



Application of Digital Radio Mondiale System in Medical Signal Transmission

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Received: 26 December 2018 / Accepted: 11 February 2019 / Published online: 14 March 2019
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Abstract

In order to study the application of digital radio mondiale (DRM) broadcasting system in medical signal transmission, taking sinusoidal signal as an example, the transmission format is designed, and the data transmission function of the system channel is verified and applied to the transmission of medical information. Taking the traditional electrocardiogram signal and magnetic resonance image as examples, the two kinds of medical information are successfully transmitted according to the appropriate transmission format. As the simplest and easiest to deploy communication mode, the system will provide the fastest and timeliest information and emergency communication function for disaster relief and rescue, which is a practical and valuable application.

Keywords DRM broadcasting system · Medical signal · Transmission

Introduction

With the rapid development of digital technology, computer technology and network information technology, the traditional analog amplitude modulation (AM) broadcasting business is facing unprecedented challenges. At present, with the increasingly prominent limitations of broadcasting, it is urgent to keep pace with the times and find a new way out for AM broadcasting. Digitalization of AM broadcasting is the best way to solve this problem. With the rise of mobile communications and the Internet, broadcasting as a single and audio-based media, compared with mobile phones, computers, etc., has not been a popular means of communication and information transmission, because mobile phones listening to radio and television have been achieved. Nevertheless, as an indispensable public infrastructure, the strong emergency response capability of broadcasting, whether at the national early warning or other emergency levels, is still of great significance and should always be paid attention to.

Digital radio mondiale (DRM) is suitable for long-distance coverage, and the sound quality is good. The transmission band can cover the medium and short wave band [1]. This is fully applicable to the expansion of AM broadcasting services in China. It does not need to occupy new band resources. Only by integrating existing broadcasting band resources, adjusting and upgrading individual modules, DRM digital broadcasting can be realized. Lee et al. proposed the architecture of DRM-as-a-service, which provides various functions of DRM. As some services in cloud environment, it is called DRM cloud [2]. Liu proposed a flexible and resource-efficient architecture that can channel the whole FM and DRM30 bands simultaneously. A method based on coarse/fine mesh partitioning is also proposed to realize multi-standard channelization, which can independently configure the parameters of each output channel at runtime [3]. DRM broadcasting is a publicly standardized digital broadcasting system, which is suitable for all frequencies, including LW (Long Wave), MW (Moderate Wave), SW (Short Wave) and VHF (Very High Frequency) bands. In addition to providing audiences with high audio quality, DRM meets the technical requirements of broadcasters, manufacturers and management, and thus has great potential for the future of global radio. Faced with the need of wide area coverage of high power transmitter, the power efficiency of DRM transmitter needs to be improved. One of the main drawbacks of DRM is the high peak-to-average power ratio (PAPR) based on orthogonal frequency division multiplexing (OFDM), which leads to the nonlinearity of the transmitted signal, low

This article is part of the Topical Collection on *Systems-Level Quality Improvement*

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power efficiency and high cost of the transmitter. To overcome this problem, Moghaddamia provided technical feasibility and DRM dedicated system [4]. Based on the characteristics of DRM, a new method for correcting the amplitude consistency of the receiving array of high frequency external emitter using direct wave frequency pilot signal is proposed. Firstly, the signal structure of DRM broadcasting is introduced, and the feasibility of using its pilot signal as a correction source is analyzed. Considering the time-varying and non-stationary characteristics of high frequency electromagnetic environment and propagation environment, a method of optimizing direct wave correction data in time based on translation invariant array pair is proposed. Finally, combined with ground wave mode and sky wave propagation mode, the measured multi-channel data of high frequency external emitter radar are analyzed. This method is compared with other auxiliary calibration source methods for receiving array calibration, and the analysis results confirm the effectiveness of this method [5]. Ahmad introduced an emergency broadcasting system based on the existing medium wave AM broadcasting network, which does not require any modification to the equipment of the medium wave broadcasting station. The transmitted digital baseband signal is pre-modulated on multiple orthogonal sub-carriers by COFDM mode through computer processing, synthesized and transmitted directly to the audio input port of the radio station after modulation and power amplification; as long as the medium wave broadcasting of the corresponding frequency is received by ordinary radio in the service area of the radio station, the required text or pictures can be obtained after demodulation by computer software. Because of the credibility and one-way closure of broadcasting, this information channel is safe and reliable, and false information cannot be invaded. It is expected to become a reliable regular channel for receiving emergency information [6].

