Advances in Wireless Communications and Networks
2018; 4(2): 30-35
http://www.sciencepublishinggroup.com/j/awcn
doi: 10.11648/j.awcn.20180402.11
ISSN: 2575-5951 (Print); ISSN: 2575-596X (Online)

Secured Audio Signal Transmission in Hybrid Prefixing Scheme Implemented Multicarrier CmWave Wireless Communication System

Laila Naznin[1], Shaikh Enayet Ullah[2]

[1]Department of Information and Communication Engineering, University of Rajshahi, Rajshahi, Bangladesh

[2]Department of Applied Physics and Electronics Engineering, University of Rajshahi, Rajshahi, Bangladesh

Email address:

lipy.naznn.ice.ru@gmail.com (L. Naznin), enayet_apee@ru.ac.bd (S. E. Ullah)

To cite this article:

Laila Naznin, Shaikh Enayet Ullah. Secured Audio Signal Transmission in Hybrid Prefixing Scheme Implemented Multicarrier CmWave Wireless Communication System. *Advances in Wireless Communications and Networks.* Vol. 4, No. 2, 2018, pp. 30-35.
doi: 10.11648/j.awcn.20180402.11

Received: September 21, 2018; **Accepted**: October 9, 2018; **Published**: October 23, 2018

Abstract: In view of expense of extra redundancy and reduced spectral efficiency, prefix based multicarrier transmission can find its major applications in 5G and beyond 5G wireless communication networks with properly designed low complexity signal detection technique. Hybrid prefixing aided multicarrier modulated system is capable of providing reasonably acceptable bit-error rate (BER). In this paper, a comprehensive study has been made on performance evaluation of hybrid prefixing scheme implemented multicarrier cmWave wireless communication system on transmission of encrypted audio signal in a hostile flat fading channel. The 4×4 multi antenna configured simulated system under investigation incorporates LDPC and Repeat and Accumulate channel coding and various types of digital modulations (16-PSK, 16-DPSK, and 16-QAM) and signal detection (MMSE, and Cholesky Decomposition based) techniques. The implementation of pulse shaping filter in the simulated system is very much convenient to improve system performance in terms of BER through reduction of intersymbol interference (ISI). Additionally, utilization of hybrid prefix scheme enhances spectrum efficiency of the simulated system. It is noticeable from MATLAB based simulation study that the Repeat and Accumulate channel encoded simulated system is very much robust and effective in retrieving audio signal under utilization of Cholesky Decomposition based signal detection and 16-QAM digital modulation techniques.

Keywords: Channel Coding, Signal Detection Schemes, HP-OFDM, CmWave

1. Introduction

In perspective of considering of increasing demand by mobile radio customers for higher data rates, multimedia services, and bandwidth availability as well as anticipated traffic related to the Internet of Things, the fifth Generation (5G) /Beyond 5G (B5G) wireless communication systems are expected to be emerged to meet up unprecedented demands beyond the capability of previous generations of wireless communication networks. The 5G networks will provide users with ultimate experience through more immersive services such as Ultra High Definition (UHD), 3D video, 3D connectivity (aircraft and drone), Online gaming applications, Augmented and virtual reality, Video/photo sharing in stadium/open air gathering, Mobile cloud/desktop cloud, Collaborative robots, Tactile Internet etc[1]. In the 40-year research history of orthogonal frequency division multiplexing (OFDM), the prefix such as the cyclic prefix (CP) and zero prefix (ZP) has played an important role in combating multipath fading in wireless communications. The authors proposed a novel hybrid prefix (HP) structure which can offer higher spectral efficiency for orthogonal frequency division multiplexing (OFDM) based future 5G and beyond 5G wireless communications systems [2]. Their proposed HP-OFDM scheme is capable of reducing the average length of the prefix with the aid of a proposed low-complexity detector for efficient signal restoration. In their simulation work, the authors demanded that HP-OFDM is capable of improving spectral efficiency through reducing the cyclic prefix overhead by 50% as compared with prefix-aided

OFDM and achieving identical BER comparable to that of prefix-aided OFDM. 5G research poses a new challenge to design efficient multicarrier waveforms towards future wireless communications. In consideration of the demand of extremely high spectral efficiency for 5G and beyond systems, the current prefix-aided multicarrier technique will induce redundancy to OFDM signals leading to the degradation of the spectral efficiency. Several researchers worked on finding an efficient way to shorten the length of prefix for improving spectral efficiency. Prefix-aided OFDM techniques started to find their way into various wireless standards such as the 802.11 wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX). Prefix-aided OFDM and other correlative multicarrier techniques have been adopted in 4G LTE system [3, 4]. In the present study, simulation results for Hybrid Prefixing scheme implemented multicarrier cmWave wireless communication system under scenario of implementing modern channel coding and signal detection techniques have been presented.

