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Performance of the audio signals transmission over wireless networks with the channel interleaving considerations

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Abstract

This article studies a vital issue in wireless communications, which is the transmission of audio signals over wireless networks. It presents a novel interleaver scheme for protection against error bursts and reduction the packet loss of the audio signals. The proposed technique in the article is the chaotic interleaver; it is based on chaotic Baker map. It is used as a randomizing data tool to improve the quality of the audio over the mobile communications channels. A comparison study between the proposed chaotic interleaving scheme and the traditional block and convolutional interleaving schemes for audio transmission over uncorrelated and correlated fading channels is presented. The simulation results show the superiority of the proposed chaotic interleaving scheme over the traditional schemes. The simulation results also reveal that the proposed chaotic interleaver improves the quality of the received audio signal. It improves the amount of the throughput over the wireless link through the packet loss reduction.

Keywords: wireless networks, Bluetooth, fading channels, interleaving techniques, mobility.

1. Introduction

With increasing utilization of wireless devices, especially Bluetooth devices, there are two important factors for all wireless systems power efficiency and efficient throughput. Bluetooth is designed to transfer data using ACL packets and SCO packets for transferring audio streams [1,2].

Bluetooth uses 64 kbps log PCM voice coding with either A-law or μ-law compression, it is the simplest. It uses an 8-bit logarithmic scale. Although it is simple to implement and it is useful in small applications. The log PCM is less robust than the continuous variable slope delta. It is a voice coding method, and is a delta modulation with variable step size. It is good noise immunity, where the damaged packets are discarded without impacting on sound quality [3-5]. In this study, the first voice coding log PCM is considered, for simplicity of the simulations.

There are variety of methods exists for optimizing the transmission of audio data, depending on the properties of the underlying network. In this article, the fixed and mobile Bluetooth networks are assumed to have bursty loss. This study is focused on the interleaving techniques to reduce the burst error effects on the audio signals through distributing the burst errors through a set of audio samples. Audio signals are transmitted as packets in many Bluetooth applications. A packet is considered lost when it is corrupted to the point that it cannot be used. When a packet is lost, a large block of the digital bit stream is missing. The article proposed using effective and powerful interleaver based on the chaotic Baker map. The proposed chaotic interleaver reduces the number of lost packets as shown in the results. So, the packet loss of the audio signal is decreased with the proposed scenarios. Also, over the communications link which permits retransmission the corrupted packets, using the proposed technique reduces the number of retransmission requirement [6-8].

The rest of the article is organized as follows. In Section 2, Bluetooth links are discussed. In Section 3, the

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proposed modifications are presented. In Section 4, the simulation assumptions are given. The simulation results are introduced in Section 5. Finally, the article is concluded in Section 6.

2. SCO, eSCO, and ACL links

Bluetooth supports both synchronous services such as voice traffic and asynchronous services such as bursty data traffic. The specifications define two different physical link types.

The SCO link is a symmetric, point-to-point link between the master and a single slave in the piconet. The SCO link is typically used to support time-bounded information like voice. The master can support up to three SCO links to the same slave or to different slaves. On the SCO links, the packets used include a CRC and are never retransmitted. The SCO packets have been designed to support 64 kbps speech. There are three pure SCO packets, namely, HV_1, HV_2, HV_3, and one hybrid SCO (DV) packet [9,10]. Also, the enhanced SCO (eSCO) link permits retransmitting the dropped voice packets. The packets of this link are EV_3, EV_4, and EV_5 Also, the extended data rate (EDR) are eSCO, $2EV_3$, $2EV_4$, $2EV_5$, $3EV_3$, $3EV_4$, and $3EV_5$ packets [11].

The ACL link provides a packet-switched connection between the master and all active slaves in the piconet. A slave can send an ACL packet if it has been addressed by the master in the previous slot. The ACL packets can be retransmitted. Only a single ACL link can exist between a master and a slave. There are encoded ACL packets such as DM_1, DM_3, and DM_5, which are protected with a rate of 2/3 FEC. Also, there are uncoded ACL packets such as DH_1, DH_2, and DH_5, which are not protected. These ACL are called classic ACL packets. In the recent Bluetooth versions, there are other packets that are specified such as $2DH_1$, $2DH_3$, and $2DH_5$ or $3DH_1$, $3DH_3$, and $3DH_5$, these packets are called EDR packets [12].

The simulations of this article concentrate on the ACL packets and EDR eSCO packets through many scenarios. The proposed technique improves the quality of the received audio signals and reduces the dropped packets over the bursty channel.

3. Proposed modifications

In this article, two audio files are used, file-1 which meets the specification audio transmission over Bluetooth network. The second audio file-2 has different properties as shown in the simulation assumption section.

First, the size of audio file-1 is 32 kbytes. This file will be segmented to small packets. There are many classic (DH_1) and EDR ($2DH_1$ & $2DM_1$) packets used for transferring audio files. For example, in the DH_1 packets,

each one of these packets contains 30 bytes. The duration of this file is 4 s.

> Number of packets (file-1) = 32 kbytes/30 bytes ≈ 1066 packets.
> Number of audio portions (file-1) = 4 s/3.75 ms ≈ 1066 portion.

Second, the size of audio file-2 is 92 kbytes. This file will be segmented to small packets. Each one of these packets contains 30 bytes. The duration of DT audio file is 8 s.

> Number of packets (file-2) = 92 kbytes/30 bytes ≈ 3066 packets.
> Number of audio portions (file-2) = 8 s/3.75 ms ≈ 2133 portion.

As shown, audio file-1 matches Bluetooth specification in its properties. But, the second audio file-2 does not meet Bluetooth specification. It is used with the long packets simulations.

In the simulation, different interleaving techniques are applied on the audio signal before transmission process. The two traditional types, bit-level interleaver and the convolutional interleaver, are used. Figure 1 shows the method of data reading in case of bit-level interleaver.

The second type is the convolutional interleaver that are introduced as no block deterministic interleavers that were investigated in some communication systems due to applying less memories in their structures compared with the block interleavers [13]. Convolutional interleavers are constructed by T parallel lines; each line has different number of memories from other line. The construction of convolutional interleaver is shown in Figure 2. This figure illustrates the convolutional interleaver with period $T = 4$ and space value $M = 1$ based on arithmetic sequence, the overall number of memories (delay) for the interleaver (T, M) is given in Equation 1 [13]

$$S = \sum_{i=1}^{T} s_i = M + 2M + \cdots + (T-1)M$$
$$= \frac{T(T-1)M}{2} = 6 \text{ (The simulation case } M = 1, \ T = 4)$$
(1)

There is the last one of the proposed scenarios, which is the chaotic randomizing. It is performed using the chaotic Baker map. The Baker map is a chaotic map that generates a permuted version of a square matrix. In its discretized form, the Baker map is an efficient tool to randomize a square matrix of data. The discretized map can be represented for an $M \times M$ matrix as follows [14-21]
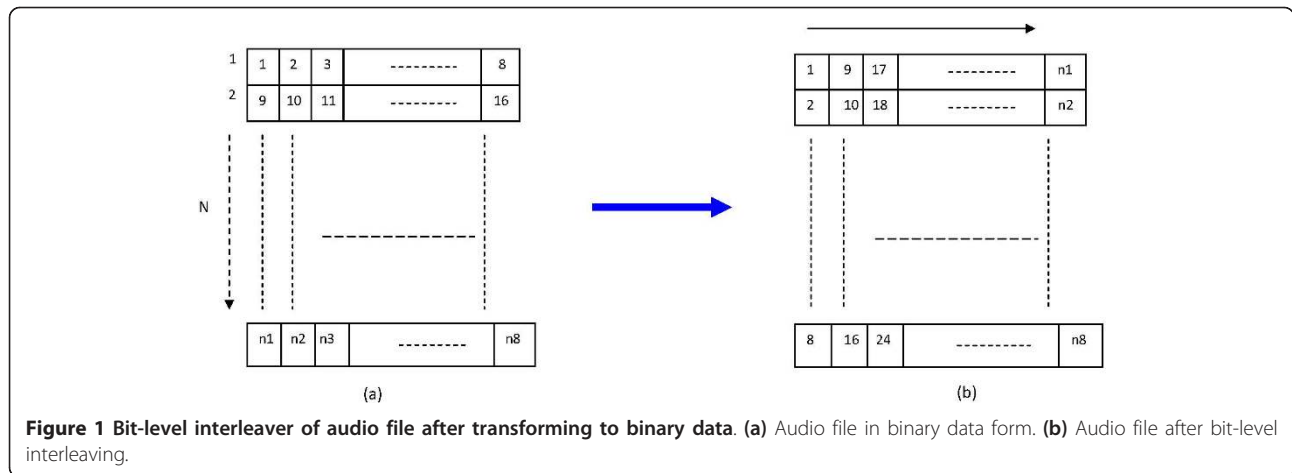
Figure 1 Bit-level interleaver of audio file after transforming to binary data. **(a)** Audio file in binary data form. **(b)** Audio file after bit-level interleaving.

