Development of Algorithm for Efficient and Secured Data Transmission in an Improved SC-FDMA Channel

Isaac Maxwell Durairaj, A. Jerlin and S. Letitia

February 7, 2020

Development of Algorithm for Efficient and Secured Data transmission in an improved SC-FDMA channel

Isaac Maxwell. D

Mrs. A. Jerlin

Dr. S. Letitia

Abstract

Single Carrier-Frequency Division Multiple Access (SC-FDMA) is used in Long Term Evolution--Advanced (LTE-A) uplink because of the reduced PAPR values compared with OFDM. In order to improve the bit error rate, there have been two equalization techniques discussed in this paper. Also the introduction of successive interference cancellation in these two equalization techniques has been proved to be more effective than the initial two equalization techniques. It helps to reduce the Bit Error rate. Also, a major problem in wireless communication is the lack of security. The paper suggests the use of chaotic encryption algorithm which is an effective algorithm to improve security. Chaotic encryption is fast, secure and reliable. The total SNR of the system can be improved by the equalization techniques used in the system. The main objective of this paper is to propose a SC-FDMA system with high security and improved performance.

1.1 Introduction

There exists a need for a reliable, secure, and high speed wireless communication system. As Long Term Evolution (LTE) came into existence, telecommunications industries were able to provide high speed voice and data communication. Security was implemented for text and image communications. Nowadays, data such as images and text are encrypted. However, there are some threats in audio communication. Hence, when the audio transmission is not strongly encrypted, it can lead to the detection of the location of the transmitter. In this paper, chaotic encryption of the audio signal helps to mask the audio and it will be impossible to decipher the audio content and the location of the transmitter. The paper also introduces the equalization techniques such as Zero forcing (ZF) and Minimum Mean Square Error (MMSE) Equalization.

In 4G LTE-A the downlink uses Orthogonal Frequency Division Multiplexing (OFDM) and the uplink uses SC-FDMA (Single Carrier- Frequency Division Multiple Access). The reason SC-FDMA replaces OFDM is because of the reduced PAPR (Peak Power to Average Power Ratio). The lower the PAPR, the lower the cost of the transmitter [2]. It also reduces power consumption. However, in spite of the benefits shown by SC-FDMA, it wasn't possible to replace OFDM in the downlink because of the low data rate. However, with the use of ZF and MMSE equalizations the achievable rate can be increased [3]. Also, with the Successive Interference Calculation in the equalization methods, a significant reduction in the bit error rate (BER) can be obtained at a given Signal to Noise Ratio (SNR).

The paper also compares the ZF and MMSE equalization techniques for reduction in BER and achievable rates. The chaotic encryption algorithm is implemented before the FFT (Fast Fourier Transform) and the decryption is performed after Inverse Fast Fourier Transform (IFFT). The PSNR value of the encrypted sample is comparatively lower when compared with other encryption algorithms. Due to low PSNR, it is not possible to recover any information from the audio without the key [1]. Also, the correlation coefficient of the encrypted audio with the original audio is very low compared with other encryption algorithms and can be impossible to decrypt without the proper key [1].

The use of the cryptography techniques along with the equalization provides a better SC-FDMA which has an improved security, increased data rate, and comparatively reduced BER.

2 Preliminaries

SC-FDMA is used in the uplink because of the low PAPR [7]. The reduction in PAPR is due to the use of FFT in the existing OFDMA block. The input to the SC-FDMA system should be binary. Therefore, a decimal to binary conversion is used and it is modulated using BPSK.

The encryption keys are developed using logistic maps. These inputs are sampled and the Fourier transform is applied. The input signal is now in the Frequency representation and the subcarrier mapping is applied. In subcarrier mapping, the symbols are mapped to a subcarrier with the entire bandwidth. The output from subcarrier mapping is applied to the IFFT block. Then, the cyclic prefix is added and transmitted over the channel. In the receiver, demodulation, demapping, and cyclic prefix removal is performed. Finally, the decryption is also done at the receiver.

2.1 *Chaotic Sequence*

Chaotic encryption is performed by the following equation

$Z_{(i+1)}=Z_{(i)}[S*(1-Z_{(i)})]$

The range of Z can be between zero and one. S can have values from zero to four. When S has a value between 3.5 and 4, the randomness present in the encrypted data is very high [8]. The value of Z impacts S.