2. Basic Concepts of HP-OFDM System

In transmitting section of HP-OFDM system, the information bits are first modulated into constellation points by amplitude and phase modulation (APM) such as phase shift keying (PSK) and quadrature amplitude modulation (QAM). Then the modulated symbols undergo the inverse fast Fourier transform (IFFT) to construct OFDM symbols. For the convenience of exposition, splitting the time indexes of the OFDM symbol into even indexes as 2i and odd ones as 2i - 1, where i is an integer. Therefore, assuming N is the number of total subcarriers, the OFDM symbols in the time domain are expressed as

$$x_n^{(2i)} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k^{(2i)} e^{j2\pi\frac{kn}{N}} \quad (1)$$

$$x_n^{(2i-1)} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k^{(2i-1)} e^{j2\pi\frac{kn}{N}} \quad (2)$$

Where, $x_n^{(2i)}$ and $x_n^{(2i-1)}$ denote the frequency-domain modulated constellation points for the even and odd indexed symbols, $x_n^{(2i)}$ and $x_n^{(2i-1)}$ (n=0,1,2,3…………N-1) stand for the time domain signals for the even and odd indexed OFDM symbols respectively, whose vector form can be written as:

$$x^{(2i)} = \left[x_0^{(2i)}, x_1^{(2i)}, ...x_{N-1}^{(2i)}.\right]^T \text{ and } x^{(2i-1)} = \left[x_0^{(2i-1)}, x_1^{(2i-1)}, ...x_{N-1}^{(2i-1)}.\right]^T$$

In comparison to conventional CP-OFDM, cyclic prefixes are added discontinuously and the proposed hybrid prefixing scheme is adopted in CP prefix –assisted OFDM. Only the even –indexed OFDM symbols $x_n^{(2i)}$ are inserted with the CP. The OFDM symbols after hybrid CP insertion can be written as:

$$s^{(2i)} = \left[x^{(2i)}_{N-N_g}, x^{(2i)}_{N-N_g+1}, ...x^{(2i)}_{N-1}, x^{(2i)}_{0,,,,,,,,}, x^{(2i)}_{N-1}\right]^T \quad (3)$$

$$\text{And } s^{(2i-1)} = x^{(2i-1)} \quad (4)$$

where, N_g is the length of the cyclic prefix [2]

3. Signal Processing Techniques

In the present study various signal processing schemes have been used. A brief overview of these schemes is given below:

3.1. Cholesky Decomposition (CD) Based ZF Detection

In $N_R \times N_T$ MIMO system, the signal model can be represented by

$$y=Hx+n \quad (5)$$

where, H is a channel matrix with its (j, i) th entry h_{ij} for the channel gain between the ith transmit antenna and the jth receive antenna, j=1,2,……. NR and i=1,2,……. NT, $x = [x_1, x_2, ...x_{N_T}]^T$ and $y = [y_1, y_2, ...y_{N_R}]^T$ are the transmitted and received signals and $n = [n_1, n_2, ...n_{N_R}]^T$ is the white Gaussian noise with a variance of with variance σ^2_n. Using Equation (4), the matched filtering (MF) based detected signal is given by

$$\hat{x}_{MF} = H^H y = H^H Hx + H^H n \quad (6)$$

where, H^H is the Hermitian conjugate of the estimated channel. In interference limited scenarios, the more advanced ZF detector is required which operates on the MF data by

$$\hat{x}_{ZF} = (H^H H)^{-1} \hat{x}_{MF} \quad (7)$$

In Cholesky Decomposition (CD) based ZF detection, Equation (6) is written in modified form as:

$$\hat{x}_{ZF} = (H^H H)^{-1} \hat{x}_{MF} = (LL^H)^{-1} \hat{x}_{MF} \quad (8)$$