$$B(r,s) = \left[\frac{M}{n_i}(r - M_i) + s \bmod \left(\frac{M}{n_i}\right), \frac{n_i}{M}\left(s - s \bmod \left(\frac{M}{n_i}\right)\right) + M_i\right] \quad (2)$$

where $B(r, s)$ are the new indices of the data item at (r, s), $M_i \leq r < M_i + n_i$, $0 < s < M$ and $M_i = n_1 + n_2 + \ldots + n_i$.

In steps, the chaotic permutation is performed as follows:

1. An $M \times M$ square matrix is divided into k rectangles of width n_i and number of elements M.

2. The elements in each rectangle are rearranged to a row in the permuted rectangle. Rectangles are taken from right to left beginning with upper rectangles then lower ones. Inside each rectangle, the scan begins from the bottom left corner toward upper elements.

Figure 3 shows an example of the chaotic encryption of an 8×8 square matrix. The secret key is $S_{key} = (n_1, n_2, n_3) = (2, 4, 2)$.

This technique is employed in the simulation as a data randomizing tool. It is employed in two forms; it is applied on the audio file to randomize the whole audio file. Also, it is applied on the packet-by-packet basis for randomize the encoded packets. The simulation results reveal that the proposed technique improves the quality of the received audio signals.

4. Simulation assumptions

In this section, the simulation environment used for carrying out the computer simulation experiments is described. An important assumption used in the simulation is that a packet is discarded if there is an error in the access code, The Header, or Payload field, was not corrected using the error correction scheme. This is a realistic assumption to simulate the real Bluetooth systems' operation [22]. This assumption is employed to measure the number of corrupted packets, but the received packets are recollected after the decoding process for reconstruct the received audio signal.

In the simulation, HV_3 packet is replaced by DH_1 (ACL packet). The length of DH_1 uncoded packet is 240 bits. There are two types of audio files used in the
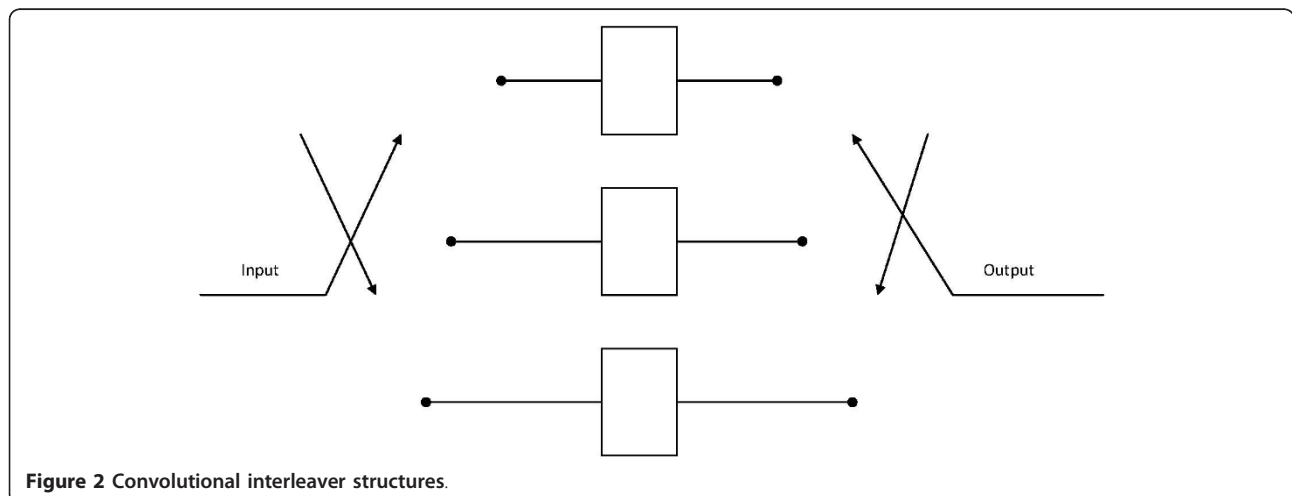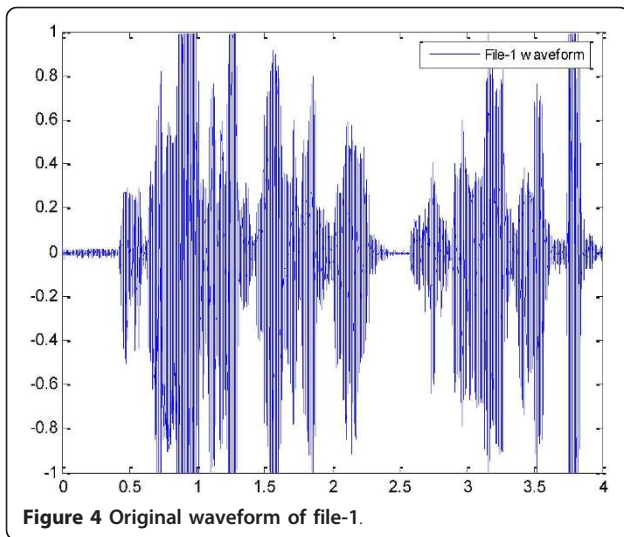

Figure 2 Convolutional interleaver structures.

Figure 3 Chaotic encryption of an 8 × 8 matrix. (a) Original square matrix. **(b)** Chaotic encrypted matrix.

simulation: the audio file-1 (32 kbytes). Its characteristics are bit rate 64 kbps, audio sample size 8 bit, channel 1 mono, audio sample rate 8 kHz, and audio format PCM; and the audiofile-2 (92 kbytes), whose file characteristics are as follows: bit rate 88 kbps, audio sample size 8 bit, channel 1 mono, audio sample rate 11 kHz, and audio format PCM. Tables 1 and 2 show the properties of the audio files [23,24].

In the simulation, there are many different packet formats employed for audio transmission, and. also a block-fading channel is assumed. It is a slow and frequency nonselective channel, where symbols in a block undergo a constant fading effect, meaning that the Doppler spread equals zero (F_d = 0). Also, the Jakes' model is utilized for simulating the correlated Rayleigh fading channel. The mobile Bluetooth device velocity is up to 20 mile/h, and the carrier frequency is 2.481 GHz. The phase difference between the paths is given from Equation 2. The Doppler spread is expressed in Equation 3 [25].

$$\Delta\phi = \frac{2\pi\,\Delta l}{\lambda} = \frac{2\pi v_c \Delta t}{\lambda}\cos\theta \tag{3}$$

$$F_d = \frac{1}{2\pi}\cdot\frac{\Delta\phi}{\Delta t} = \frac{v_c}{\lambda}\cdot\cos\theta \tag{4}$$

The obtained binary data are used to build the audio file again. The waveform of received audio signal is compared to original waveform of transmitted signal to evaluate the effects of the proposed modifications. In this study, the audio signal is transmitted and interleaved using the bit-level interleaving and the convolutional interleaving over the fading channels. Figures 4 and 5 show the original waveform of audio files 1 2, respectively. MATLAB was used for carrying out the simulations of different scenarios. The simulation results have been acquired by the transmission of audio files over different SNR values.

