Performance of Analog and Digital Modulation Schemes Under Sweep Jamming

Dong-Yeol Choi, Dong-Hak Lee, and Jae-Hyun Kim  
School of Electrical and Computer Engineering  
Ajou University  
Suwon, Republic of Korea  
Email: acdy, inspire109, jkim@ajou.ac.kr

Huirae Cho  
National Security Research Institute  
Dajeon, Republic of Korea  
Email: huirae@nsr.re.kr

Abstract—Wireless Communications is used in various applications and the number of wireless devices has also increased over the past several decades. However, wireless communication systems may be significantly affected by interference signal. In this paper, the carrier to noise ratio (CNR) or the bit error rate (BER) performance of Amplitude Modulation (AM), Frequency Modulation (FM), MPSK (M-array Phase Shift Keying), MFSK (M-array Frequency Shift Keying), Minimum Shift Keying (MSK) and Gaussian Minimum Shift Keying (GMSK) have been evaluated under sweep jamming as an intended interference. In addition, we measured the quality of received audio signal by perceptual evaluation of speech quality (PESQ). From the result of performance analysis, we concluded that orthogonal frequency-division multiplexing (OFDM) sweep jamming severely affects power of the transmission signal and chirp sweep jamming provided a strong influence over the phase and frequency of the transmission signal. By using our simulators, it is possible to determine an appropriate modulation scheme according to the channel environment. In addition, we know the parameter of jammer for blocking the unnecessary communications.

Keywords—Modulation, Intended interference, Jamming, BER, PESQ, Chirp, OFDM.

I. INTRODUCTION

The number of wireless devices has been increasing over the past several decades. Owing to the open features of wireless communication, security has become an important issue. If someone uses a generator of interference signal for malicious purposes, it seriously affects the reliability of wireless communication especially in military communication systems [1].

The interference can be divided into two different type. One as unintended interference and the other as intended interference. Unintended interference is caused by radiating signals from all kinds of the wireless devices. This interference is not aimed at any wireless system target. Intended interference is known as jamming and aims to disturb the information transmission of particular wireless communication systems. Recently, the damage case of wireless communication system caused by jamming is increased. An example of jamming incidents that jamming signal caused disruption to the South Korean mobile phones and navigational devices using global positioning system (GPS) in 2011 [2]. This jamming signal prevented the user from obtaining accurate information. So, the analysis of the effects of jamming in the efficiency of data transmissions is required to find an adequate anti-jamming method [3]. We consider the chirp signal and the OFDM signal of changing carrier frequency according to time as the sweep jamming signal. Sweep jamming combines the properties of both spot noise jamming and barrage noise jamming by rapidly sweeping of a narrow band of jamming signals over a wide frequency band [4].

In this paper, we analyze the performance of analog modulation schemes of AM, FM and digital modulation schemes of MPSK, MFSK, MSK and GMSK under sweep jamming environment. In addition, the objective speech quality of the demodulated signal was measured by PESQ in different modulation schemes under sweep jamming and we can assumed that it is possible to obtain the objective degree of speech quality from the user’s experience [5]. The result of simulation enables to verify the reliability of the wireless communication systems in accordance with the respective modulation schemes. Moreover, invented simulator can be used as an engineering guideline for the wireless communication systems in the development phase.

II. SYSTEM MODEL

In this section, we propose a system model as shown in Figure 1. The input data is audio signal. In analog system, the input data is processed through modulation without pulse code modulation (PCM) encoding. Using the digital system, the input data is processed through modulation after PCM encoding. Using PCM, it is possible to digitize forms of analog data. For a 4 kHz voice channel, the sampling rate is 8 kHz by

![Figure 1. System block diagram](image-url)
the Nyquist-Shannon sampling theorem. The number of quantization levels is 256. This is sufficient to distinguish the voice. Thus, 64 kbits per second are obtained after quantizing the eight bits per sample. We assumed that the wireless channel is a free space environment which only considered jamming signal and path loss without other interference. We assumed the jamming model is sweep jammer using OFDM signal and chirp signal. After demodulating the received signal, we evaluate the performance of analog and digital modulation schemes under sweep jamming.