With forward and backward substitution, the detected signal in CD based ZF detection would be

$$\hat{x}_{ZF} = L^{-H} L^{-1} \hat{x}_{MF} \quad (9)$$

3.2. Minimum Mean Square Error (MMSE) Signal Detection

Following signal model presented in Equation 5, the Minimum mean square error (MMSE) weight matrix can be written as:

$$W_{MMSE} = (H^H H + \sigma_n{}^2 I)^{-1} H^H \quad (10)$$

and the detected desired signal from the transmitting antenna is given by [7, 8]

$$\tilde{X}_{MMSE} = W_{MMSE}\, y \quad (11)$$

3.3. LDPC Channel Coding

The low-density parity-check (LDPC) code was invented as early as 1962 by Gallager. An LDPC code is linear block code and its parity-check matrix H contains only a few 1's in comparison to 0's (i.e., sparse matrix). Such LDPC codes are graphically represented by the bilateral Tanner graph. It nodes are grouped into one set of n bit nodes (or variable nodes) and the other set of mcheck nodes (or parity nodes). Check node i is connected to bit node j in case of any elemental value of the parity matrix unity. The decoding operates alternatively on the bit nodes and the check nodes to find the most likely codeword c that satisfies the condition cHT=0. In iterative Log Domain Sum-Product LDPC decoding under consideration of AWGN noise channel of variance σ2 and received signal vector r, log-likelihood ratios (LLRs) instead of probability are defined as:

$$\left.\begin{array}{c} L(c_i) \triangleq ln[P(c_i = 0|r_i)/P(c_i = 1|r_i)] \\ L(P_{ij}) \triangleq ln[P_{ij}^0/P_{ij}^1] \\ L(Q_{ij}) \triangleq ln[Q_{ij}^0/Q_{ij}^1] \\ L(P_j) \triangleq ln[P_j^0/P_j^1] \end{array}\right\} \quad (12)$$

where ln(·) represents the natural logarithm operation. The bit node jis initially set with an edge to check node i:

$$L(P_{ij}) = L(c_i) = 2r_i / \sigma^2 \quad (13)$$

In message passing from check nodes to bit nodes for each check node I with an edge to bit node j; L(Q ij) is updated as:

$$L(Qij) = \prod_{j'} \alpha_{ij'}\, \varphi[\sum_{j'} \varphi(\beta_{ij'})] \qquad (j' = 1, 2..............n \;\; and \;\; j' \neq j\;) \quad (14)$$

where $\alpha_{ij} \underline{\underline{\Delta}} sign[L(P_{ij})]$ and $\beta_{ij} \underline{\underline{\Delta}} [L(P_{ij})]$. Theϕfunction is defined as:

$$\varphi(x) = -\ln[\tanh(x/2)] = \ln[(e^x + 1)/(e^x - 1)] \quad (15)$$

From bit nodes to check nodes for each bit node j with an edge tocheck node i; L(Pj) is updated as:

$$L(Pij) = L(c_i) + \sum_{i'} L(Qij) \qquad (i' = 1, 2..............m \;\; and\, i' \neq i\;) \quad (16)$$

Decoding and soft outputs: for j= 1,2,…, n; L(Pj) is updated as:

$$L(Pj) = L(c_i) + \sum_i L(Pij) \qquad (i = 1, 2..............m) \quad (17)$$

$$c_i = \begin{cases} 1 \;\; if \;\; L(P_j) < 0 \\ 0 \qquad else \end{cases} \quad (18)$$

the number of iterations reaches the maximum limit when $cH^T = 0$. The LDPC channel coding and decoding in MATLAB have been executed with the aid of programs available in website at [9, 10].

3.4. Repeat and Accumulate (RA) Channel Coding

The Repeat and Accumulate (RA) is a powerful modern error-correcting channelcoding scheme. In such channel coding scheme, all the extracted binary bitsfrom the audio has been arranged into a single block andthe binary bits of the such block is repeated 2 times andrearranged into a single block containing binary data which isdouble of the number of input binary data [11].

4. System Description

The conceptual block diagram of the Hybrid Prefixing scheme implemented multicarrier cmWave wireless communication system is shown in Figure 1. In such system, a segment of digitally recorded audio signal is considered as input data and its sampled analog values are converted into corresponding integer values under consideration of 256 quantization levels. The extracted binary bits in 0/1 format are encrypted with a secret key of bit length 8 [12].

