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An Improved Method of Demodulation for Air-Ground Data Link Communication System

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Abstract

The Aircraft Communication Addressing and Reporting System (ACARS) is playing an increasingly important role to guarantee the safety and the efficiency of aircraft, so more effective method of receiving is necessary. The modulation of the ACARS system is MSK, the aim of this paper is to find a better demodulation method for the signal of ACARS. The characteristic of mapping relationship between code-element and the signal of waveform is analyzed. A new demodulation method is proposed based on the characteristic. Compared to the traditional demodulation method, it has a more simple structure. A simulation is made to verify its performance in the background of Gaussian noise. The comparison with traditional methods is also be made. Finally the benefit and weakness of this method is discussed.

Keywords: *ACARS; Digital Demodulation; MSK; BER*

1. Introduction

With the fast development of air transport, the number of air vehicle is increasing rapidly, the safety and efficiency requirement also become higher and higher. Now the role played by modern electronic information technology to auxiliary the air transport is more and more prominent. In this context, the Aircraft Communications Addressing and Reporting System (ACARS) was put forward in 1988 by international civil aviation organization (ICAO), it is a ground-to-air data communication system with functions of communication, navigation, monitoring [1].

The system includes the subsystems of airborne equipment, data link service providers, ground dada communications network, ground work management and information processing systems and data link user [2]. It uses the radio signal of VHF with the frequency between 118MHz to 137MHz to transmit the information. The system works in an automated manner, which can reduce crew workload and improve data trustiness. The modulation used is minimum shift keying (MSK) which has the advantages of constant amplitude, continuous phase and the concentrated power spectral density [3]. The symbol rate is 2400Hz, the baseband signal has two frequency wave 2400Hz and 1200Hz [4]. The ARINC-618 protocol is the basic protocol of the ACARS system.

The demodulation of the MSK signal is one of the key technologies of ACARS system. This paper mainly studied the characteristic of the MSK waveform of ACARS, and proposed a more efficiency demodulation method for the signal of ACARS. This paper discussed the advantage of this method and made comparisons with traditional method from the perspectives of complexity and bit error rate.

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2. The Mapping Relationship Between Waveform and Code-element

The ACARS system uses the modulation of MSK, the frequency of waveform is 2400Hz and 1200Hz.The different combinations of the two kinds of frequency represent the code element "0" and "1" [5].As for 2400Hz waveform, a cycle of the waveform represents an element. When the wave is over with a positive slope, it stands for "1"; when the wave is over with a negative slope, it stands for "0". As for 1200Hz waveform, a half cycle of the waveform represents an element. When the waveform is over with a positive slope, it stands for "1"; when the waveform is over with a negative slope, it stands for "0". The mapping relationship is shown in the Figure 1.

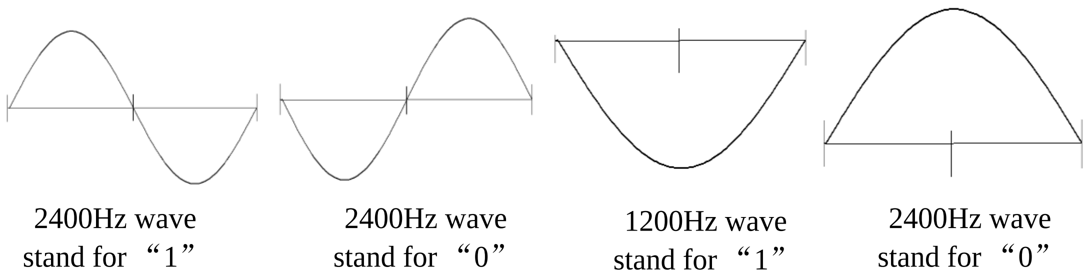
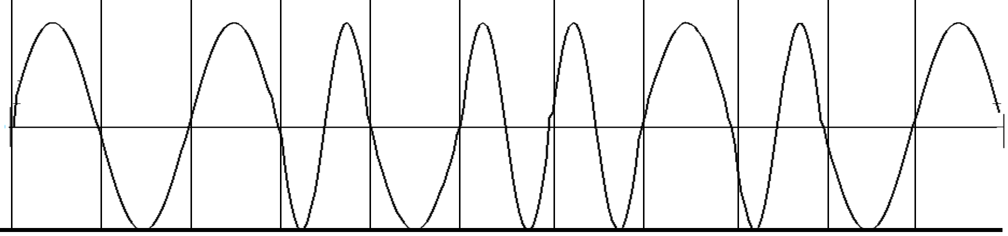


