2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

Performance Improvement of 7200 bps IMBE Vocoder with Improved FEC

Ali Ekşim and Hasan Yetik
TUBITAK BILGEM UEKAE, P.K. 74, 41470, Gebze, Kocaeli, TURKEY

Abstract

APCO Project 25 (P25) digital radios became widespread for either government or personal communication in the last two decades. Since the P25 standards are quite old, performance of its voice services is not satisfactory when compared to today's standards. Although 7200 bps Improved Multi-band Excitation vocoder used in P25 incorporates a decent rate of forward error correction, it does not provide fine error correction for noisy communication channels. In order to improve performance of P25 radios, we proposed a better forward error correction scheme which consists of 11/18 punctured convolutional coder and Viterbi decoder. The proposed forward error correction scheme provides 4.82 dB coding gain hence increases the performance of P25 radios.

1. Introduction

APCO Project 25 digital radios are employed in public and private safety systems worldwide [1,2,3,4]. However, P25 digital radio is primarily developed for North American public safety services. P25 is developed by the governance of collaboration of state, local and federal representatives and Telecommunications Industry Association (TIA) [1]. P25 Phase 1 utilizes a 12.5 kHz bandwidth channel using Frequency Division Multiple Access (FDMA) access method and the Improved Multi-Band Excitation (IMBE) vocoder. Additionally, all P25 Phase 1 radios mandated to adopt the Common Air Interface (CAI) and the IMBE vocoder components in order to comply with P25 standards [2].

IMBE speech coding technology provides crisp speech quality, while utilizing fairly low computational power and memory. It is also resistant to background noise. Thanks to good features given above, IMBE has become standard speech coder for digital mobile radio, secure communication systems, satellite communication, commercial aircraft telephony, voice storage and video conferencing. Also in 1992 IMBE speech coder was selected by the TIA as standard speech coder for P25. 7200 bps IMBE speech coder developed by Digital Voice Systems Inc. contains 4400 bps of encoded speech, and 2800 bps of error correction coding [5].

As listed above IMBE vocoder employed in various communication applications. Although it is very popular among low bitrate communication systems, its error correction scheme is fairly simple and consists of block codes. As the technology advances, processing power increases exponentially. What is proposed for 7200 IMBE vocoder forward error correction (FEC) when it was developed, may be limited by those days' processing power or availability. But, today's communication systems can pack enormous processing power in a single chip and thus better FEC.

In this work we proposed a better FEC scheme for 7200 bps IMBE vocoder without changing any properties of vocoder except the existing FEC. Proposed FEC is achieved coding gain of approximately 4.82 dB for a BER value of $P_b = 10^{-5}$. The rest of the paper is organized as follows. In section 2, existing IMBE FEC scheme is reviewed. In section 3, proposed FEC scheme is introduced, by giving performance comparison. Finally, section 4, concludes the paper.

2. Existing IMBE FEC Scheme

Digital Voice Systems Incorporation's (DVSI) AMBE+2™ vocoder library and integrated circuits are fully operable with the current 7200 bps IMBE vocoder that is adopted by P25 standards. IMBE voice coder uses 20 ms long voice frames and produces 144 bits for each frame. 144 bits are consists of 88 encoded voice bits and 56 FEC bits. As seen in Fig. 1, IMBE FEC encoder scheme is consist of four Golay codes and three Hamming codes along with data dependent binary modulation. First 12 bits of the vocoder voice frame is encoded using Golay (23, 12), and this encoded data is used to create a modulation key. Using modulation key, modulation vector can be created to modulate rest of the data to be encoded. Remaining vocoder voice bits are coded with three Golay (23, 12) coded and three Hamming (15, 11) coded and scrambled using the data dependent scrambler sequence created in previous step. Remaining 7 bits are not processed and left unprotected in vocoder frame.