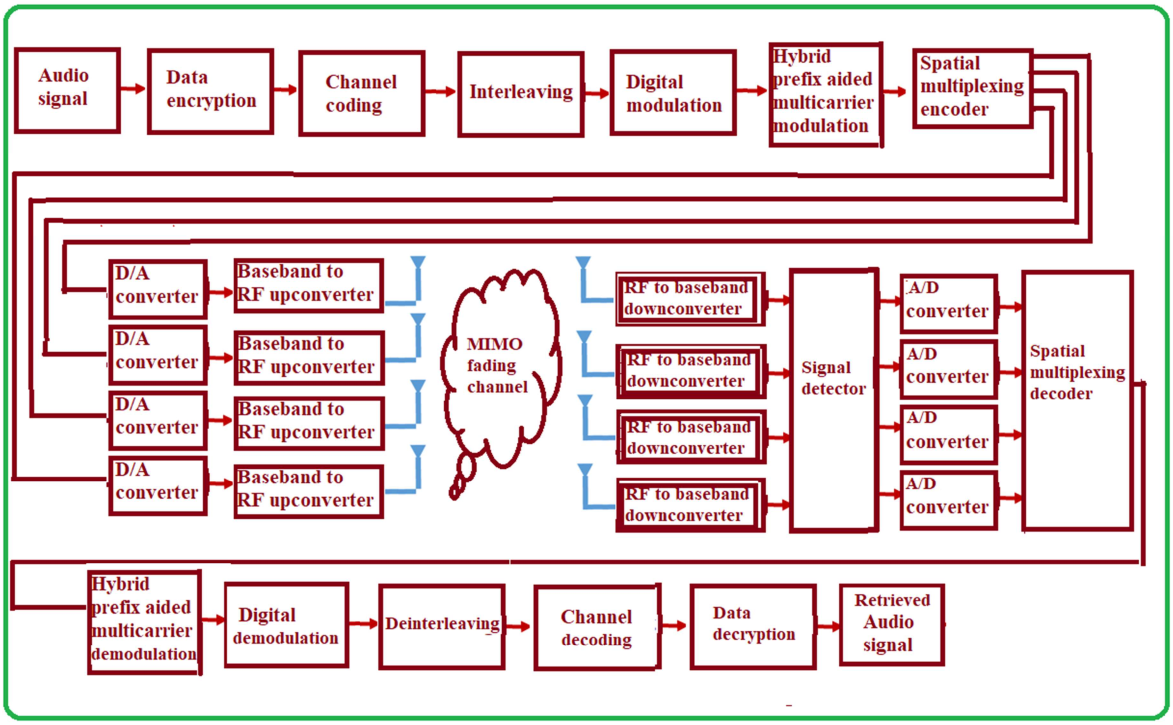

Figure 1. *Block diagram of Hybrid Prefixing scheme implemented multicarrier cmWave wireless communication system.*

The encrypted binary bits arechannel encoded, interleaved and subsequently digitally modulated [13]. The digitally modulated complex symbols are processed in Hybrid Prefixing scheme implementation for multicarrier modulation and fed into spatial multiplexing encoder section for production of four independent data stream. In each of four data stream, D/A conversion and subsequently Baseband to RF up conversion are executed prior to transmission. In receiving section, after RF to Baseband down conversion, the signals are processed for detection of transmitted signals, A/D conversion and fed into spatial multiplexing decoder section for production of single data stream. The spatially multiplexed decoded signal is sent up in Hybrid Prefixing scheme based multicarrier demodulation and subsequently digitally demodulated, deinterleaved, channel decoded and decrypted to retrieve eventually the transmitted audio signal

5. Results and Discussion

In this section, simulation results using MATLAB R2017a have been presented to illustrate the significant impact of various types of channel coding and signal detection techniques on performance analysis of hybrid prefixing scheme implemented multicarrier cmWave wireless communication system in terms of bit error rate (BER). It has also been considered that the channel state information (CSI) of the cmWave MIMO Rayleigh fading channel is available at the receiver and the fading channel coefficients are constant during simulation. The proposed model is simulated to evaluate the system performance under consideration of parameters presented in the Table 1.