A. Jamming Signal Model

We consider a sweep jammer using an OFDM signal or chirp signal as a jamming model. Jammers sweep the frequency from 20 MHz to 6 GHz according to time. OFDM sweep jammer radiates the OFDM signal during the radiating time ($T_{\text{rad}}$). After the time of radiating OFDM signal, Jammer does not radiate the jamming signal during the PLL time ($T_{\text{ll}}$). OFDM signal has a 40 MHz of bandwidth and sets the number of the subcarriers as 1024, 2048 and 4096 respectively. Chirp sweep jammers have a sinusoid where its frequency increases linearly and referred to as the linear frequency modulation (LFM). The chirp signal can be expressed as

$$f(t) = f_0 + kt, \quad k = \frac{f_1 - f_0}{T_{\text{sw}}}.$$  \hspace{1cm} (1)

Where $k$, $f_1$, $f_0$, and $T_{\text{sw}}$ denote the chirp rate, starting frequency, final frequency, and sweep period that the time it takes to sweep from $f_0$ to $f_1$, respectively.

B. Transmission Signal Model

The analog and digital modulation schemes are considered in the modulation step. Table 1 shows the key parameters of each modulation scheme. The carrier frequency of the modulated signal is assumed to 900 MHz.

<table>
<thead>
<tr>
<th>TABLE I. PARAMETERS OF EACH MODULATION SCHEMES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulation</strong></td>
</tr>
<tr>
<td>AM</td>
</tr>
<tr>
<td>FM</td>
</tr>
<tr>
<td>PSK</td>
</tr>
<tr>
<td>FSK</td>
</tr>
<tr>
<td>MSK</td>
</tr>
<tr>
<td>GMSK</td>
</tr>
</tbody>
</table>

III. SIMULATION RESULT AND DISCUSSION

In this section, we evaluate the CNR or BER performance of each modulation scheme in accordance with varying the power of the jamming signals. Figure 2 shows that CNR performance of AM and FM under sweep jamming. CNR is linearly decreased according to jamming to signal ratio (J/S) for all cases. For OFDM jamming, CNRs are similar regardless of the number of subcarriers, AM and FM. However, changing of $T_{\text{ll}}$ causes small differences of CNR because OFDM sweep jammer does not radiate any signal during the $T_{\text{ll}}$. The FM shows about 0.5 dB gain in this case. For the chirp jamming, CNR performance of AM is stable relative to FM. The CNR of AM also better than that of AM with OFDM sweep jamming. Thus, we can assume through the result that the chirp sweep jamming causes frequency and phase error more so than amplitude error.

Figure 3 shows the BER performance of the digital modulation schemes under an OFDM sweep jamming environment. The number of subcarrier of the OFDM signal is set as 4096 and $T_{\text{ll}}$ is set as 15 $\mu$s. As can be seen from Figure 3, BER of digital modulation schemes is increased exponentially. When the J/S is larger than 30 dB, BER of all digital modulation schemes is measured higher than 0.1. In OFDM jamming, BER performance of BPSK and GMSK are
similarly measured and best stable digital modulation schemes. On the other hand, BFSK and MSK are not reliable for the OFDM sweep jamming.

Figure 4 shows the BER performance of the digital modulation schemes under chirp jamming environment. The sweep period of chirp jamming is $20\,\mu \text{s}$ . From Figure 4, it can be seen that the BER of digital modulation schemes increased rapidly from a certain point. GMSK outperforms other digital modulation schemes because the Gaussian filtering in GMSK improved spectral efficiency by limiting interference more than other modulation schemes. We also can guess that sweep jamming using chirp signal affects the frequency and phase of transmission signals.

Figures 5 and 6 show that the evaluation of speech quality of the received signal when using the digital modulation method. When bit errors occurred, PESQ is measured without regularity and has been slightly fluctuant.

IV. CONCLUSION

In this paper, we evaluated the CNR or BER performance of AM, FM, PSK, FSK, MSK, and GMSK under sweep jamming environment. From the result of simulation, we concluded that BER performance BPSK is the best under OFDM sweep jamming and GMSK is stable modulation for chirp jamming. In analog system, the CNR of AM is seriously affected by the OFDM sweep jamming. On the contrary to AM, CNR of FM is weak for the chirp jamming. We also measured PESQ to analyze the quality of speech. The simulator can be used as an index of evaluation of wireless communication systems.

REFERENCES