Design of High Frequency Digital Transceiver in Coastal Radio Station and Shipborne

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Abstract. A novel high frequency digital transceiver scheme using audio port as signal modulation and demodulation interface is proposed. The system adding human-computer interaction module, business service module, base station modulation and demodulation module, shipboard modulation and demodulation module, and using advanced modern digital signal processing algorithm to complete signal modulation and demodulation in digital domain, which overcomes the anti-interference ability of analog demodulation circuit poor power, low spectrum utilization, poor user experience and other shortcomings. The simulation results show that when SNR of the baseband is 4.9dB, the BER of the system can reach about 10^{-4}, the design scheme can meet the ITU-R M.2058-0 recommendation and the actual communication requirements.

1. Introduction
The modernization of global maritime distress and safety system (GMDSS) will fully integrate digital technology, broadband technology, mobile terminals and other modern communication technologies, and the future development of coastal radio should meet the development requirements of digital technology. NCSR(Navigation, communication and search and rescue) proposes to replace NBDP(Narrow-Band Direct-Printing) with HF digital transmission system. China will also cancel NBDP service in due time and adjust part of the frequency for the research and application of HF Digital Technology [1-2].

At present, the high frequency circuit of coastal radio station is mostly single sideband voice analog circuit [3], which has the disadvantages of poor anti-interference ability and low spectrum utilization. This kind of simple voice communication mode restricts the communication performance and user experience of coastal radio station.

Based on the existing coastal radio communication equipment, this paper designs the data communication interface of radio communication equipment, digitizes the modulation and demodulation equipment, and adds channel coding, high-order modulation and other methods to improve the reliability and transmission rate of the system. As a result, the data transmission function is realized, the communication performance and user experience becomes better.

2. The scheme of coastal radio system
This scheme is based on the existing equipment and facilities of coastal radio station for upgrading. The reformed system consists of six parts: human-computer interaction module, business service module, base station modulation and demodulation module, HF transmitter module, HF receiver module and shipboard modulation and demodulation module. The overall framework of the system is shown in Figure 1.
Human-computer interaction module and business service module should upgrade to develop new digital services. HF transmitter module and HF receiver module can make use of the existing equipment and facilities of the old coast radio station. The modulation and demodulation module is the key part of the system.

### 2.1. Base station modulation and demodulation module

The base station modulation and demodulation module is the core part of the digital transformation of coastal radio high frequency circuit. It is connected with the existing base station receiving module and base station transmitting module of coastal radio. It mainly includes central control and information processing unit, transmitting unit, receiving unit, data interaction unit, time synchronous unit and system real-time monitoring unit. The system function module is shown in Figure 2.

![Function module of modem system](attachment:diagram.png)

**Fig.1** The scheme of coastal radio system

**Fig.2** Function module of modem system

Transmitting module: It obtains the instructions such as messages to be sent and transmitting parameters from the external network, and then stores the messages to be sent into the message queue with certain rules. The modulation unit encodes the information data to be transmitted in the message queue by channel coding, framing, GMSK modulation, and outputs 1.8kHz audio data.
existing PCM equipment of coastal radio station, the signal is directly sent to the transmitter, which then modulates the signal to the short wave band for transmission.

Receiving module: The high frequency antenna of coastal radio station is used to receive the signals from other shore stations or shipyards within the communication range. The received signals are converted into baseband signals by the receiver. The GMSK waveform signals are demodulated by the demodulation unit, and the demodulated code stream is de-interleaved and decoded accordingly. Finally, the processor analyzes the code stream, recovers the original data, and transmits it through the network Port, WiFi or IEC port.

GMSK modulation algorithm is adopted in the design. The scheme of GMSK modulation and demodulation is shown in Fig.3. GMSK modulation signal is a kind of signal with continuous phase and constant envelope. It has the characteristics of fast channel sidelobe fading, strong anti-interference, high frequency band utilization and small out of band radiation. It is developed on the basis of MSK (minimum frequency shift keying). The original signal is firstly filtered by Gaussian filter, and then modulated by MSK. The specific process is shown in Figure 4 [4].