Table 1. *Summary of the simulated model parameters.*

Parameters	Types
Data Type	Audio
Data sample length	8192
No of subcarriers	1024
CP length	192 samples
Carrier frequency	2GHz
Multiplexing technique	HP-OFDM
System bandwidth	20 MHz
Sampling frequency	40 MHz
Pulse shaping filter	Raised cosine filter with rolloff 0.25 and filter order 40
signal detection technique	MMSE and Cholesky Decomposition based signal detection
Antenna configuration	4 x 4 MIMO Channel
Channel Coding	Repeat and Accumulate and LDPC
LDPC Channel decoding	Log-domain sum product
Constellation Modulation	16-PSK, 16-DPSK and 16-QAM
Signal Detection Scheme	ZF, MMSE, ZF-SIC and MMSE-SIC
SNR	0 to 15 dB
Channel	AWGN and Rayleigh

The graphical illustrations presented in Figure 2 through Figure 5 are very much well defined showing system performance comparison in terms of Bit error rate (BER) and clearly indicate that in all cases, the simulated system shows comparatively better performance in 16-QAM as compared to 16-PSK and 16-DPSK.

In Figure 2 with utilization of Repeat and Accumulate channel coding and Cholesky Decomposition based signal detection techniques, the estimated BERs are found to have values of 0.0677, 0.1779 and 0.2423 for a typically assumed SNR value of 2 dB which imply system performance improvement of 5.56 dB and 4.20 dB in 16-QAM as compared to 16-DPSK and 16-PSK respectively. At 5% BER, SNR gain of approximately 5 dB and 8 dB are obtained in16-QAM as compared to 16-PSK and 16-DPSK.

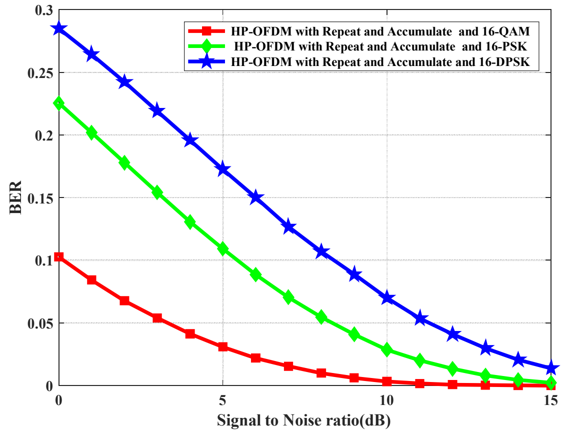

Figure 2. *BER performance of Hybrid prefixing scheme implemented multicarrier cmWave wireless communication system under utilizationof Repeat and Accumulate channel coding, Cholesky Decomposition based signal detection and variousdigital modulation schemes.*

In Figure 3, with consideration of LDPC channel coding, Cholesky decomposition based signal detection techniques and identical SNR value, the estimated BER values are 0.0952, 0.2507 and 0.3112 which imply system performance improvement of 5.14 dB and 4.21 dB in 16-QAM as compared to 16-DPSK and 16-PSK respectively. At 5% BER, SNR gain of approximately 4 dB and 7 dB are obtained in16-QAM as compared to 16-PSK and 16-DPSK.

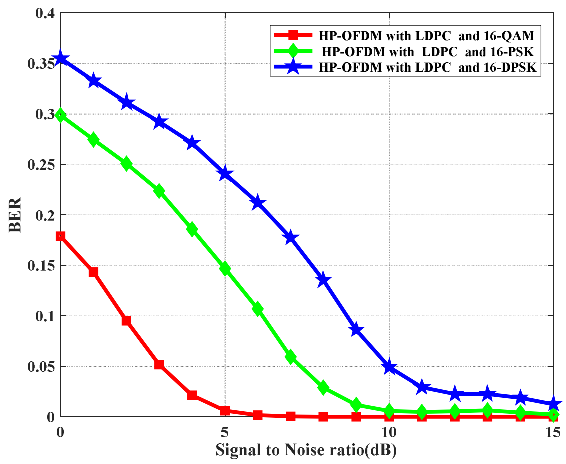

Figure 3. *BER performance of Hybrid prefixing scheme implemented multicarrier cmWave wireless communication system under utilization of LDPC channel coding, Cholesky Decomposition based signal detection and various digital modulation schemes.*

In Figure 4, with consideration of identical SNR value, LDPC channel coding, MMSE signal detection techniques, the estimated BER values are 0.1106, 0.2513 and 0.3169 which imply system performance improvement of 5.14 dB and 4.21 dB in 16-QAM as compared to 16-DPSK and 16-PSK respectively. At 5% BER, SNR gain of approximately 4.2dB and 6.7 dB are obtained in16-QAM as compared to 16-PSK and 16-DPSK.