DRM system cannot only transmit audio, but also provide text, picture and other information transmission. However, the data service implemented by Packetmode in Section 6.6 of DRM standard is more complex. It requires not only forward error correction coding, RS data calculation and encapsulation, but also parameter setting of several SDC data entities. This topic will make use of the existing audio transmission service channel to explore the transmission of data stream service.

Source coding is the first step of audio data stream transmission. Source coding mainly compresses audio information and makes special processing for information such as sound and hearing. Simple data signals do not contain sound information. If the same audio compression is used, it will inevitably cause the loss of predictable data information in the process of audio compression, leading to the incomplete data information after decompression. Therefore, the channel transmission module of DRM system is used, focusing on the design of a suitable transmission format to match the channel for data transmission.

Methodology

DRM broadcasting technology is a broadcasting technology that can utilize the existing frequency band without occupying additional frequency band resources (still occupying 9 kHz or 10 kHz bandwidth), but also can provide digital AM broadcasting technology which is close to FM stereo quality. It can provide digital AM broadcasting bandwidth close to FM stereo quality. As shown in Fig. 1, it is the structure block diagram of DRM transmission system in DRM standard.

From the perspective of channel, DRM transmission system consists of three logical channels: MSC (Main Service Channel), FAC (Fast Access Channel), and SDC (Service Description Channel). MSC includes all the traffic data to be transmitted in different protection types in DRM multiplexing, including audio data stream and other data stream, FAC is used to provide service-type information, including some information about channel parameters, so that receivers can quickly search services, and SDC contains the information of decoding MSC [7].

Furthermore, it can be known that the information of the above three channels is formed by two different processing units of input signals. One is the audio and data after source coding and precoding, which forms information belonging to MSC channel on the multiplexer (MUX); the other is that the FAC and SDC information without MUX is directly used as input information on the FAC and SDC channels. The former is composed of multiplexing, energy dissipation, channel coding and interleaving modules to form a symbol mapping unit for MSC transmission frames. Nevertheless, the data of FAC and SDC are mapped with MSC transmission frames and pilot units after energy dissipation and channel coding modules, respectively, and the symbols are mapped to different carrier positions [8]. Then, the time domain OFDM baseband signal can be obtained by IFFT (Inverse Fast Fourier Transform) and other operations. The baseband signal can be transmitted by modulating the modulator to a specific broadcast frequency.

From the perspective of system module composition, the three logical channel modules are different. MSC channel mainly consists of precoding and source coding, multiplexing, energy diffusion, channel coding, unit interleaving, OFDM modulation and so on. FAC channel and SDC channel do not involve multiplexing and unit interleaving, but mainly consist of precoding, energy dissipation, channel coding, OFDM modulation and so on.

It should be noted that there are five robust modes in DRM system, and this research only deals with four of them, namely ModeA/B/C/D, and does not involve the fifth mode, namely ModeE. The main work completed is based on the first four modes, and will not be repeated in the future.

The current channel bandwidth of AM broadcasting is 9 kHz and 10 kHz. Table 1 shows the frequency occupancy mode of DRM system.

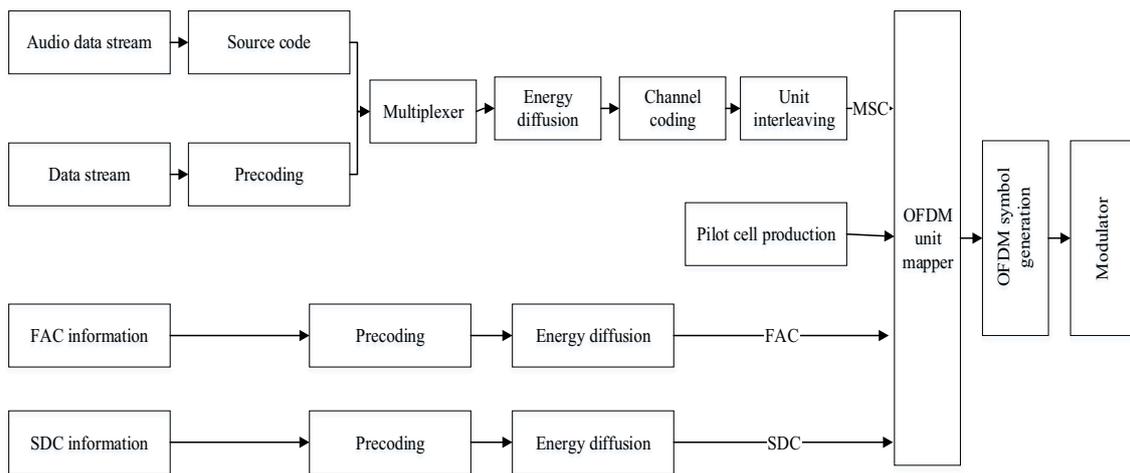


Fig. 1 Structural block diagram of DRM transmitter system

The function modules are programmed according to the structure block diagram of DRM transmitting system. The flow chart of software implementation of each module of DRM transmitting system is shown in Fig. 2.