Figure 1. The Relationship between Waveform and Code Element

So the waveforms of ACARS can be divided into above four forms. The modulation process of continuous code element becoming the MSK waveforms can be summarized as follows. If we want to send the sequence P = {0,1,0,0,1,1,1,0,0,1,0}; we first change the sequence into a differential coding sequence P'={0,0,0,1,0,1,1,0,0}; then we use the sequence P' to generate the MSK waveform, the "0" will be mapped to a 1.2KHz waveform while the "1" will be mapped to a 2.4K waveform. This process has been shown in the Table 1. The waveform generated is a ideal shape of the signal of the ACARS [6].

Table 1. The Generation of MSK Waveform

sequence	1	2	3	4	5	6	7	8	9	10	11
P	0	1	0	0	1	1	1	0	0	1	0
P'	0	0	0	1	0	1	1	0	1	0	0



3. The Principle of the Digital Demodulation Method

3.1. The Traditional Demodulation Method

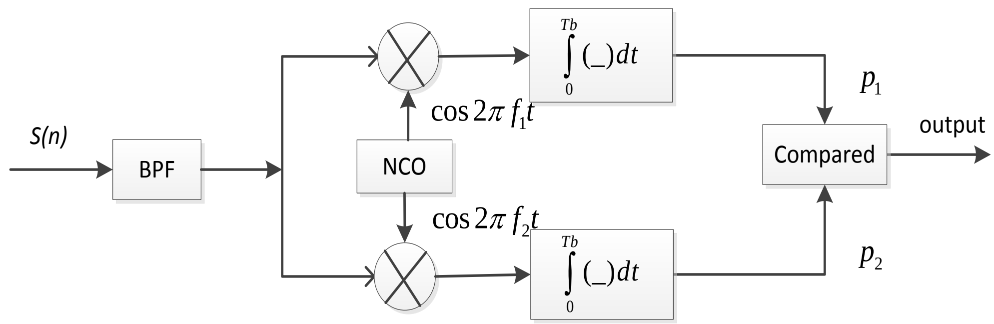


Figure 2. The Traditional Demodulation Method of MSK

The demodulation method of the MSK signal is one of important technologies for the ACARS system [7]. The structure of Figure 2 is one of traditional demodulation methods of MSK, called digital orthogonal demodulation algorithm [8]. This method can be reduced to the following steps.

Firstly, the received MSK signal through a BPF filter to cut off the noise. Then the signal is divided into two branches, the upper branch is multiplied with a coherent carrier which frequency equals f_1, the lower branch is multiplied with a coherent carrier which frequency equals f_2. The local frequency-shifting carrier waveform $\cos 2\pi f_1 t$, and $\cos 2\pi f_2 t$ is synchronized with '0' code wave and '1' code wave.

Secondly, after a code-element period integrating, the upper output is p_1; the lower output is p_2.

Finally, compare p_1 and p_2, if p_1 less than p_2, the signal is '0' code, otherwise the signal is '1' code [9].

3.2. The Principle of Demodulation of Half Part Accumulation

This traditional method is nearly suitable for all kinds of MSK waveform [10]. However from the Figure 1 we know there is a special mapping relation between the code-element and waveform of ACARS, so we guess there would be a special demodulation method for ACARS. Now we will further analyze the feature of MSK waveform of ACARS, and get a more efficiency demodulation method for the signal of ACARS.