Table 1 Simulation audio signal (file-2) parameters

Parameter	Description
Bit rate	88 kbps
Audio sample size	8 bit
Channel	1 (mono)
Audio sample rate	11 kHz
Audio format	PCM
File size	92 kbytes
Duration	8 s

Table 2 Simulation audio signal (file-1) parameters

Parameter	Description
Bit rate	64 kbps
Audio sample size	8 bit
Channel	1 (mono)
Audio sample rate	8 kHz
Audio format	PCM
File size	32 kbytes
Duration	4 s

Figure 4 Original waveform of file-1.

5. Simulation results

In this section, the performance of the proposed transmission audio signal through ACL link over correlated and uncorrelated Rayleigh fading channels is studied through simulation. For the comparison purpose, using different scenarios, non-interleaving, bit-level interleaver, convolutional interleaver, and the proposed chaotic randomizing techniques are also simulated. In the case of correlated Rayleigh fading channel, the Jakes' model is used in the simulation.

In this section, there are many simulation scenarios devoted for evaluating the proposed scenarios of the audio signal transmission.

5.1. Short classic packets DH$_1$

This simulation studies the interleaving effects on the received waveform of audio signal over Rayleigh fading channel. The file-2 is transmitted over uncorrelated Rayleigh fading channel using the DH$_1$ packets. Figure 6 illustrates the waveform of received audio signal at SNR = 25 dB. It is clear that using the interleaving improves received waveform at the same SNR value.

As shown in Figure 6, the bit-level interleaving scenario performs better than other scenarios in this simulation over an uncorrelated Rayleigh fading channel.

The previous computer simulation is repeated over a correlated fading channel. This simulation is devoted to indicate the velocity (V_c) of the mobile terminal on the waveform of the received audio signals. The simulation utilized the Jakes' model communication channel. The result of this simulation is given in Figure 7, this figure shows the waveform of the received audio

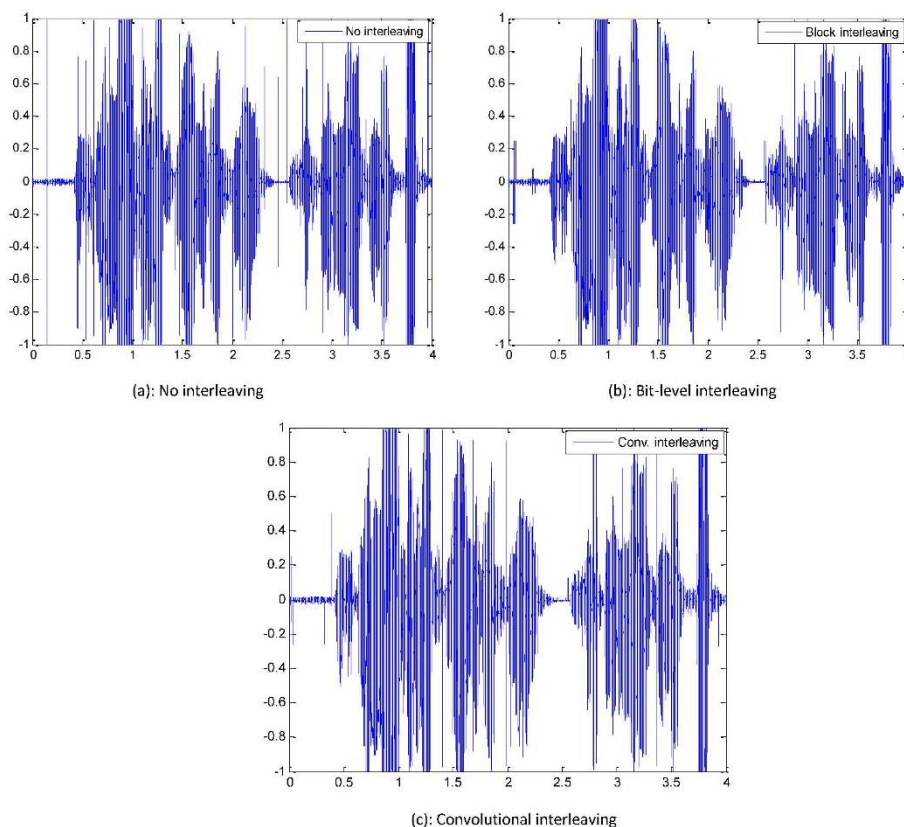**Figure 5 Original waveform of file-2**.