Likewise in IMBE FEC encoder, IMBE FEC decoder employs Golay and Hamming codes along with data dependent binary demodulation. To decode IMBE vocoder frames, first 23 bits decoded using Golay (23, 12) code. Modulation key and modulation vector are generated using this decoded 12 bits. Before decoding Golay and Hamming codes, remaining data excluding unprotected bits should be demodulated. After demodulation process, three Golay (23, 12) and Hamming (15, 11) codes are utilized to decode rest of the data. Unprotected bits are not processed and conveyed to output.

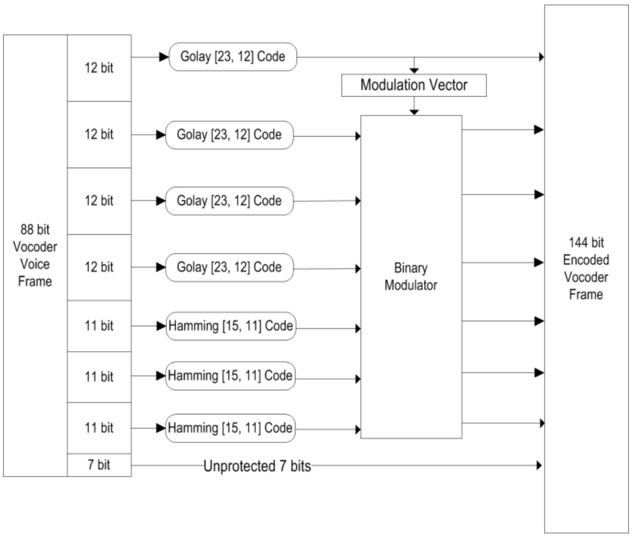

Figure 1. 7200 bps IMBE vocoder FEC encoder

Due to the weak error correction codes and the existence of unprotected bits in voice frames causes the bit error rate to climb up in noisy communication channels. For the communication channels where the SNR is very low or the distortion is high, convolutional codes perform better than block codes [6]. If the SNR level gets below 7.28 dB, impaired voice reconstruction occurs. We can call the 7.28 dB SNR figure as critical value for P25 voice services. This critical value can be lowered by employing convolutional codes in the place of block codes. Additionally, data dependent binary modulation has dramatically important effect on most of the voice bits. If the modulation vector is generated incorrectly, affected bits become erroneous. Hence, it reduces the FEC performance in low SNR conditions. So, we thought the binary modulation should not be utilized in the new FEC scheme

3. Proposed FEC Scheme

The need for better FEC scheme arose from communication loss in noisy environments and reduced communication range in P25 radios. Due to the weak protection by block codes in IMBE FEC, voice frames cannot be recovered and reconstructed in noisy environment or when the received signal strength is low. In such cases, IMBE FEC conveys silence frame or frame repetition in the place of irrecoverable frames. As the SNR level gets below 7.28 dB, voice reconstruction process becomes incapacitated and voice loss occurs.

Although 7200 bps IMBE vocoder frame structure reserves fairly good amount of bits for forward error correction, its coding gain is as low as 1 dB compared to uncoded transmission. One can easily see that the culprit of the low performance of the IMBE FEC scheme is the block codes. If the block codes are replaced with convolutional codes, coding gain with respect to uncoded transmission would be far better. Having said, we proposed an 11/18 rate punctured convolutional code (PCC). Proposed punctured convolutional code can be obtained a 1/2 convolutional code with constraint length 12 and the generator polynomial [6765 4627] [7,8]. Block diagram of proposed 11/18 rate PCC encoder is given in Fig. 2.

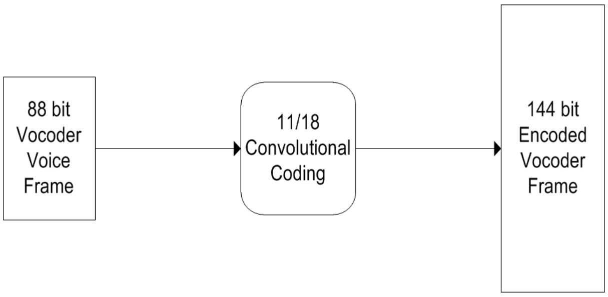

Figure 2. Proposed FEC encoder for 7200 bps IMBE vocoder

In order to compare FEC performance of IMBE and proposed FEC in an additive white Gaussian noise (AWGN) channel, computer simulations are performed using MATLAB. In order to compare performance results, the BER curves of uncoded 4-FSK, IMBE standard and proposed 11/18 punctured convolutional code FEC are given in Fig. 3.

