

Joint Detection and Evaluation of MODEM and CODEC for Multi-Mode DSRC System

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Abstract—In this paper, the joint detection and evaluation of amplitude-shift keying (ASK) and frequency-shift keying (FSK) modem and codec schemes are proposed for multi-mode Dedicated Short Range Communication (DSRC) system. The proposed joint ASK detection scheme with single threshold can provide better performance than the separated ASK scheme. Besides, the proposed joint FSK detection scheme can outperform the conventional separated FSK scheme about 3 dB. It is due to the joint modem and codec FSK scheme providing the time diversity gain to enhance the performance of the DSRC system. Moreover, the proposed joint algorithms are realized in the SDR platform. Based on the measurement results, it is confirmed that the proposed joint detection schemes can provide robust performance over high mobility Rayleigh fading channel environment.

Keywords- *Dedicated Short Range Communication (DSRC), software defined radio (SDR), Amplitude-shift keying (ASK), Frequency-shift keying (FSK), Joint modem and codec*

I. INTRODUCTION

In this paper, we will study two different modulation modes, i.e., ASK and FSK, for Dedicated Short Range Communication (DSRC) system [1]. ASK and FSK modulations with FM0 and Manchester encoders are used for low and high data rate communications, respectively. There are three contributions we want to achieve in this paper. Firstly, the joint demodulation and decoding schemes are proposed to improve bit error rate (BER) performance. Secondly, a multi-mode structure is proposed for joint ASK and FSK schemes, which can reduce the computational complexity. Finally, a software defined radio (SDR) platform [2] with arbitrary waveform generator (AWG), RF up/down converter, channel emulator, and digital scope is established to evaluate the proposed joint detection algorithm over the high mobility Rayleigh fading channel environment.

As usual, the demodulation and decoding schemes are separated to detect the transmit signal for DSRC system [3]. However, for the separated receiver, BER and energy lose would be increased. Based on the problem, we propose a joint modem and codec scheme to decrease the energy lose and increase efficiency, and expect to decrease the computational complexity. For ASK and FSK systems, due to some functions in receiver being similar, if ASK and FSK receivers can share the same resources, e.g., matched filter, it will enormously reduce the computational loading.

In hardware verification, we build up a software defined radio (SDR) platform. The SDR platform includes transmitter

and receiver equipments, i.e., arbitrary waveform generator (AWG), RF up/down converter, and digital scope. That is, AWG is used to transmit ASK and FSK signals which are designed by MATLAB software. Next, the passband signals are modulated by RF up converter. Then, the RF signal is faded by the high mobility Rayleigh channel which are generated by channel emulator. At the receiver, RF down converter is used to transfer the faded signal back to baseband signal. In the end, the digital scope can catch the digital signal and MATLAB software is designed to demodulate and decode the ASK and FSK signals.

The paper is organized as follows: In Section II, we introduce the system model including FM0, Manchester encoder, ASK, and FSK modulations. In Section III, the joint demodulation and decoding schemes are proposed to use for ASK and FSK receivers. In Section IV, computer simulation and SDR platform verification results of the proposed system are then demonstrated. In Section IV, some conclusions are made.

II. SYSTEM MODEL

A. FM0 Encoding

FM0 encoding which is also called Bi-Phase space encoding is one kind of coding which only switch at the beginning, end, or the middle time of symbol '0'. Because FM0 encoding with narrow bandwidth property is suitable for synchronization and easy to be used for circuit implementation, it is widely used in Radio Frequency Identification (RFID) and Dedicated Short Range Communication (DSRC) systems.

B. Manchester Encoding

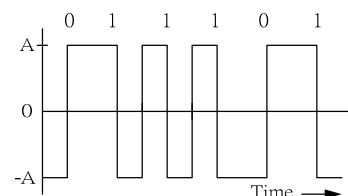


Figure 1. Illustration of Manchester encoding.

Manchester encoding also called Bi-Phase encoding which is a synchronous clock encoding technique. Manchester encoding uses one binary sequence to encode one transmitted data, and it can prevent synchronous clock loss. Otherwise, Manchester code also can prevent shifting mistake from low bit data. In Manchester code, voltage will switch every bit per second. For instance, it is assumed that transmit one bit data

needs t_1+t_2 time interval, then when the t_1 time interval is high and the t_2 time interval is low it means a '1'. On the other hand, it is a '0', like Figure 1. This characteristic makes Manchester code to synchronize signal between transmitter and receiver.

C. Amplitude-Shift Keying (ASK)

In ASK system, a binary symbol '1' is represented by transmitting a sinusoidal carrier wave with fixed amplitude and fixed carrier frequency for one bit duration, whereas binary symbol '0' is represented by switching off the carrier for one bit duration [4], as illustrated in Figure 2(a).