Figure 6 Received audio signal of file-2 waveform over uncorrelated fading channel at SNR = 25 dB. (a) No interleaving. (b) Bit-level interleaving. (c) Convolutional interleaving.
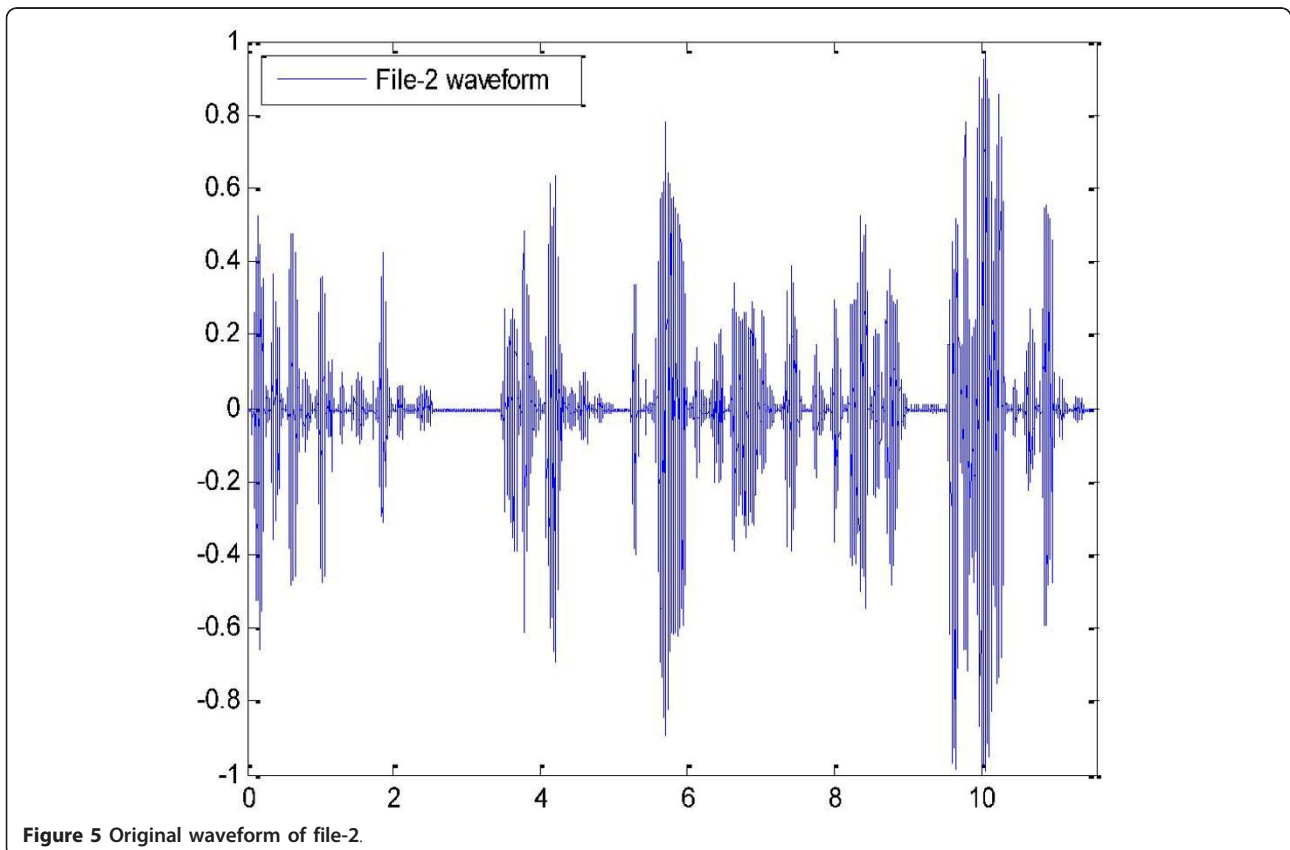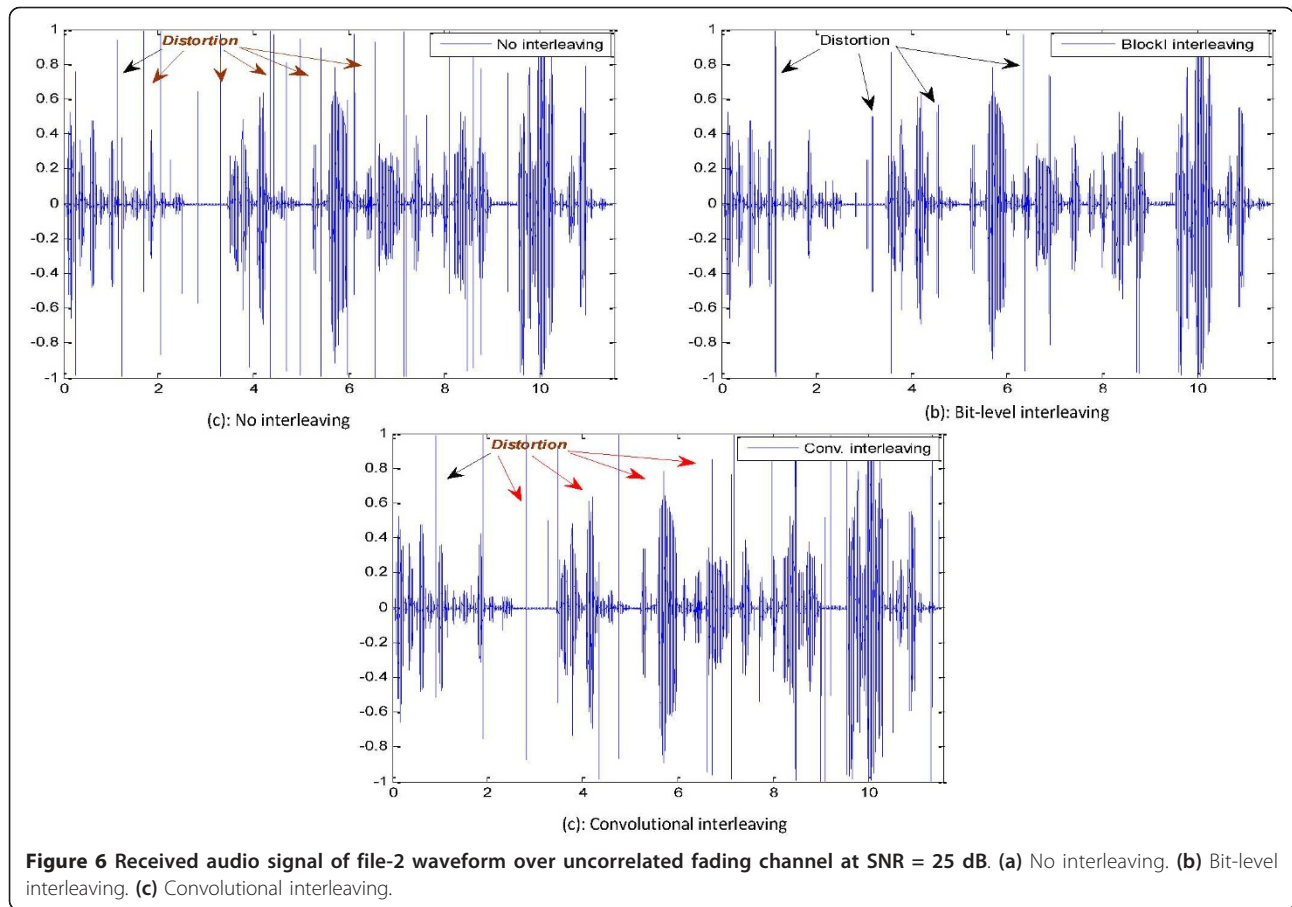
signal with assuming the velocity of the mobility is 3 and 10 mile/h.

The result of this simulation reveals that the mobility of the transmitter increases the distortion of the received audio signal. Also, the audio signal transmission needs strong interleaving technique to spread the errors and reduce the bad mobility effects.

In the following simulation, the interleaving effect on the received waveform of audio signal over uncorrelated fading channel is studied. The file-1 is transmitted using the uncoded classic DH_1 packets. Figure 8 illustrates the waveform of received audio signal at SNR = 20 dB. It is clear that using the interleaving improves received waveform at the same SNR value. The audio file-1

Figure 7 Received audio file-2 signal waveform over a correlated fading channel at SNR = 25 dB. (a) V_c = 3 mile/h. (b) V_c = 10 mile/h.
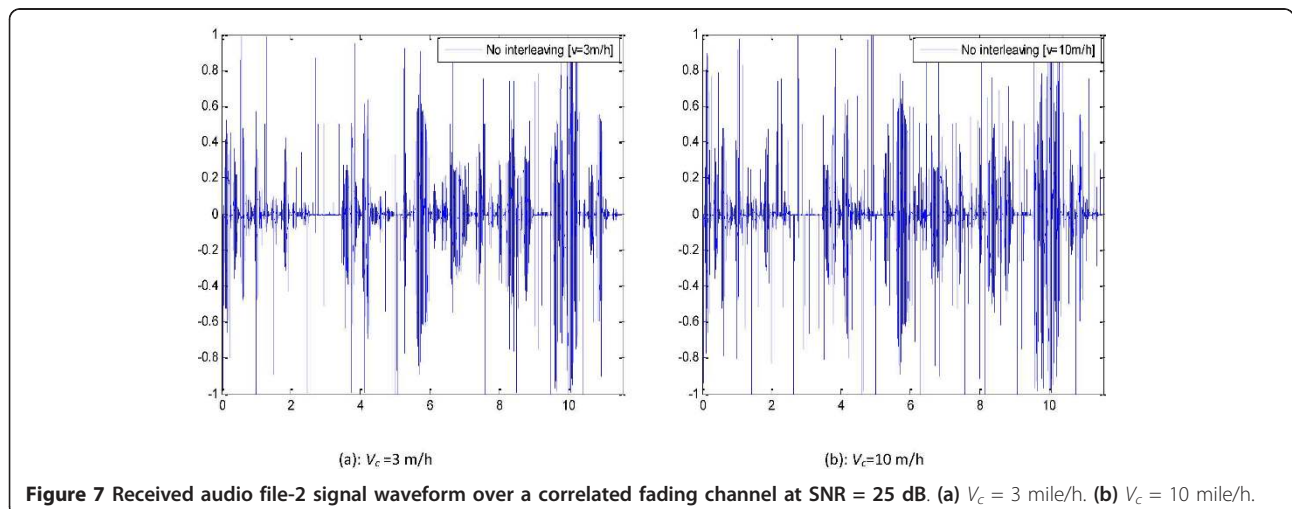
Figure 8 Received audio signal of file-1 waveform over uncorrelated fading channel at SNR = 20 dB. **(a)** No interleaving. **(b)** Bit-level interleaving. **(c)** Convolutional interleaving.

characteristics match the Bluetooth specifications as mentioned previously. As shown in this simulation results, the waveforms of the received audio signals clear that the bit-level interleaver performs better than the convolutional interleaver. Figure 8 also reveals that the convolutional interleaver enhances the waveform of the received audio signal more than the no interleaving scenario.

In the last simulation of this section, the audio file-2 is transmitted over a correlated Rayleigh fading channel $[V_c = 10$ mile/h] using the DH_1 packets. Figure 9 illustrates the waveform of received audio signal at SNR = 20 dB. It is clear that the convolutional interleaver scenario performs better than other scenarios over a correlated fading channel.