Fig.3 The realization of GMSK Modulation process

The waveform of MSK signal can be expressed by formula (1), where, \( nT_b \leq t \leq (n+1)T_b \). And GMSK signal can be expressed by formula (2), where \( \varphi(t) \) is the phase of the signal, which can be expressed by formula (3).

\[
S_{[MSK]}(t) = A \cdot \cos[2\pi f_c t + \varphi_n(t)]
\]

\[
S_{[GMSK]}(t) = \cos[\omega_c(t) + \varphi(t)] = \cos(\omega_c t) \cos \varphi(t) - \sin(\omega_c t) \sin \varphi(t)
\]

\[
\varphi(t) = \frac{\pi}{2T} \int_{-\infty}^{t} \sum_{n=-\infty}^{\infty} a_n g(\tau - nT - \frac{T}{2}) \, d\tau
\]

The implementation of GMSK is as below: the phase of GMSK modulation signal is directly obtained by using look-up table method; the RF modulation signal is directly generated by using two-point modulation and PLL phase-locked loop. The specific operation process is shown in Figure 4.

Fig.4 The realization process of GMSK Modulation

GMSK demodulation adopts differential demodulation algorithm. The phase difference of a symbol time interval of GMSK baseband signal is recorded as \( \Delta \phi_n = \phi(nT_b) - \phi((n-1)T_b) \). It can be concluded that the symbol of \( \Delta \phi_n \) is the same as the symbol of the symbol \( a_{n-2} \), as shown in equation (4)[5]. Where \( q(t) \) is the shaping filter. The \( a_{n-2} \) is the main term, and the other two are ISI interference terms. The above formula can be used as the final input signal of the decoder.

\[
\Delta \phi_n = \pi \left( \sum_{k=-\infty}^{n-1} a_k q((n-1)T_b) - \sum_{k=-\infty}^{n-1} a_k q((n-k-1)T_b) \right)
\]

\[
= \pi(a_{n-3} [0.5 - q(2T_b)] + a_{n-2} [q(2T_b) - q(T_b)] + a_{n-1} q(T_b))
\]

2.2. The shipborne modulation and demodulation system

The shipborne modulation and demodulation system mainly includes modem module and app unit, as shown in Figure 5. The onboard modem module can not only be directly connected with the ship HF radio equipment, but also can be connected with the mobile app and PC through WiFi. Similar to the
base station modulation and demodulation module, the output signal of the shipboard modulation and demodulation module is 1.8kHz GMSK modulated signal. At the same time, the modem module receives the audio signal from the shipboard radio equipment and demodulates the signal.

![Diagram of shipborne modem and APP system](image)

Fig.5 The scheme of shipborne modem and APP system

The shipboard app unit provides data communication functions to crew, including text, voice and image, mainly including modem control unit, message processing unit, local database and display control unit.

1. Modem control unit. It mainly completes the data interaction with the shipboard modem unit. After the app starts, it will connect to the shipboard modem unit. Only after the connection is successful, the user can use it later.

2. Address book function. The system provides a unique identification code for each communication user, so as to realize the dialing and point-to-point communication functions.

3. Communication services. App provides two kinds of communication services: single chat and group chat. In single chat mode, users can only communicate with one platform, while in group chat mode, users can communicate with multiple platforms. The communication content includes text, voice and image data.

3. Simulation result

The simulation result of the system BER performance is shown in Figure 6. It is shown that the BER performance gradually gets better with the increase of SNR. When SNR of the baseband is 4.9dB, the BER of the system can reach about $10^{-4}$, and it will fully meet the actual communication requirements. The requirement of digital NAVDAT system specified in ITU-R M.2058-0 proposal is $BER \leq 10^{-4} @ SNR = 10$dB. In comparison, the proposed system in this paper has a design margin of 5dB, and it is suitable to be used in the audio communication of shortwave radio stations, which fully meets the needs of the system.
4. Conclusion
This paper proposes a novel scheme of high frequency digital transceiver in coastal radio station. The simulation results show that the system can meet the design requirements. It not only realizes the original analog HF coastal radio system, but also makes full use of the advantages of digital circuit.

Relying on the existing transceiver equipment of coastal radio high-frequency communication system, when the human-computer interaction module, business service module, base station modulation and demodulation module and shipboard modulation and demodulation module are added, the advanced modern digital signal processing algorithm can complete signal demodulation in the digital domain, and overcome the shortcomings of current analog demodulation circuit, such as low precision, poor sensitivity, unable to transmit data and image information. It greatly improves the anti-interference ability and user experience of the system. Otherwise, it lays the foundation for the application of practical engineering, and has good practical application and promotional value.

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