The Reliability Analysis and Improvement Method on the Wireless transmission of Radar Station's Long Message

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Abstract: Most of the radio sets in radar stations used for sending out air intelligence messages lack the specialized design to enhance the data transmission reliability. Bit errors are quite often under the short-term burst interference on compound channels, thus influence the correctness of the message. At the same time, because of the disaccord between the desire for the long message transmission reliability and the focus of the radio performance test, some radios that passed the test still possibly fail to meet the reliability demand on long message transmission. This article makes a theoretical analysis on the BER (Bit Error Rate) standard for FM radio and modulation mode, quantities the nonlinear relation between MER (Message Error Rate) and BER, raises a method to enhance the message transmission reliability with the current available devices, and is testified through the emulator.

Keywords: Wireless communication, Long Message transmission, Reliability.

1 Introduction

Radar stations usually works in the open field, the air intelligence which they get is sent to intelligence center via shortwave radios or ultra-short wave radios. The data transmission reliability of these radios directly influences the functioning reliability of the whole system. With the constant development of the radar technology, the information that radars get is even more abundant, so the messages transmitted by the radios are even longer, and the radios' long message transmission ability becomes more important. Now the research on it is quite urgent.

2 Analysis on BER Standard

GJB regulates that the FM Radio BER should below 10^{-5} when SNR is 12dB[1]. According to the GJB standard, the cannel noise is presumably the Gaussian white noise. From the information theory perspective, communication is the process that eliminates the uncertainty. Gaussian white noise has the maximum entropy[2] , when the Signal-to-average power is limited and it has the biggest influence on receiver's uncertainty elimination. Since Gaussian white noise has very strong autocorrelation, very weak mutual-correlation, and very wide power spectrum, it is hard to eliminate or decrease its interference on signals in terms of methods on whether time-domain, frequency-domain space-domain or power-domain. So theoretically speaking, to choose Gaussian white noise as interfering signals for SNR calculation is very strict. The BER acquired under this condition is most conservative, that is, the radios that meet the above mentioned standard, under the condition of 12dB SNR, should acquire the BER lower than 10^{-5} for other forms of noises.

However, Gaussian white noise mainly acts on signal amplitude, influencing largely on Amplitude modulation, while the demodulation mode of FM radios is not sensitive to the signal amplitude aberration. Only when the noise is too great, does the communication fail. When SNR is 12dB, viz. $10\lg(S/N)=12$, and S/N is about 16; the statistic average value of the noise amplitude is just 1/4 of that of signal. FM radio receiver mainly focuses on the carrier frequency within the code duration time when demodulating. The superposition of the noise amplitude whose statistic average value is 1/4 of that of signal is hard to influence the correct judgment of the receiver.

Besides, since non-Gaussian distributed colored noise is mutual-correlated, radio itself can't have corresponding design for it due to the variety of noises, although theoretically some methods can be used at the receiver for restraint or even elimination. So even under the SNR higher than 12dB circumstances, if the noise is the one sensitive to the FM receiving system, the BER

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will be higher than that under the 12dB SNR Gaussian white noise circumstances. In this way although the GJB-regulated noise condition is theoretically strict, due to the insensitivity of the FM system to amplitude superposition interference, as well as the variety of channel interference that prevent the one-by-one anti-jamming design for the radio, its BER standard becomes actually very loose, even though the radio passes this GLB standard, it can't ensure the reliability the system needs.