In the previous simulation, the performance of the audio signals transmission is studied over uncorrelated and correlated fading channels with different mobility velocities. These simulation scenarios indicated that there are bad effects of the mobility on the received audio signal waveforms. Also, it reveals that the interleaving techniques improve the audio waveforms. In the following section, the simulation evaluates the proposed

interleaving technique which is the chaotic randomizing technique, based on the chaotic Baker map.

5.2. Randomizing technique

In this section, the simulation results of the proposed technique are presented. The simulation senarios have been carried out for different types of Bluetooth packets; $2DH_1$ and $2DM_1$ with the different signal-to-noise ratios (SNRs). The peak SNR, the absolute number of lost frames (NLF), NLF percentage (NLF %), bit error rate (BER), and the correlation coefficient (Cr) are employed for measuring the correlation between the original and the received images; the mean square error (MSE) and the throughput (T) are used for performance evaluation of the Bluetooth network in the different simulation scenarios [26]. The MSE is the cumulative squared error between the received audio signal and the original signal. The mathematical formula for MSE is given in Equation 4 [27].

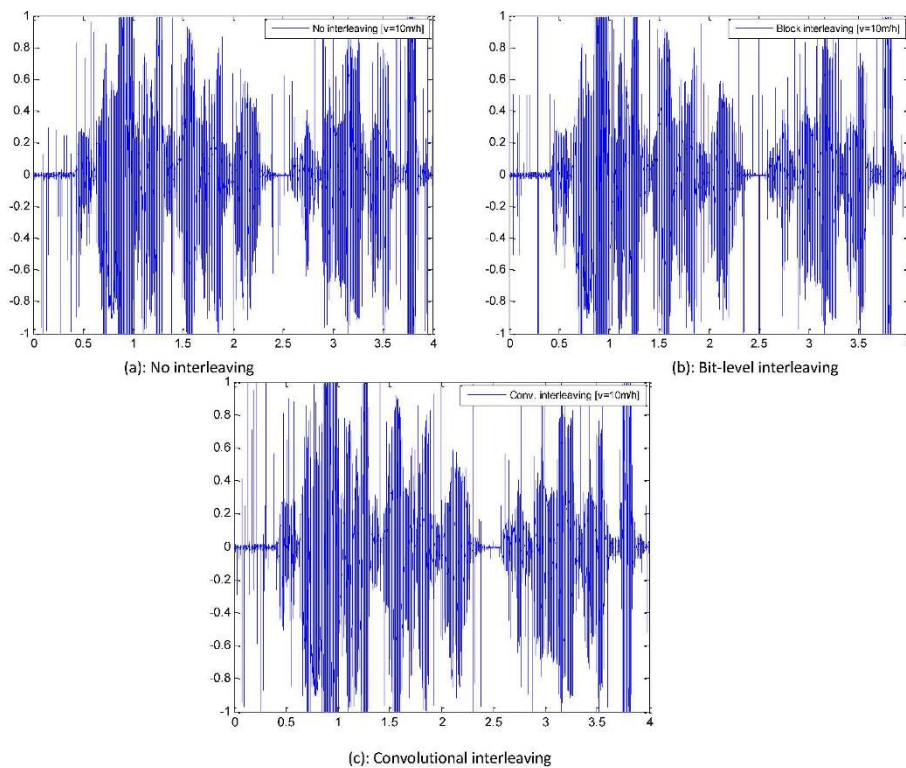$$MSE = \frac{1}{MN} \sum_{\gamma=1}^{M} \sum_{x=1}^{N} \left[I(x, \gamma) - I'(x, \gamma) \right]^2 \tag{5}$$

Figure 9 Received audio signal of file-1 waveform over a correlated fading channel (V_c = 10 mile/h) at SNR = 20 dB. (a) No interleaving. **(b)** Bit-level interleaving. **(c)** Convolutional interleaving.

The throuput is defined as [28]

$$T = \frac{P_l(1 - PER)}{(x + 1)\,t} \tag{6}$$

where P_l is the payload length, PER is the packet error rate, x is the number of time slots occupied by the Bluetooth packet, and t is the duration of the Bluetooth time slots.

In the following, the EDR Bluetooth packets are used for transmitting audio signal over mobile Bluetooth network. The proposed Bluetooth terminal velocity (V_c) is 10 and 3 mile/h and the frequency carrier is 2.46 GHz. As shown in the following results, with increasing the velocity of Bluetooth terminal, the performance is degraded and the effect of channel on the transmitted signal is increased. Figure 10a gives the frame error rate (FER) of standard 2DH$_1$ and proposed 2DM$_1$ packets which is used for transmitting the audio signal with many proposed cases at V_c = 3 mile/h. Figure 10b gives FER at V_c = 10 mile/h. Figure 11 gives the comparison of NFL and FER with the velocity variations with the standard uncoded packets.

From the previous section, the following is concluded: Over mobile Bluetooth network, the quality of audio transmission is decreased with V_c increasing. Traditional block interleaving of audio file is inefficient over mobile network. The proposed encoded EDR packets with block interleaving of encoded packet performs better than encoded packets (2DM$_1$), which represents 2EV$_3$ voice packets. The performance of standard packets (2DH$_1$) is very bad compared with proposed cases.

Also in this section, the proposed different scenarios for studying the audio signal performance with the proposed randomize techniques are presented. The results of these scenarios are shown in Figure 12. The results of this simulation indicate the effects of the mobility on the audio signal. As shown in this figure in case of V_c = 3 mile/h, the NFL of the whole simulation scenarios are much closed but with V_c = 10 mile/h its performance became different.

As shown in the previous results, the randomize technique which is based on the chaotic Baker map concepts scenario performs better than other technique. From these results, the proposed chaotic interleaver packet by packet basis is presented as a novel efficient interleaver. The proposed technique is evaluated through two groups of simulations according to the type of packets which is employed for the proposed technique testing. These packets are the uncoded 2DH$_1$ and encoded 2DM$_1$ EDR packets.
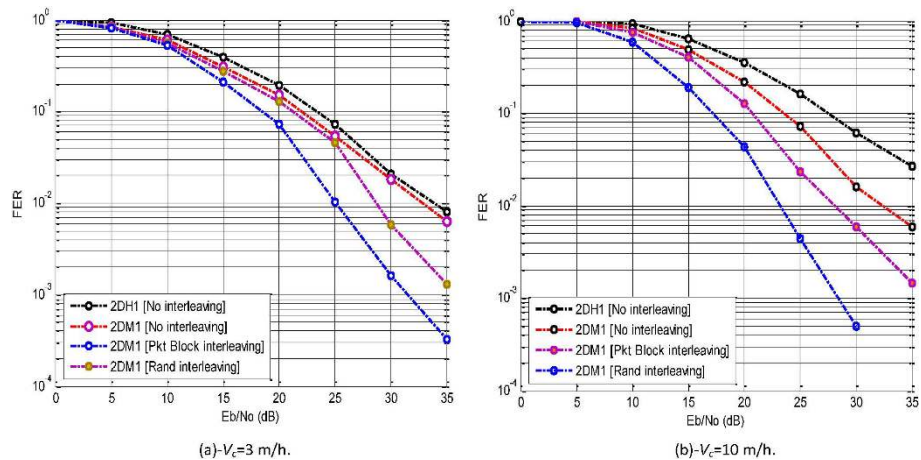
Figure 10 FER of audio signal versus SNR over correlated fading channel. (a) V_c = 3 mile/h. (b) V_c = 10 mile/h.

5.3. The mobility effects on the audio transmission performance

This section is devoted for studying the effects of the mobility of the wireless ad hoc network device (V_c) on the transmitted packets and the received audio signals. In this computer simulation, the v is 1 up to 20 miles/h. Figures 13, 14, and 15 show the NLF, Cr, and MSE variation with the channel SNR with the shortest EDR uncoded packets 2DH$_1$, respeceively. It is clear that with increasing the V_c of the terminal the NLF increased and the correlation between the original audio signal and the received signal is decreased. As shown in Figure 13, the MSE increased with the velocity increasing. Figure 16 gives the throughput variation with the different velocity of the mobility. So, these results indicate the

mobility effects on the different metric of the perfromance evaluation.