2.2 *Process involved in the proposed SC-FDMA system*

Step 1: Initially the audio signal is taken and sampled

Step 2: BPSK modulation is performed

Step 3: The chaotic encryption is performed using the equation

$Z_{(i+1)}=Z_{(i)}[S*(1-Z_{(i)})]$

Step 4: FFT is performed

Step 5: Subcarrier mapping is done

Step 6: IFFT is performed

Step 7: Cyclic prefix is added

Step 8: The output is converted from parallel into serial for sequential transmission

Step 9: The reverse of transmission is performed in the receiver

Step 10: The decryption is performed using chaotic sequence

Step 11: Equalization is performed using ZF, MMSE, ZF-SIC and MMSE-SIC

2.3 Equalization:

2.3.1 Zero forcing

It is a linear equalization algorithm. It applies the inverse of the frequency of the channel

Frequency response of equalizer, H(f)

$H(f) =1/C(f)$

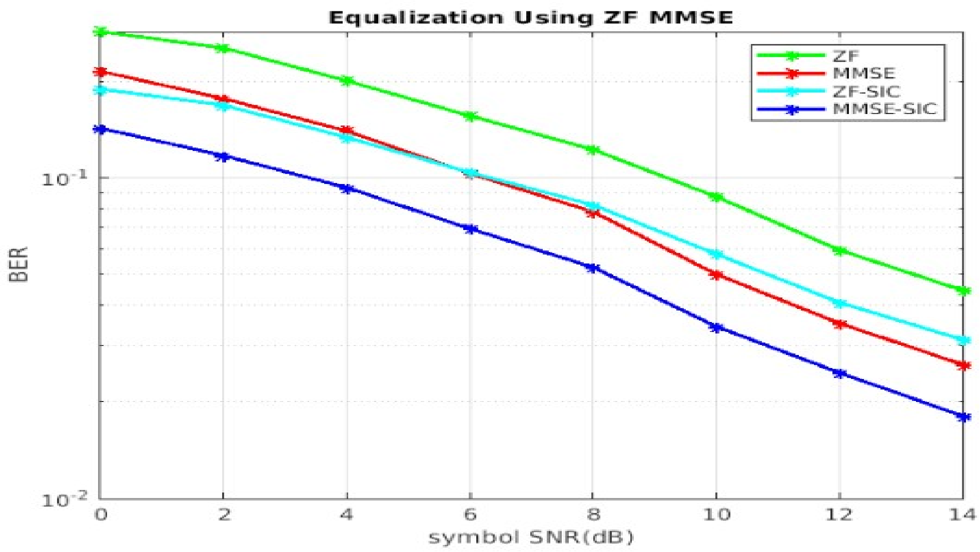
C(f) - frequency response of the channel

2.3.2 MMSE Equalizer

It is used to minimize the intersymbol interference and additive noise effects. At elevated SNR values, it acts as a zero forcing equalizer. At low SNR, it makes not to amplify the noise as the ZF equalizer does

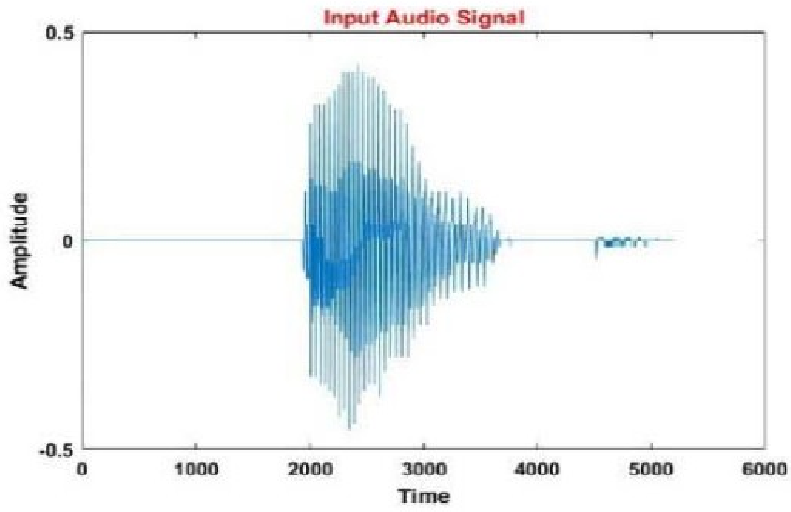
3. Result Analysis

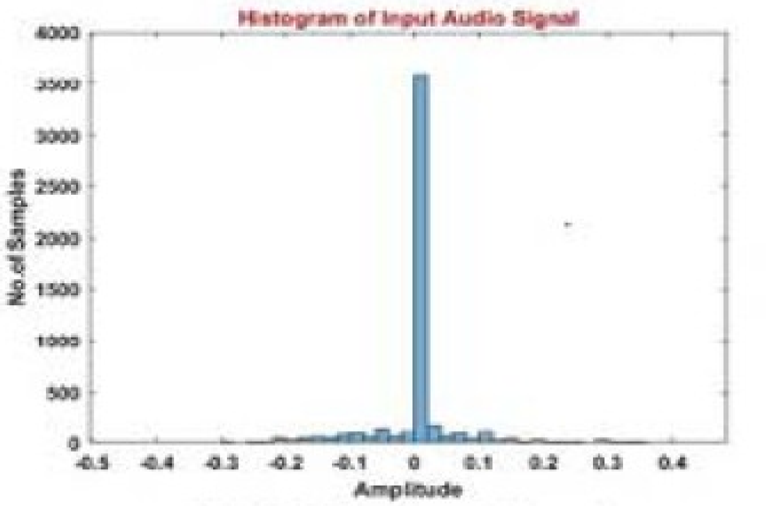
3.1 Equalization



In the above result, the MMSE-SIC method offers a better reduction in BER for any value of SNR. While, the ZF-SIC method provides a lesser BER compared with MMSE method for SNR values up to 6dB. MMSE equalization provides better BER values at higher SNR values