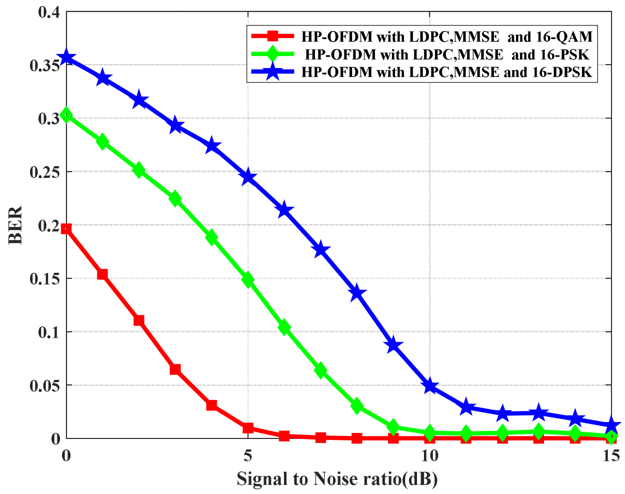

Figure 4. *BER performance of Hybrid prefixing scheme implemented multicarrier cmWave wireless communication system under utilization of LDPC channel coding, MMSE signal detection and various digital modulation schemes.*

In Figure 5, with consideration of identical SNR value, LDPC channel coding, MMSE signal detection techniques, the estimated BER values are 0.073, 0.1749 and 0.243 which imply system performance improvement of 5.22 dB and 3.79 dB in 16-QAM as compared to 16-DPSK and 16-PSK respectively. At 5% BER, SNR gain of approximately 4 dB and 7 dB are obtained in16-QAM as compared to 16-PSK and 16-DPSK.

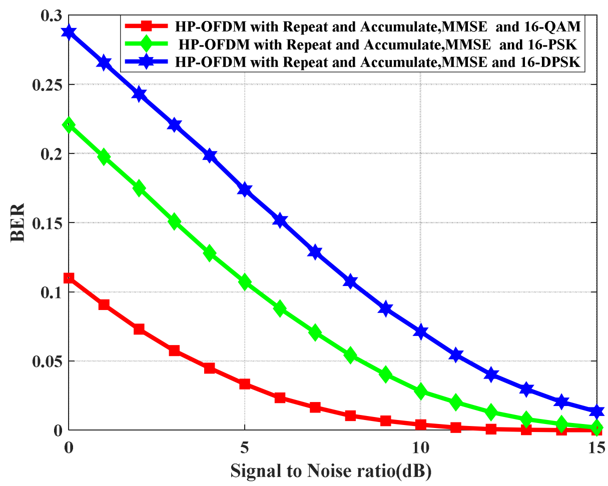

Figure 5. *BER performance of Hybrid prefixing scheme implemented multicarrier cmWave wireless communication system under utilization of Repeat and Accumulate channel coding, MMSE signal detection and various digital modulation schemes.*

In Figure 6, the transmitted and retrieved audio signals at 10dB SNR value under utilization of Repeat and Accumulate channel coding, Cholesky Decomposition based signal detection and 16-QAM digital modulation schemes have been presented. The estimated bit error in such case is found to have value of 0.0032.