The previous results reveal that it should be finding efficient technique for reducing the bad effect of the mobility on the audio signal transmission. In the following simulation scenarios, number of scenarios are proposed for this purpose. The proposed scenarios are applied on different packet lengths. These scenarios depend on that the interleaving technique is an efficient method for anti-fading, and is raised to solve serious long burst interference in some fading channels. The proposed scenarios are tested in two groups of the EDR packets with different velocities with employing the widely accepted Jakes' model to modelate the simulation environment. Figure 17 gives the waveforms
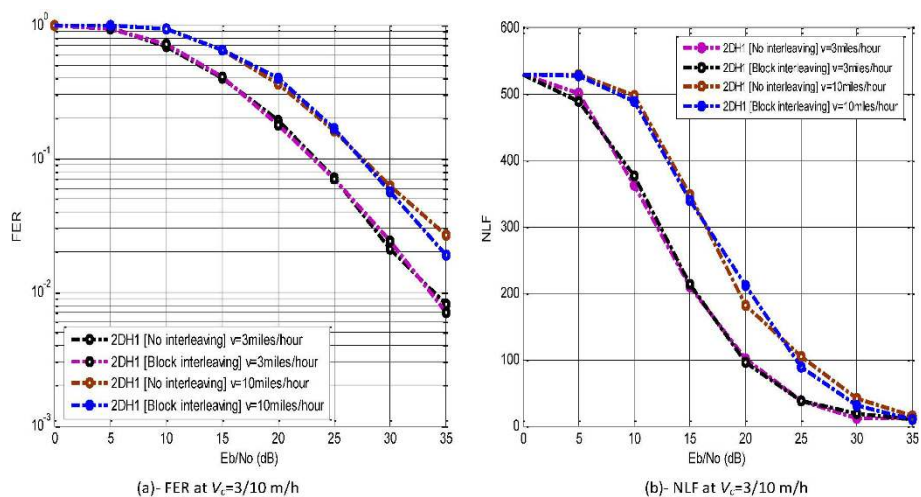
Figure 11 FER and NFL of audio signal versus SNR over correlated fading channel. (a) FER at V_c = 3/10 mile/h. (b) NLF at V_c = 3/10 mile/h.
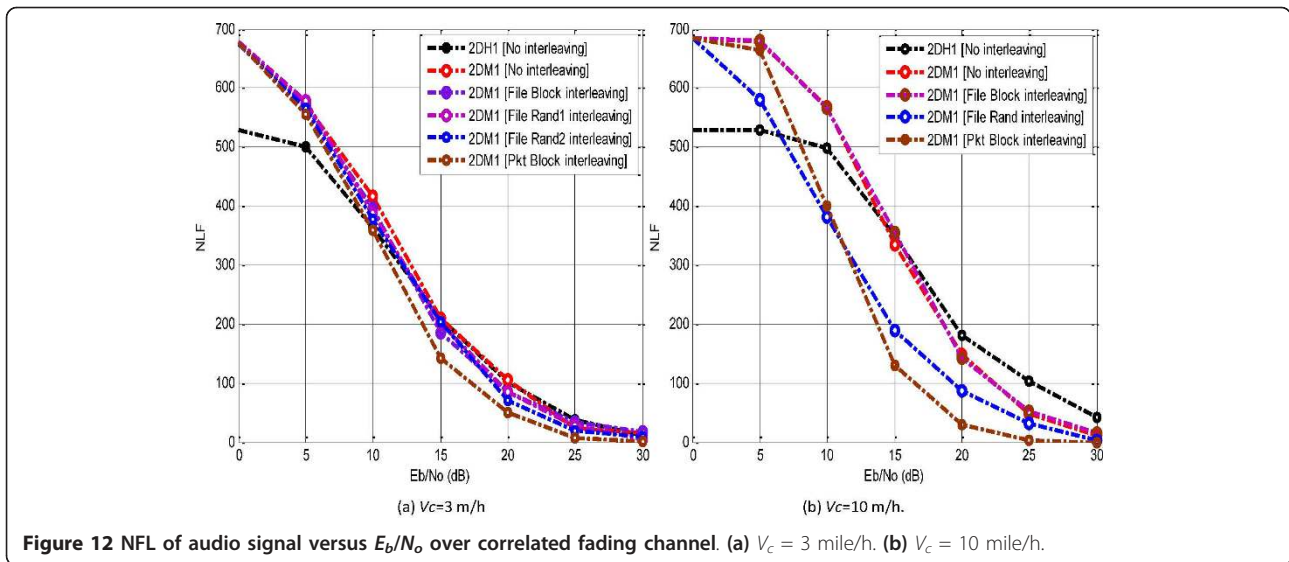
Figure 12 NFL of audio signal versus E_b/N_o over correlated fading channel. **(a)** V_c = 3 mile/h. **(b)** V_c = 10 mile/h.
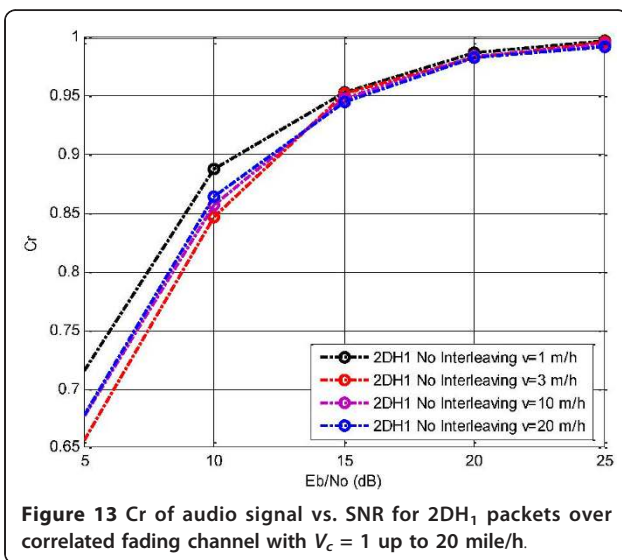
Figure 13 Cr of audio signal vs. SNR for 2DH$_1$ packets over correlated fading channel with V_c = 1 up to 20 mile/h.
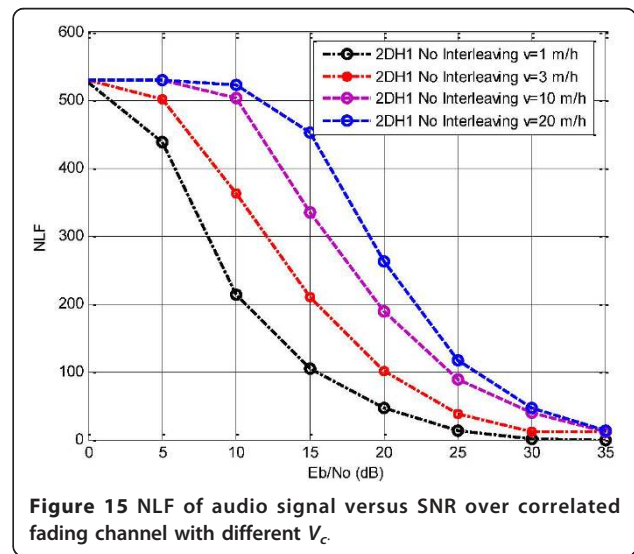
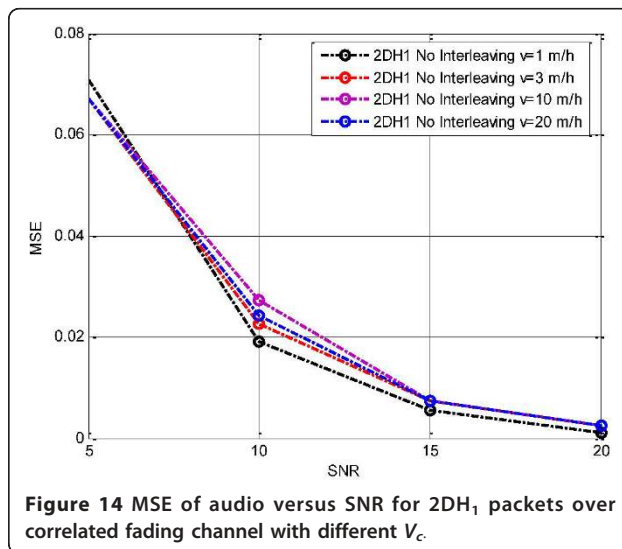**Figure 15 NLF of audio signal versus SNR over correlated fading channel with different V_c.**