The MSK waveform of ACARS can be expressed as the mathematical formula (1).

$$s_k(t) = \begin{cases} \sin(2\pi f_2 t), -\sin(2\pi f_1 t) & \text{when the } a_k = +1 \\ -\sin(2\pi f_2 t), \sin(2\pi f_1 t) & \text{when the } a_k = +0 \end{cases} \quad kT_s < t \le (k+1)T_s \tag{1}$$

$s_k(t)$ is the waveform of MSK, $f_1 = 1200Hz$, $f_2 = 2400Hz$,the a_k is the code element, k is the order of message sequence, $T_s = (1/2400)s$ is period of the code element.

When the signal is transported in the channel, it will be affected by the noise $n(t)$. So the signal we receive is the sum of signal and noise, it can be expressed as following.

$$s'_k(t) = s_k(t) + n(t) \tag{2}$$

From the Figure 1, we divide the wave of each code-element into two half from the center. We can get the conclusion that when the code element is “1”, the second half the waveform is below the zero; while when the element is “0”, the second half the wave is above the zero. This conclusion can be expressed as following formula.

$$\begin{cases} \dfrac{1}{T_s/2}\sum\limits_{kT_s+T_s/2}^{(k+1)T_s} s_k(t) < 0 \text{ when } a_k = 1 \\ \dfrac{1}{T_s/2}\sum\limits_{kT_s+T_s/2}^{(k+1)T_s} s_k(t) > 0 \text{ when } a_k = 0 \end{cases} \quad kT_s < t \le (k+1)T_s \tag{3}$$

Usually $n(t)$ is a Gaussian random process with a mean equal to zero. So

$$\frac{1}{T_s/2}\sum_{kT_s+T_s/2}^{(k+1)T_s} n(t) \approx 0 \tag{4}$$

$$\begin{cases} \dfrac{1}{T_s/2}\sum\limits_{kT_s+T_s/2}^{(k+1)T_s} \left(s_k(t) + n(t)\right) < 0 \text{ when } a_k = 1 \\ \dfrac{1}{T_s/2}\sum\limits_{kT_s+T_s/2}^{(k+1)T_s} \left(s_k(t) + n(t)\right) > 0 \text{ when } a_k = 0 \end{cases} \quad kT_s < t \le (k+1)T_s \tag{5}$$

So we only need to accumulate the second half sampling points of every code-element waveform. If the sum is above the zero, the waveform will be demodulated to code-element “0”; if the sum is below the zero, the waveform will be demodulated to code-element “1”. The process of this method could be showed by the Figure 3. Firstly the signal passes a low pass filter to remove the high frequency component. Then the preprocessor changes the waveform into N sampling points and gives the sign of the beginning of each waveform. The ‘N’ is a constant even integer like 16 or 32. The accumulation will accumulate the sampling points from the N/2+1 to N of each waveform. Finally the result will be judged and get the elements of demodulation.

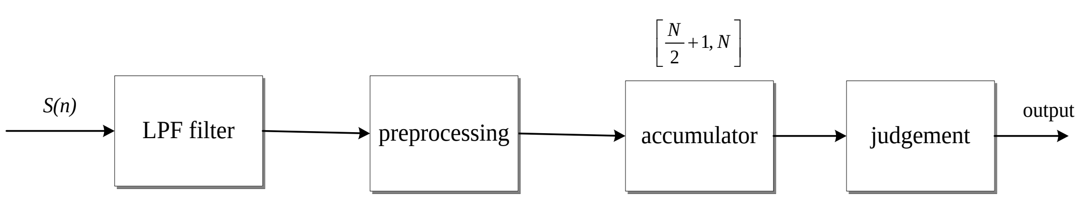


Figure 3. The Process of New Demodulation Method

4. Confirmation and Comparison

4.1. The Validity Verification of Algorithm

In order to prove the validity of the method, we did a simulation, using the computer. The process is shown by the Figure 4, first we generate eleven random code elements, then we modulated them into MSK waveform, then we accumulate the second half of sampling points of each code-element, finally we got the demodulated elements after judging, the result is correct.