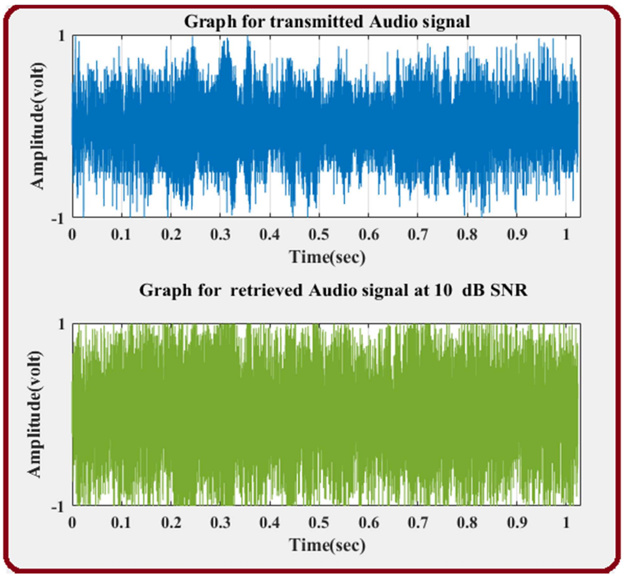

Figure 6. *Transmitted and Retrieved audio signal in Hybrid prefixing scheme implemented multicarrier cmWave wireless communication system under utilization of Repeat and Accumulate channel coding, Cholesky Decomposition based signal detection and 16-QAM digital modulation schemes.*

6. Conclusions

In this paper, the performance of hybrid prefixing scheme implemented multicarrier cmWave wireless communication system has been investigated on secured audio signal transmission with utilization of various channel coding and channel equalization/signal detection techniques. In all cases, the proposed simulated system out performs in 16-QAM and shows worst performance in 16-DPSK digital modulation. The simulation results show that the implementation of Cholesky Decomposition based signal detection technique with utilization of 16-QAM digital modulation scheme ratifies the robustness of Repeat and Accumulate channel encoded hybrid prefixing scheme implemented multicarrier cmWave wireless communication system in retrieving audio signal transmitted over noisy and Rayleigh fading channels.

References

[1] Wei Xiang, KanZheng, Xuemin (Sherman) Shen, 2017: 5G Mobile Communications, Springer International Publishing, Switzerland

[2] Yue Xiao, Xun Lli, Peng Wei, Lixia Xiao and Wei Xiang, 2018: Hybrid Prefix OFDM Transmission Toward Future Wireless Communications, IEEE Express, Special Section on Recent Advances on Radio Access and Security Methods in 5G Networks, vol.6, pp. 22341 - 22352

[3] L. Hanzo, J. Akhtman, L. Wang, and M. Jiang, 2010: MIMO-OFDM for LTE, WIFI and WIMAX,: Coherent Versus Non-Coherent and Cooperative Turbo-Transceivers. Hoboken, NJ, USA: Wiley.

[4] E. Dahlman, S. Parkvall, and J. Skold, 1013: 4G: LTE/LTE-Advanced for Mobile Broadband. San Francisco, CA, USA: Academic.

[5] Nicola Michailow, Maximilian Matthé, Ivan Simões Gaspar, Ainoa Navarro Caldevilla, Luciano Leonel Mendes, Andreas Festag, Gerhard Fettweis, 2014:Generalized frequency division multiplexing for5th generation cellular networks, IEEE Trans. Communication., vol. 62, no. 9, pp. 3045-3061

[6] M. Matthé, L. L. Mendes, and G. Fettweis, 2014: Generalized frequency division multiplexing in a Gabor transform setting, IEEE Communication. Letter, vol. 18, no. 8, pp. 1379-1382

[7] Rakesh Gangarajaiah, Hemanth Prabhu, Ove Edfors, and Liang Liu, 2017: A Cholesky Decomposition based Massive MIMO Uplink Detector with Adaptive Interpolation, In proceeding of IEEE International Symposium on Circuits and Systems (ISCAS).

[8] Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, 2010: MIMO-OFDM Wireless Communications with MATLAB, John Wiley and Sons (Asia) PTE Limited, Singapore.

[9] Yuan Jiang, 2010:A Practical Guide to Error-Control Coding Using MATLAB, Artech House, Norwood, MA, USA.

[10] dpc - bsnugroho - Google Sites, Retrieved from https://sites.google.com/site/bsnugroho/ldpc

[11] Giorgio M. Vitetta, Desmond P. Taylor, Giulio Colavolpe, Fabrizio Pancaldi and Philippa A. Martin, 2013: Wireless Communications Algorithmic Techniques. John Wiley and Sons Ltd, United Kingdom.

[12] William Stallings, 2005: Cryptography and Network Security Principles and Practices, Fourth Edition", Prentice Hall Publisher, New Jersey, USA

[13] Theodore S Rappaport, 1996: Wireless Communications Principles and Practice, Second Edition.