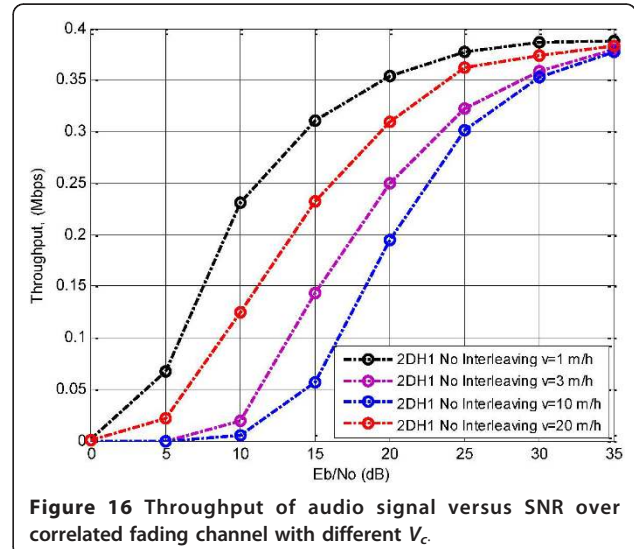**Figure 14 MSE of audio versus SNR for 2DH$_1$ packets over correlated fading channel with different V_c.**

Figure 16 Throughput of audio signal versus SNR over correlated fading channel with different V_c.

a- V_c =1 m/h, Cr=0.953.

b- V_c =3 m/h, Cr=0.952.

c- V_c =10 m/h, Cr=0.947.
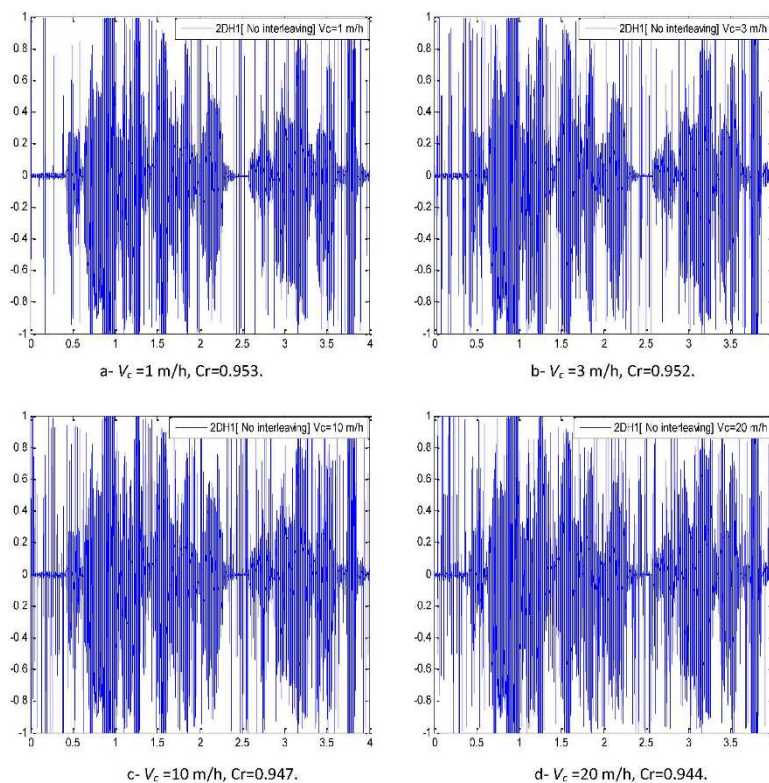
d- V_c =20 m/h, Cr=0.944.

Figure 17 Audio signal transmission using 2DH$_1$ packets over a correlated Rayleigh fading channel at SNR = 15 dB with different V_c. **(a)** V_c = 1 mile/h, Cr = 0.953. **(b)** V_c = 3 mile/h, Cr = 0.952. **(c)** V_c = 10 mile/h, Cr = 0.947. **(d)** V_c = 20 mile/h, Cr = 0.944.

a- 2DH$_1$ [No interleaving], Cr=0.953.

b- 2DM$_1$ [No interleaving], Cr=0.957.

c- 2DM$_1$[Block interleaving], Cr=0.97.

d- 2DM$_1$[Chaotic randomizing], Cr=0.98.
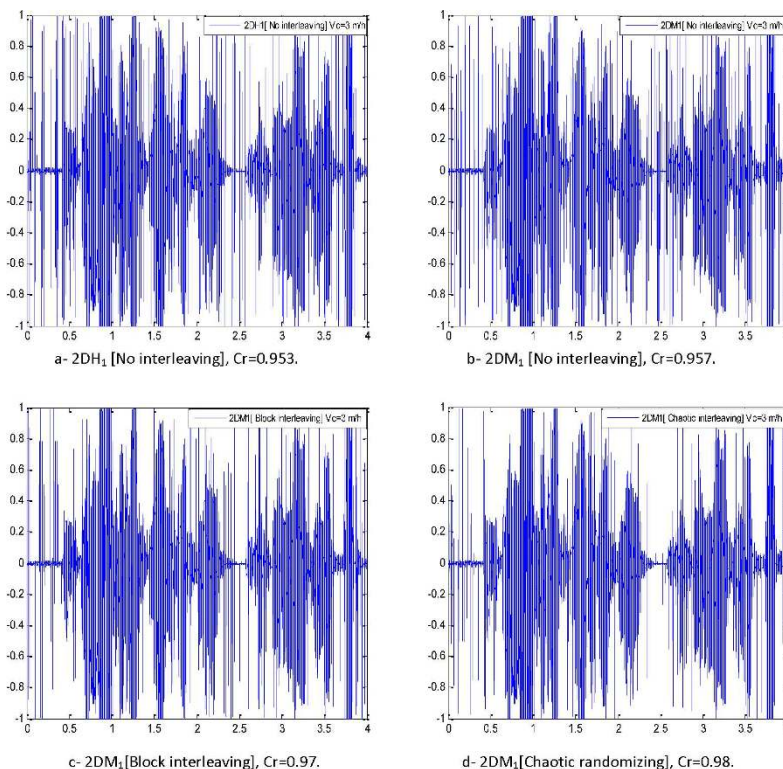
Figure 18 Audio signal transmission using 2DH1&2DM$_1$ packets over a correlated Rayleigh fading channel at SNR = 15 dB with different scenarios {V_c = 3 mile/h}. **(a)** 2DH$_1$ (No interleaving), Cr = 0.953. **(b)** 2DM$_1$ (No interleaving), Cr = 0.957. **(c)** 2DM$_1$ (Block interleaving), Cr = 0.97. **(d)** 2DM$_1$ (Chaotic randomizing), Cr = 0.98.

of the received audio signal with different V_c of the mobility.

5.4. Audio signal transmission using 2DH$_1$ and 2DM$_1$ packets

This section is devoted to test the efficiency of audio transmission using the short uncoded 2DH$_1$ and encoded 2DM$_1$ EDR packets with the different scenarios. In the first computer simulation, the audio signal has been transmitted over a correlated fading channel with an SNR = 15 dB. The results of this simulation are shown in Figure 18. From these results, it is clear that the effect of the proposed randomizing interleaving based on the chaotic Baker map is better than that of the other schemes. As shown in Figure 18, the waveform of the received audio signal is improved with the proposed scenarios. The proposed velocity of the mobility in this simulation is $V_c = 3$ mile/h.