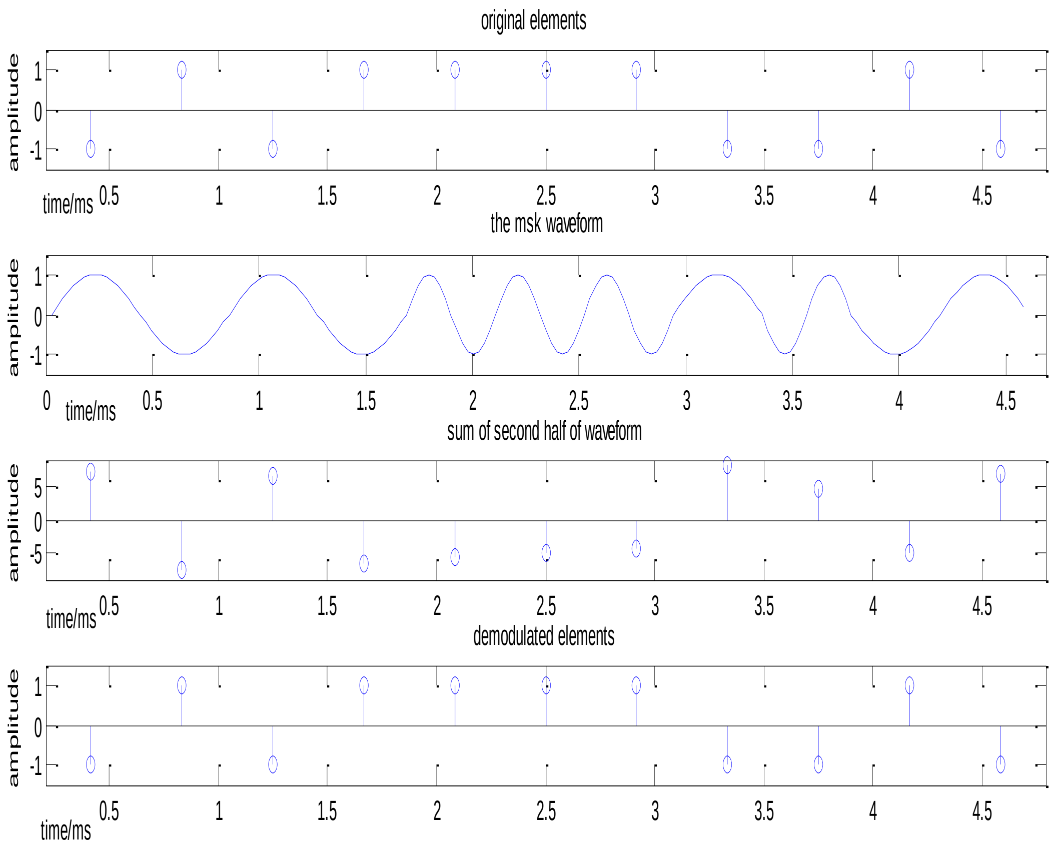


Figure 4. The Simulation of this Demodulation Method

4.2. The Ber Performance Compared to the Traditional Algorithm

In order to verify the superiority of the new algorithm, we made a further test. Here we tested the bit error rate of this demodulation method using the monte carlo algorithm. Firstly, we generate 500,000 code-elements randomly, then we modulate them into MSK waveform and add the Gaussian noise interference, finally we demodulate with our method and draw the ber curve. In order to reflect the performance more intuitively, we also demodulate the code-element with the traditional demodulation method and draw another ber curve. And the result is shown in the following Figure 5.