D. Frequency-Shift Keying (FSK)

FSK is a frequency modulation method. The simplest frequency modulation is binary frequency-shift keying. For binary FSK, we employ two different frequencies, i.e., f_1 and $f_2 = f_1 + \Delta f$, to transmit a binary information sequence, as illustrated in figure 2(b). Thus the two signal waveforms can be expressed as the following two equations [5].

$$\begin{aligned} u_1(t) &= \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_1 t, \quad 0 \leq t \leq T_b \\ u_2(t) &= \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_2 t, \quad 0 \leq t \leq T_b \end{aligned} \quad (1)$$

E_b is the signal energy per bit and T_b is the duration of the bit interval.

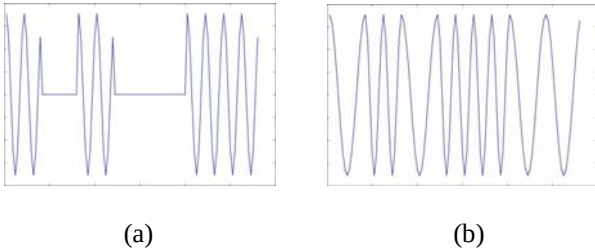


Figure 2. (a) Amplitude-Shift Keying (b) Frequency-Shift Keying

In this research, two different modes are studied, i.e., mode A being ASK modulation with FM0 encoding, and mode B being FSK modulation with Manchester encoding.

III. JOINT DEMODULATION AND DECODING SCHEMES FOR ASK AND FSK RECEIVERS

Traditional demodulation and decoding schemes are separated. For example: In mode B, the non-coherent detector is used to demodulate FSK signal [5] and then decode the Manchester code. Mode A is the same as the procedure. But in this way, it might loss some signal energy that causes BER degradation and has high computation. Therefore, to improve BER performance and reduce the computation, the joint the demodulation and decoding schemes are proposed in this section.

A. Joint ASK Demodulation and FM0 Decoding

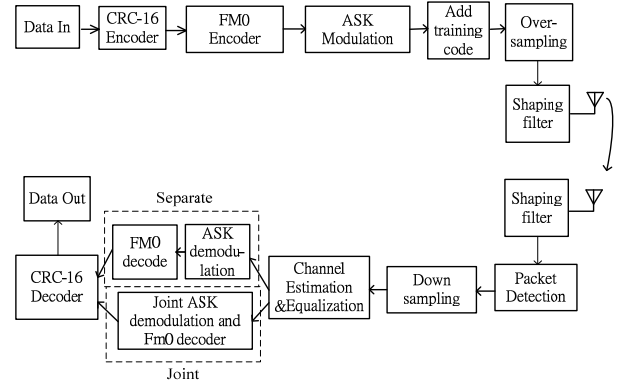


Figure 3. Block diagram of ASK modem and FM0 codec.

In FM0 encoding, bit 0 has two different voltages and bit 1 has just one voltage. That means bit 0 will change voltage but bit 1 not. Based on the encoding output, we can summarize four situations.

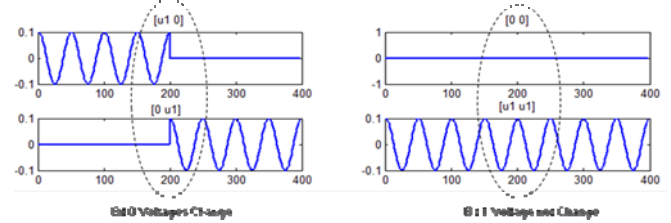


Figure 4. Four situations of FM0 encoding.

In receiver, we firstly use the $[u_1(t) u_1(t)]$ signals in (1) to match the received signal. Next, the two thresholds, i.e., 0.5 and 1.5, can be used to compare the matched result and detect the original transmit signal. That is, when the matched result is larger than 1.5 or smaller than 0.5, it means the transmit bit is 1. When the matched result is between 0.5 and 1.5, it means the transmit bit is 0. However, the detection method is not best scheme for the joint demodulation and decoding receiver, because it utilizes more thresholds for joint demodulation and decoding. In other words, the joint ASK detection scheme with two threshold is very sensitive to fading, noise and the neighbor signal interference due to pulse shaping. It will conduct the detection error for ASK receiver. Besides, when the ASK demodulation and decoding schemes are considered respectively, there is just one threshold (0.5) to demodulate ASK, and then decoding FM0 received signal. For the separated scheme, the receiver performance will degrade due to fading and noise effects.

To improve the joint ASK detection scheme, we can observe that the FM0 encoding scheme makes one bit to two bits. The first bit's energy will be affected by the second bit. But the second bit's energy is more steady. Use the property, we can change the joint ASK detection scheme. As shown in Figure 5, the joint matched $[u_1(t) u_1(t)]$ scheme can be modified that the matched result of the second bit is utilized to compare with one threshold (0.5) and detect the transmit signal.

