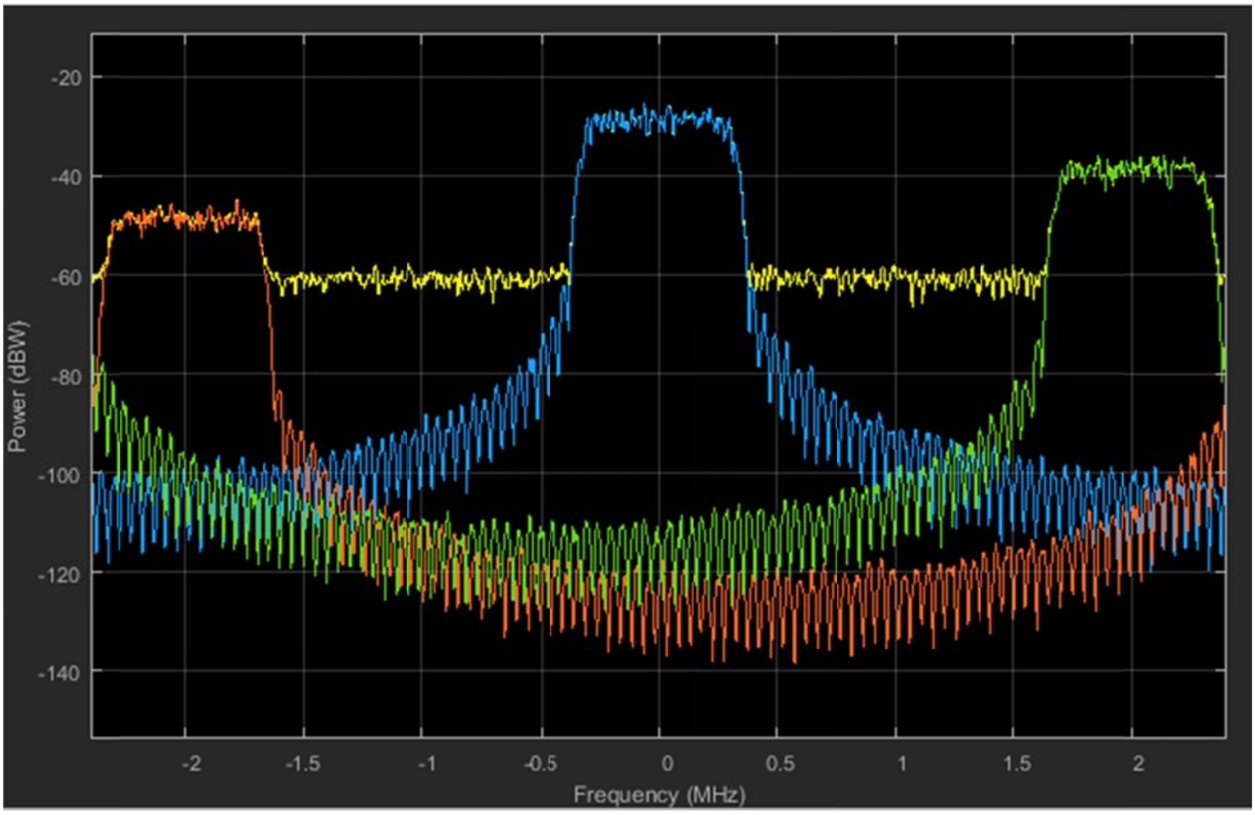


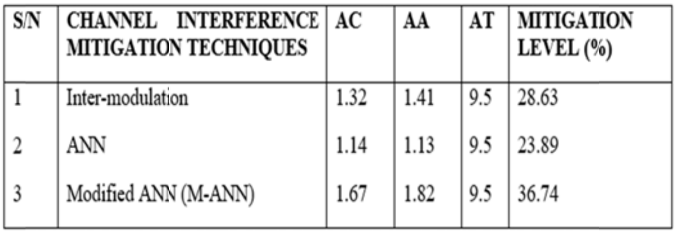
Figure 13: Signal interference reduction with the Modified Artificial Neural Network (M-ANN) technique

Based on the results in Figure 12 and Figure 13, the time at which the signal interference would re-occur on the cleaned signal with M-ANN model would be longer than the time of that of the signal cleared with the ANN model. This implies that there is an improvement when the ANN model was modified with the fuzzy logic model.

3.4 Comparison of the interference mitigation techniques

From the signal interference mitigation methods discussed in this work, the Modified Artificial Neural Network (M-ANN) mitigation method best controls the interference effect and then followed by inter-modulation technique. Hence, the best process of ensuring minimized channel interference for a longer period of time in real time is to embark on the Modified Artificial Neural Network (M-ANN) solution. The process of non-linear device control is not capital intensive and is much more effective in signal interference mitigation. In terms of longer period of time before signal interference occurrence, it is much more preferable to implement the M-ANN model. Therefore, the utilization of improved ANN ensured the existence of clean channel for a longer period which was better than the existing models deployed and hence making it much more preferred than the existing channel interference mitigation techniques. The results for the level of impact of channel interference on the clean signal with the implementation of channel mitigation techniques are shown in TABLE 1. The outcome in Table 1 showed that modified ANN had the highest signal mitigation reduction impact of 36.74%.

Table 1; The results for the level of channel interference impact with mitigation techniques



S/N	CHANNEL INTERFERENCE MITIGATION TECHNIQUES	AC	AA	AT	MITIGATION LEVEL (%)
1	Inter-modulation	1.32	1.41	9.5	28.63
2	ANN	1.14	1.13	9.5	23.89
3	Modified ANN (M-ANN)	1.67	1.82	9.5	36.74

4. CONCLUSION

Modified Artificial Neural Network (M-ANN) interference mitigation technique is presented. The co-channel and intermodulation interference in 5G network are considered and the M-ANN interference mitigation technique is compared with the intermodulation technique and the Artificial Neural Networks (ANN) technique.

The outcome of the level of impact of the interferences mitigation with the introduction of interference mitigation techniques showed that the M-ANN technique was the most effective in minimizing the level of impact of the channel interference on the clean 5G signal. This simply implies that the pattern of M-ANN technique should be utilized in the signal interference minimization process in 5G networks.

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