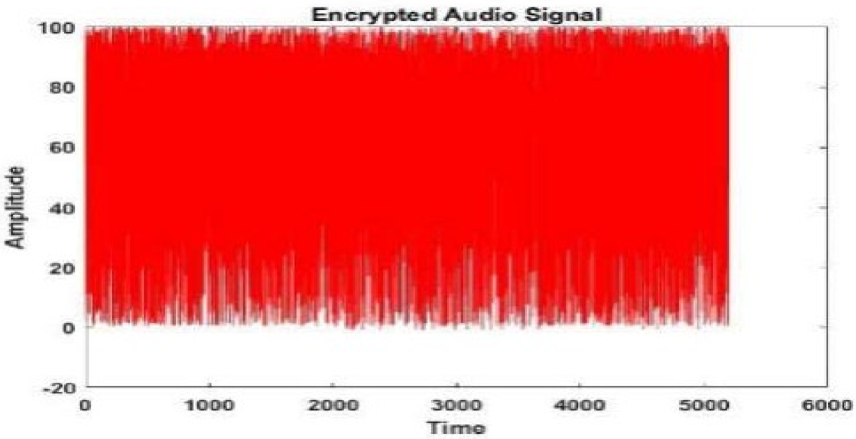
3.2 Chaotic Encryption

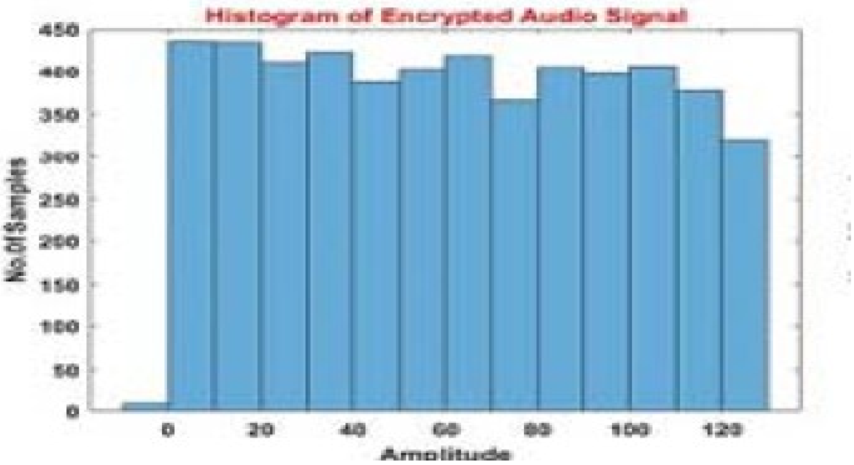




The histogram for the audio input is taken. Most of the samples are concentrated in the centre. Thus, it is very easy to decipher the information. In order to improve the security, histogram should be spread across the entire amplitude range.