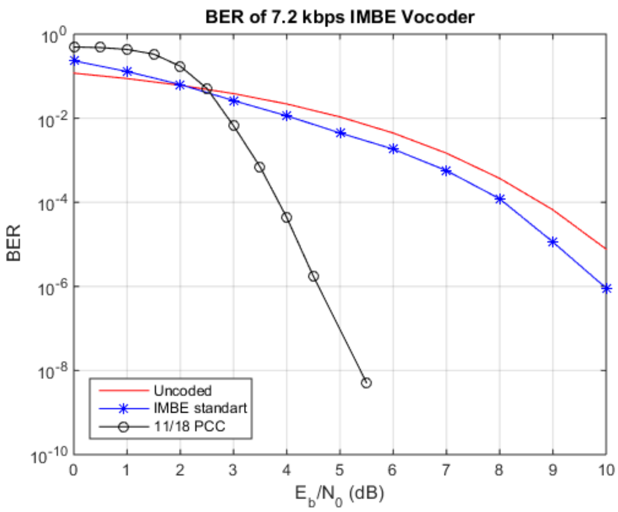

Figure 3. FEC performance of IMBE standard and proposed FEC in AWGN channel

As seen in Fig. 3, proposed FEC scheme outperforms existing IMBE FEC with a coding gain of 4.82 dB for a BER value of $P_b = 10^{-5}$. It also provides an E_b/N_0 advantage of approximately 5.65 dB with respect to the uncoded transmission.

4. Results

7200 bps IMBE speech coder utilized in P25 radios provides superior voice quality in noise free and in low in noise environment. But, when it comes to fairly noisy channels, existing IMBE's weak FEC cannot recover frames and impairs the voice. To increase noisy immunity of the vocoder, we proposed an 11/18 PCC FEC in the place of block codes used in existing IMBE FEC. Since the convolutional codes are far better than block codes in noisy environment, we achieve a coding gain of approximately 4.82 dB.

Better noise performance means increased voice communication performance and communication range. It may also extend the battery life; due to the need of lower RF transmit power.

5. References

1. P. T. I. Group, “Technology benefits to p25”, April 2012.

2. Telecommunications Industry Association. “APCO Project 25 System and Standarts Definition”. Arlington, 1995. TIA/EIA102.A

3. A. Kumbhar, F. Koohifar, İ. Güvenç and B. Mueller, “A Survey on Legacy and Emerging Technologies for Public Safety Communications”, in IEEE Communications Surveys & Tutorials, vol. 19, no. 1, pp. 97-124, Firstquarter 2017.

4. P. Kiley, T. Benedett, “Public Safety Interoperability With an Sca Military Radio Using The P25 Waveform”, Military Communications Conference, IEEE, 2007.

5. DVSI Inc. “AMBE-3003™ Vocoder Chip One IC chip-3 Vocoder Channels User Manual”, March 2011.

6. M. K. Simon, S. M. Hinedi, W. C. Lindsey, Digital Communication Techniques: Signal Design and Detection, Englewood Cliffs, New Jersey, USA:Prentice-Hall, 1995.

7. P. Lee, "Futher Results on Rate 1/N Convolutional Code Constructions with Minimum Required SNR Criterion", IEEE Transactions on Communications, vol. 34, no. 4, pp. 395-399, April 1986.

8. H. Moon, D. C. Cox, "Performance of unequally punctured convolutional codes", IEEE Transactions on Wireless Communications, vol. 8, pp. 3903-3909, August 2009.