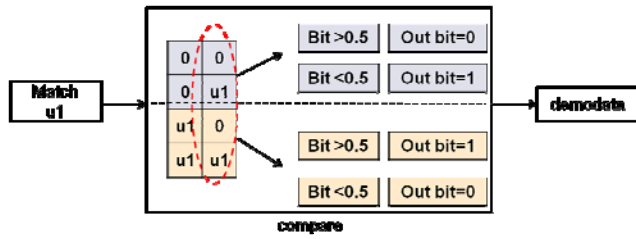


Figure 5. Joint ASK demodulation and FM0 decoding.

B. Joint FSK Demodulation and Manchester Decoding

In mode B, we want to study the joint FSK demodulation and Manchester decoding scheme. The diagram is shown in Figure 6.

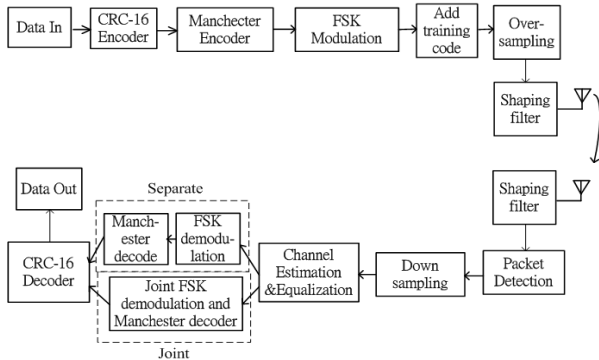


Figure 6. Block diagram of FSK modem and Manchester codec.

In FSK with Manchester code, bit 0 is encoded into $[-1, 1]$, i.e., the encoding signal $[u_1(t) \ u_2(t)]$, and bit 1 is encoded into $[1, -1]$, i.e., the encoding signal $[u_2(t) \ u_1(t)]$. $u_1(t)$ and $u_2(t)$ are denoted by a cosine waveform with frequency-shifting f_1 and f_2 in (1), respectively. Next, based on the Manchester encoding property, we proposed a simple joint detection technique, i.e., using the joint signals $[u_1(t) \ u_2(t)]$ and $[u_2(t) \ u_1(t)]$. Moreover, as shown in Figure 7, the dual matched filters with $[u_1(t) \ u_2(t)]$ and $[u_2(t) \ u_1(t)]$ reference signals are designed to match the received FSK with Manchester code signal. Due to the orthogonality property of $[u_1(t) \ u_2(t)]$ and $[u_2(t) \ u_1(t)]$ signals, the transmit signal can be detected by the branch of the matched signal with the larger envelope signal. It is noted that the proposed joint FSK detection scheme can acquire the time diversity gain to enhance the performance of the FSK receiver.

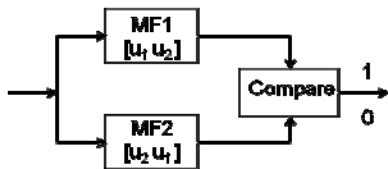


Figure 7. Joint FSK demodulation and Manchester decoding scheme.

IV. SIMULATION AND VERIFICATION RESULTS

In this section, the joint modem and codec schemes proposed in Section III are simulated and evaluated to confirm the system performance. And then a high mobility Rayleigh fading channel environment established by SDR platform can be used to verify the joint detection algorithms. Table I shows all parameters we need.

Table I. System simulated parameters.

Mode	Mode A (ASK)	Mode B (FSK)
Sinusoidal Frequency Shifting	512 KHz	$f_1=512$ KHz $f_2=1$ MHz
Packet Data Length	512 Bits	512 Bits
Sampling Rate	50 MHz	50 MHz
Oversampling Rate	8	8

A. Computer Simulation

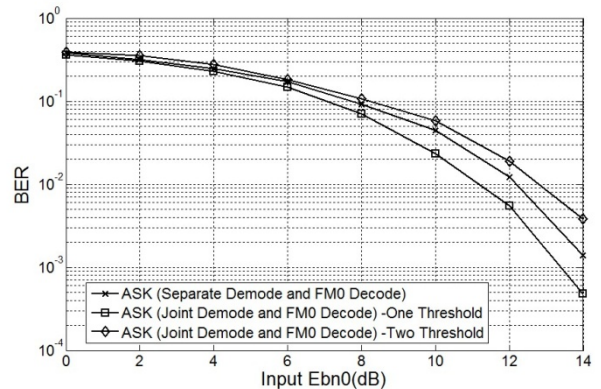


Figure 8. BER performance of ASK scheme.