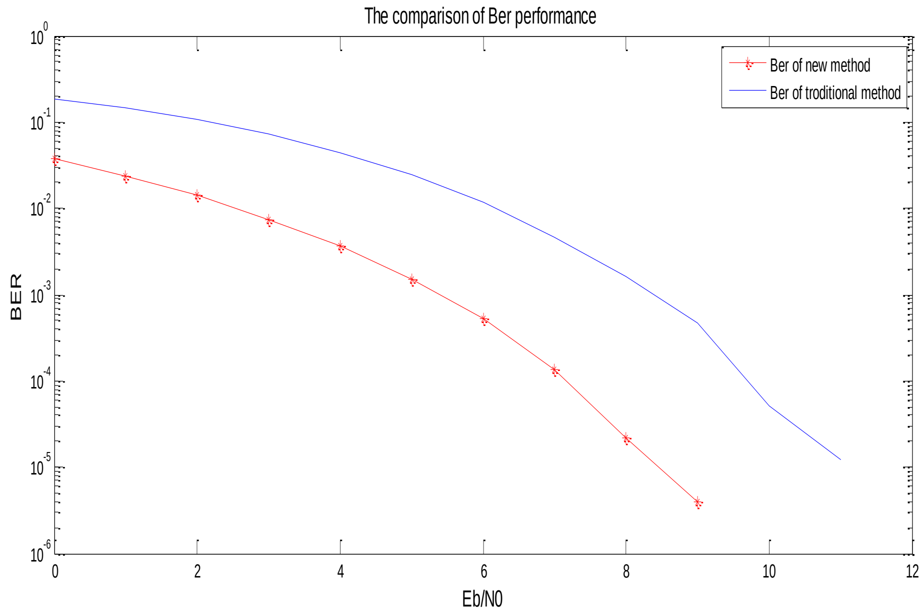


Figure 5. The Comparison of Ber Performance of Two Methods

From the result we can get the conclusion that under the same Gaussian noise interference, the method of half part accumulation has a better performance of bit error ratio.

From the Figure 3 and Figure 2, we could see the new demodulation method can save many source, such as the local oscillator, multiplying unit and so on. This means the method can save the precious hardware resources of receiver, and the simple structure also means the stability is higher. However because we only accumulate the second half of the waveform sampling point, the accumulator must be a flexible one. So this method is more suitable for a software radio receiver with a core processor like FPGA or DSP. And the method is just put forward for the signal of ACARS, so it's not suitable for other MSK signal.

5. Conclusion

In this paper, the Aircraft Communications Addressing and Report System (ACARS) is introduced. The mapping relationship of code-element and waveform is analyzed. We presented a new demodulation method for the signal of ACARS base on the characteristic. This method demodulates the signal by accumulating the second half of sampling points of every code-element waveform. The mathematics of this method is deduced. Through the simulation of computer, we proved the validity of the method, and compared the performance of Ber with the traditional method. The advantages and weakness are also discussed.

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References

[1] R. Curtis and J. McMath, "Experimental Encryption of Aircraft Communications Addressing and Reporting System(ACARS) Aeronautical Operational Control (AOC) Messages", Digital Avionics Systems, vol. 2, **(2001)**, pp. 7D4/1 – 7D4/8.
[2] S. Shuguang, "ACARS Data Identification and Application in Aircraft Maintenance", Database Technology and Applications, **(2009)**, pp. 255-258.
[3] S. Pasupathy, "Minimum Shift Keying: A Specially Efficient Modulation", IEEE CommunicationMag. **(1979)** July, pp. 14-22.
[4] Air/Ground Character-oriented Protocol Specification, VHF ACARS ARINC Specification 618-5, Chapter 4.0, **(2000)**.
[5] M. Hurfin, A. Mostefaoui and M. Raynal, "A Versatile Family of Consensus Protocols based on Chandra-toueg's Unreliable Failure Detectors", IEEE Transactions on Computer, **(2002)**, pp. 395-408.
[6] J. Xingcheng, L. Cao and D. Xueyun, "The Modulation and Demodulation of Air-Ground Data Link Communication base on MSK", Information Technology, vol. 8, **(2012)**, pp. 5-8.
[7] Z. Jingli, Y. Guang and D. Lijun, "Implementation and Performance Evaluation of an Adaptable Failure Detector for Distributed System", Proceedings of 2007 International Conference on Computational Intelligence and Security. Los Alamitos, California: IEEE Computer Society Press, **(2007)**, pp. 266-270.
[8] L. Liu and Z. Song, "The Research on ACARS Digital Signal Demodulation Method", Advances in Electric and Electronics, vol. 155, **(2012)**, pp. 645-651.
[9] S. A. Gronemeyer and A. L. McBride, "MSK and offset QPSK Modulation", IEEE Transactions on Computer. **(1976)**, pp. 809-820.
[10] S. M. Ryu and C. K. Un, "A Simple Method for MSK Modulation and Demodulation", Proceedings of the IEEE, vol. 73, **(1985)**, pp. 1690-1691.