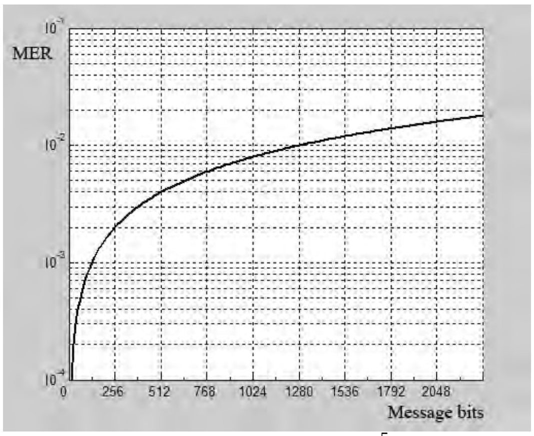
3 Analysis on Modulation Mode

The data transmission function of the radio, from the initial simple modulation, to completely digital modulated such as MSK and GMSK method, is essentially the binary FSK (Frequency Shift Keying). According to the best receiving principle, BER depends on the ratio between the power for receiving signals and Gaussian white noise power spectrum density E_b/n_0, the minimum BER a radio can reach, with coherent demodulation is $\frac{1}{2}\exp\left(-E_b/2n_0\right)$, with non-coherent demodulation is $\frac{1}{2}erfc\sqrt{E_b/2n_0}$.

In actual receiver, the minimum BER a radio can reach, with coherent demodulation is $\frac{1}{2}erfc\sqrt{SNR/2}$, with non-coherent demodulation is $\frac{1}{2}\exp(-SNR/2)$. Because only when system bandwidth satisfies Nyquist criterion does the SNR equal to E_b/n_0, so the actual receiver performance cannot reach the best condition[3]. According to the above formula, taking coherent demodulation, which performs better, as a case, to reach 10^{-5} BER, its SNR cannot be lower than 12.6dB, which is higher than 12dB that GJB requires. That means under the condition of 12dB SNR with Gaussian white noise, the binary FSK mode that FM radio adopts cannot reach the 10^{-5} BER. Taking other elements such as multi-path delay and signal decline into consideration, the BER will be even worse.

4 BER and MER(Message Error Rate)

Radar stations have a high requirement on the correctness and completeness on air intelligence message transmission. They often use CRC method at the terminal to verify the message and refuse the whole message even when there is only one error bit in it. The message will be correct only when its every bit is correct. From this we can see radar stations care about not the BER but the MER. If BER is p, and a message has n bits, the condition for the correct message is that these n bits are all correct, then the probability should be $(1\text{-}p)^n$, and the probability for MER should be $1\text{-}(1\text{-}p)^n$. even though the value of p is low as to be under 10^{-5}, with the growth of the message, the probability for the message correctness displays the exponentially decreasing tendency. As graph 1 shows, when BER is 10^{-5}, the MER for sending a 2kbit long message will be 10^{-2} high. If the length of the message increases, the condition will be even worse, which is not acceptable.



Graph 1: the MER with 10^{-5} BER

5 Analysis on Solution

The technological condition of current radios is fixed, that it is difficult to use some "hard" methods such as changing modem mode, increasing transmitter power, and diversity reception, thus only some "soft" methods can be adopted. According to Shannon's Noisy-channel coding theorem, with the premise that information transmission rate is lower than the maximum channel capacity, if the code length is long enough, new code groups and corresponding decoding rules can always be found to make BER arbitrarily low. The essence of this theorem is to get the communication reliability at the expense of communication validity. Radio can lower BER by some proper slowing-down methods. Current transmission speed of short wave radio can reach 2.4kbps; that of ultra short wave radio can reach 16kbps. Both of them are much higher than before, which provides the basis for the speed-for-quality method.

The short and ultra short wave channels are compound channels with co-existent random error and burst error. With the increase of the communication rate, a burst error caused by instantaneous interference contains usually several bits. FM radio's own FEC encoding mode uses Linear block codes, usually (7, 4) codes, and one block can only correct one bit error. This mode can effectively correct a one bit random error, but the code distance of the permissible code block must be more than twice larger than the number of corrected bits. If a block is asked to correct several error bits, its encoding efficiency will drastically go down. For this question, time dispersion technology can be used to diminish the correlation between burst error bits, that is, using interwoven technology to disperse the time-sequential burst error bits into newly interwoven blocks of random errors, so as to make judgment with "optional majority decoding" principle when receiving. This codec mode can greatly reduce MER with certain BER. On the assumption that BER is p, and that a block of message has 10bytes (80bits), with no encoding, its completely correct receiving probability is $(1-p)^{80}$. If 8 lines intertwined coding is adopted, with the setting that when 6 of 8 bits in each row are the same, then they belong to the message, the probability that accords with judging condition should be:

$$C_8^2(1-p)^6 p^2 + C_8^1(1-p)^7 p + (1-p)^8 \qquad (1)$$

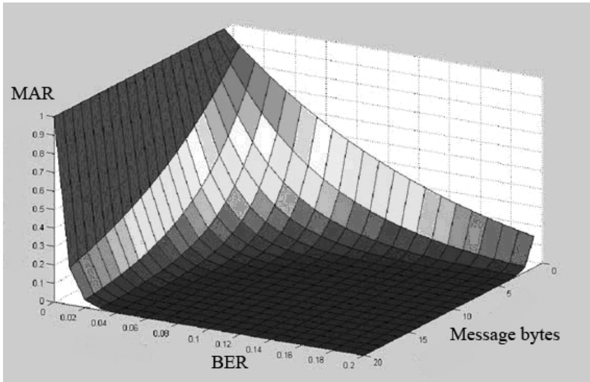
When BER itself is low, the possibility that 6/8 of a row are the error bits is quite low, and with the increase of the times of transmitting, this possibility goes down exponentially. However in the extreme case there will be the phenomenon of wrongly correcting the codes. In this case, the probability for each row to have more than 6 (including 6) error bits is:

$$C_8^2(1-p)^2 p^6 + C_8^1(1-p)\ p^7 + p^8 \qquad (2)$$

And in the above extreme condition, the probability for the complete correct decoding through using 8 lines intertwined coding is:

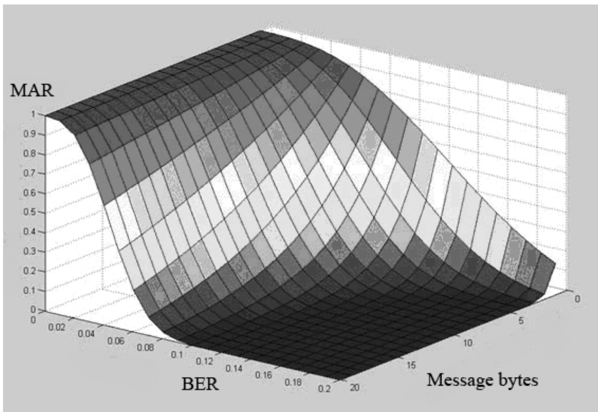
$$\left[C_8^2(1-p)^6 p^2 + C_8^1(1-p)^7 p + (1-p)^8\right]^{80} \times \left[1 - C_8^2(1-p)^2 p^6 - C_8^1(1-p)\ p^7 - p^8\right]^{80} \qquad (3)$$

The longer the message is, the lower the probability for completely correct decoding is. Graph 2 is the dimensional picture for the message reliability without interwoven coding. To make the result obvious, the BER is set bigger. From the graph we can see with the increase of BER and the bytes sent, the reliability goes down drastically. When sending 10 bytes with 0.01 BER, the probability for completely correct decoding (MAR: Message Accuracy Rate) is lower than 0.5.



Graph 2: dimensional picture for the message reliability without interwoven coding

Graph 3 is the dimensional picture for the message reliability with 8 lines interwoven coding. From the graph we can see the MAR is greatly enhanced compared with the one without interwoven coding. When sending 10 bytes and BER is high, the influence on reliability is minor. When BER is 0.01, the MAR is as high as 0.996, and on the condition of low BER, with the increase of the bytes sent, the MAR does not go down obviously.



Graph 3: dimensional picture for the message reliability with interwoven coding

6 Conclusion

The method this article suggests is to effectively raise the message accuracy rate with certain radio BER within the timeliness range that the system requires,

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through dispersing short-term burst errors on time by interwoven coding and correcting at the receiving end. Since most of the current radios lack specialized design for wireless data transmission reliability, this method has an important practical value for the enhancement of radar station's long message transmission reliability. Although some new types of radios are added error control codec function, this method just make codec improvement on wireless data transmission terminal, which does not influence the working condition of the radios themselves, so it also helps for enhancing their transmission reliability.

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