In the first set of simulations, the BER performances of three different ASK methods are shown in Figure 8. For the cross solid curve, it is the conventional separated ASK demodulation and FM0 decoding schemes. For the diamond solid curve, it is the proposed joint ASK demodulation and FM0 decoding schemes with two thresholds in Section III. For the square solid curve, it is the new joint detection method with one threshold proposed in Section III. As shown in Figure 8, the new joint ASK detection scheme can provide better performance than other methods due to one threshold design being insensitive to noise effect.

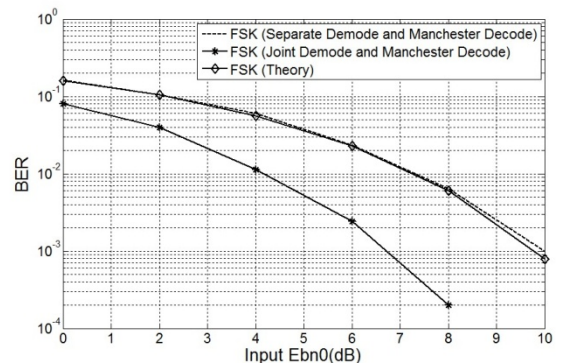


Figure 9. BER performance of FSK scheme.

In the second set of simulations, the BER performance is evaluated as a function of input E_b/N_0 for the separated and joint FSK demodulation and Manchester decoding schemes. The results shown in Figure 9, the BER performance of the separated FSK detection scheme can approach the theoretical FSK performance. It is noted that the proposed joint FSK detection scheme in Section III can outperform the separated FSK detection scheme about 3 dB at $BER=10^{-3}$. It is confirmed that the proposed joint FSK detection scheme can provide better BER performance for the DSRC system.

B. Hardware Verification

To verify the feasibility of the proposed joint ASK and FSK detection schemes, SDR platform is established by equipments and laptop. The block diagram of the SDR platform with fading channel emulator is shown in Figure 10.

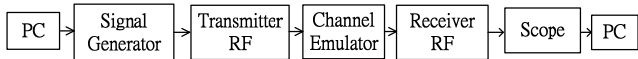


Figure 10. Block diagram for SDR platform with fading channel emulator.

The SDR platform consists of a waveform generator (AWG), RF up-converter (Agilent signal generator), RF down-converter (VN6000 signal demodulator), scope (Lecroy digital scope), mobile fading channel emulator, and laptop. The SDR platform can help us to use hardware equipments to verify the performance of the proposed software algorithms. Moreover, the transmit FSK and ASK signals can be generated by the MATLAB program in laptop. Then, the digital signals can be downloaded into AWG equipment by Ethernet cable. Next, the analog signals will be up-converted by Agilent RF equipment. Thus, the RF signal can be fed into fading channel equipment to perform the mobile fading signal. At receiver side, the VN6000 demodulator can down-convert the RF mobile fading signal to the analog baseband signal. Next, the analog signal can be sampled by the digital scope to generate the digital signal. Then, the digital signal can be transferred to laptop by Ethernet. Finally, the digital received signal via SDR transceiver platform can be synchronized, equalized, joint detected FSK and ASK signals by the proposed receiver MATLAB program. Based on the previous SDR design procedure, we can verify the performance of the proposed algorithms over Rayleigh mobile fading channel environment. The overall SDR hardware platform is shown in Figure 11.



Figure 11. SDR platform hardware setting.

Using SDR platform, the frame error rate (FER) performance results of the ASK and FSK schemes are shown in Table II. For the evaluation scenarios, the high speed mobility fading channels, i.e., 60 Km/Hr, 80 Km/Hr and 100 Km/Hr, are generated by the channel emulator. It is noted that the proposed joint ASK and FSK schemes can provide better than the conventional separated detection schemes over different mobile fading channel environments. Moreover, the SDR platform can assist us to confirm the proposed joint schemes with excellent performance and provide the low computational complexity.

Table II. FER performance results of the ASK and FSK schemes.

Mode\ Speed	60 Km/Hr	80 Km/Hr	100 Km/Hr
Joint FSK	0	0.005	0.009
Separated FSK	0	0.01	0.018
Joint ASK	0	0.05	0.13
Separated ASK	0	0.09	0.17

V. CONCLUSIONS

The joint detection and evaluation of modem and codec for multi-mode DSRC system is proposed in this paper and can really improve BER performance and reduce receiver computational complexity by computer simulation and SDR platform hardware verification. Furthermore, the system efficiency still keeps stable over different high mobility Rayleigh fading channel environments. In the future, the common algorithms of ASK and FSK schemes will be considered to merge for single algorithm, which can reduce the circuit design area and cost.

ACKNOWLEDGEMENTS

This work is sponsored by the National Science Council, R.O.C., under the Contract NSC 100-2220-E-155 -006.

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