Figures 19 and 20 show the variation of the Cr and the MSE of the received audio signals with the channel SNR, respectively. These figures reveal that the proposed chaotic interleaver improves the quality of the received audio signal. It increases the correlation and decreases the error between the received and the original signals. Figure 21 indicates the effectiveness of the proposed scenarios on the error performance through the BER variation with the channel SNR. As shown in this figure, the error spreading capability of the proposed chaotic randomizing technique enhances the error performance over the mobile channel for the audio signal transmission. Figure 22 gives the NLF % variation with the channel SNR. The effect of the velocity on the dropped packets is indicated in Figure 15 for the uncoded 2DH$_1$ EDR packets, in this simulation the dropped packets are
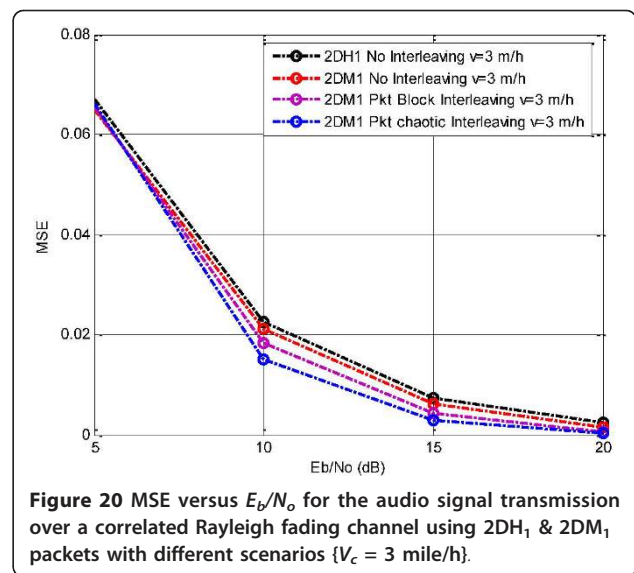

Figure 20 MSE versus E_b/N_o for the audio signal transmission over a correlated Rayleigh fading channel using 2DH$_1$ & 2DM$_1$ packets with different scenarios {$V_c = 3$ mile/h}.

calculated as percentage where the audio file is segmented and transmitted through uncoded and encoded packets.

In the previous simulation, the mobility effect is studied on the audio signal transmission in a fixed and mobile communication channels in many of scenarios. Also, it evaluates the proposed chaotic interleaver on the whole audio file and packet-by-packet basis. The simulation results reveal that the ACL link improves the throughput of the audio signal. Also, the interleaving techniques enhance the received audio signals. The proposed data randomizing tool performs better than traditional interleavers over the mobile Bluetooth network. As shown in the results, the MSE and Cr of the received
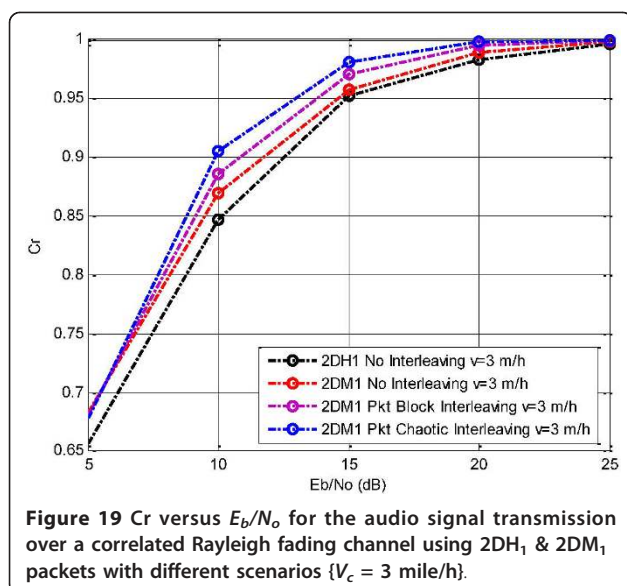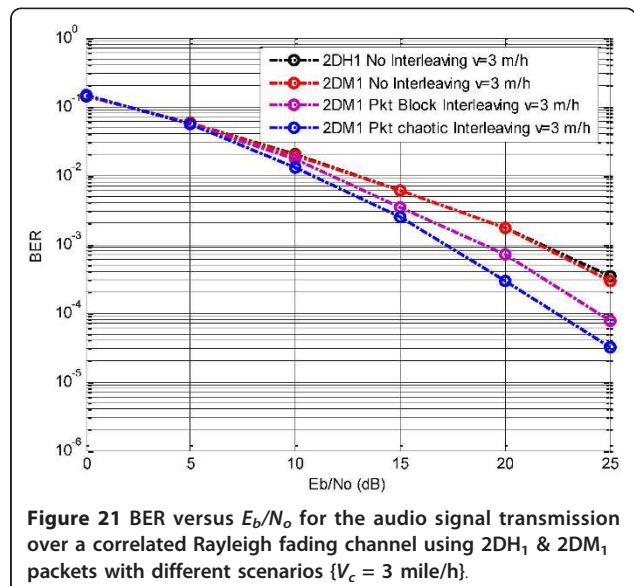

Figure 19 Cr versus E_b/N_o for the audio signal transmission over a correlated Rayleigh fading channel using 2DH$_1$ & 2DM$_1$ packets with different scenarios {$V_c = 3$ mile/h}.
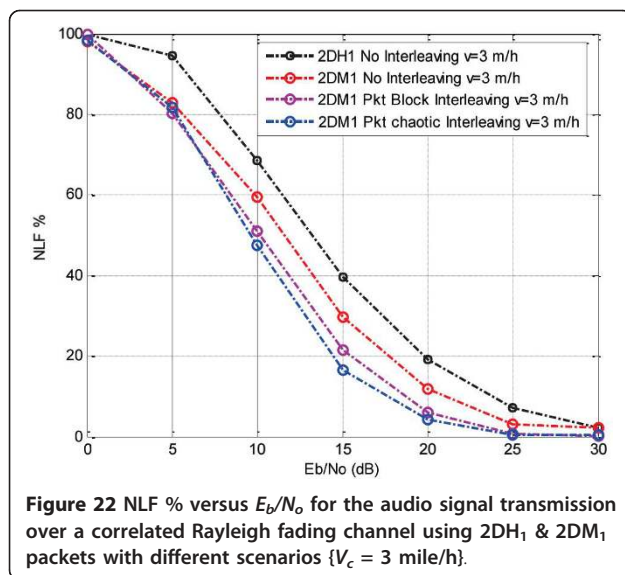

Figure 21 BER versus E_b/N_o for the audio signal transmission over a correlated Rayleigh fading channel using 2DH$_1$ & 2DM$_1$ packets with different scenarios {$V_c = 3$ mile/h}.

Figure 22 NLF % versus E_b/N_o for the audio signal transmission over a correlated Rayleigh fading channel using 2DH$_1$ & 2DM$_1$ packets with different scenarios {V_c = 3 mile/h}.

audio signals are improved by applying the proposed scenario of the chaotic randomizing technique.

6. Conclusions

In this article, the transmission of voice using ACL link is discussed. In the simulation two different audio files and different interleaver types were used. The simulations were carried out over Rayleigh correlated and uncorrelated fading channels. The simulation results reveal that over uncorrelated fading channel the best choice is bit-level interleaver in case of the classic uncoded packets, whereas over correlated fading channel, the convolutional interleaver is efficient. Also, the effectiveness of the interleaving techniques is inefficient with audio file that has higher bit rate than 64 kbps. The ACL link is an efficient for carrying voice unless there is a need for high-quality voice. Using this link for carrying voice also leads to improving the throughput. ACL link is a suitable choice for carrying voice specially with using interleaving technique. The article proposes a novel data randomizing tool for enhance the quality of the audio signal transmission over ACL link. The proposed chaotic technique performs better than the traditional interleaver over the mobile channel. It can be then applied on the EV packets and on the mobile Ad hoc network. It reduces the packet loss of the transmitted audio file and also it is an efficient tool for decreasing the mobility bad effects on the transmitted audio signals.

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