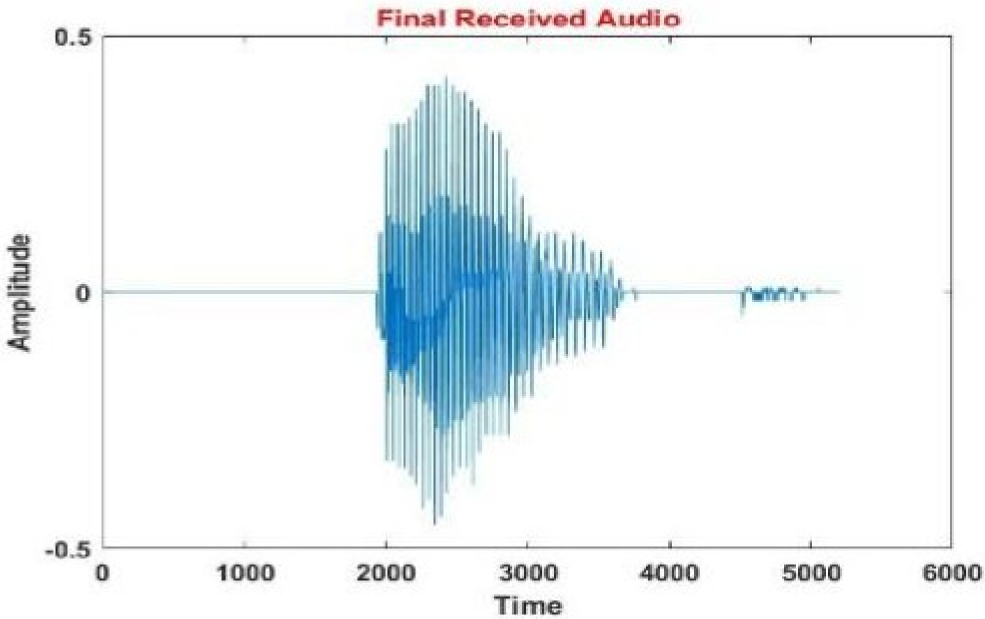
3.2.1 *Encrypted signal*

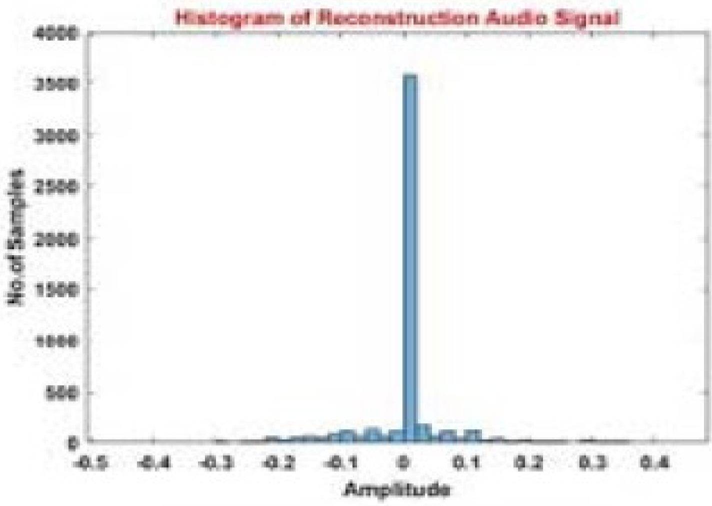




Chaotic algorithm is a strong encryption method. Therefore, it produces a histogram in which the samples are scattered all over the varying amplitudes. It is impossible to decipher information without the key and it is a very fast encryption algorithm

3.2.2 Decrypted audio





The decrypted graph is similar to the initial information.The histogram gives a clear information that the decryption has produced the original audio.

4. Conclusion

The system that has been proposed is an improved version of the SC-FDMA system. It has a very strong security for audio signals and using the equalization techniques discussed above, the noise can be reduced in the system along with an improved BER rate.

References

[1] Padma Priya, Meruva Priyanka, Thenmozhi,"Chaos aided audio secure communications over SC-FDMA system", IEEE 2019

[2] Xiaoxia Zhang, Xumen Shen, Liang-Liang Xen,"Uplink achievable rate and Power allocation in cooperative LTE-A Networks, IEEE 2015

[3] Tanvir Ahmed,Nezam Uddim,Motiur Rahaman,"Performance analysis of zero forcing equalizer in 2*2 and 3*3 MIMO wireless channel,Global journal of researches in engineering.(Volume:14,Issue:9,Version 1.0,2014)

[4] Shaohe Lv, Weihua Zhuang, Xiaodong Wang, and Xingming Zhou,"Scheduling in Wireless Ad Hoc Networks with Successive Interference Cancellation, April 2011, IEEE

[5] Richa Chouhan,Rahul Dubey,S G Kerhalker,"DFT based MMSE equalizer in MIMO-OFDM,IOSR journal of electronics and Communication engineering(Volume:4,Issue:4,Jan – February 2013)

[6] Vora LJ,"Evolution of mobile generation technology: 1G to 5G and review of upcoming wireless technology 5G", International Journal of Modern Trends in Engineering and Research , pp.281-90,2015.

[7] Naresh Kumar, Ishu, "BER analysis in wavelet-based SC-FDMA for LTE Up link transmission", Fifth International Conference on Advanced Computing & Communication Technologies, pp.437 - 440,2015

[8] Sathiyamurthi P, Ramakrishnan S," Speech encryption using chaotic shift keying for secured speech communication", EURASIP Journal on Audio, Speech, and Music Processing, pp.20, Dec 1,2017.

[9] A. Ghosh, R. Ratasuk, B. Mondal, N. Mangalvedhe, and T. Thomas, "LTE-Advanced: next-generation wireless broadband technology," *IEEE Transactions on Wireless Communications*, vol. 17, no. 3, pp. 10–22, 2010

[10] E. Altubaishi and X. Shen, "Performance analysis of spectrally efficient amplify-and-forward opportunistic relaying scheme for adaptive cooperative wireless systems," *Wireless Communications and Mobile Computing (Wiley)*, July 2013.