In the process of research, such an exploratory scheme is designed: the data stream information A is directly fed into the channel transmission module of DRM transmission system (without source coding module), the baseband transmission signal is generated after modulation, and the baseband signal is fed into the DRM receiving system. The data A', after demodulation and decoding (before source decoding), is obtained, and the data information A is compared with A'. If the information is consistent, it is proved that the transmission is valid; otherwise, it is invalid.

Taking the sinusoidal signal as an example, the scheme verification is carried out. Specific ways are as follows: Firstly, a sinusoidal signal is simulated; secondly, the simulated signal is processed and the format is matched according to requirements; finally, the simulated signal after processing is used as input signal for transmission verification.

Data simulation is mainly used in MATLAB (matrix laboratory) to generate a multi-period sinusoidal signal Sin(x) [9]. Firstly, it is necessary to understand the basic conditions that sinusoidal signal needs to meet:

$$\text{sampling frequency } f_s = 24\text{kHz} \tag{1}$$

Have certain length.

According to the known sampling frequency f_s , the frequency of sinusoidal signal is chosen as $f = 600$ Hz to ensure

that the Nyquist sampling theorem is satisfied. At the same time, in order to meet the requirement of a certain length of time, the period $N = 1000$ is chosen, so the simulation program is as follows:

$$f = 600 \tag{2}$$

$$N = 1000 \tag{3}$$

$$tf = N \times 1/f \tag{4}$$

$$f_s = 24000 \tag{5}$$

$$t = 0 : 1/f_s : tf \tag{6}$$

$$y = \sin(f \times 2 \times \pi \times t) \tag{7}$$

The purpose of signal processing is to match the simulated sinusoidal signal format with the channel signal transmission format.

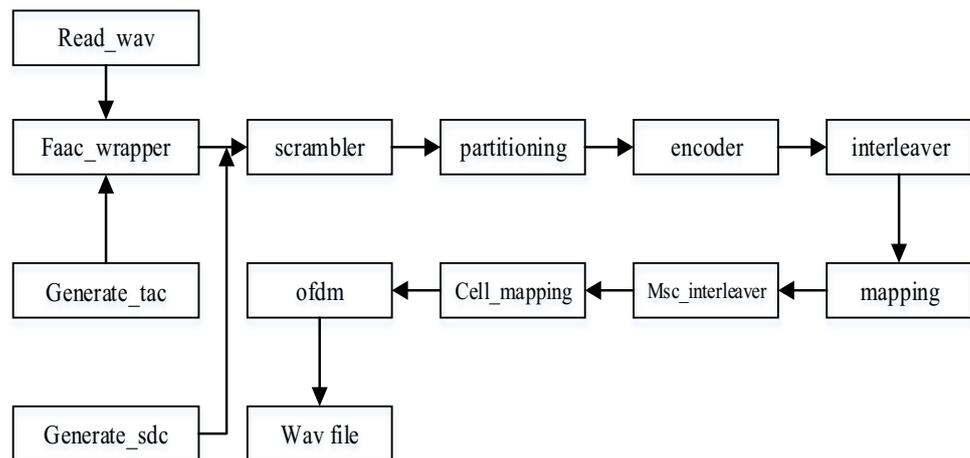
According to the data file produced by the function `drm_transmitter()` of audio data stream transmission in MATLAB, the simulation signal is further processed.

According to the observation, after the audio signal is encoded by the source, an `aac_data` array is generated as the input signal into the MSC logical channel. It is a two-dimensional array of binary numbers 0 and 1 with a size of $17478 \times n$, and n depends on the size of the input signal. The sinusoidal signal is composed of decimal numbers between - 1 and 1. The data are positive and negative, and all of them are decimal except that 0 and 1 are integers. Therefore, first of all, it is supposed to consider the positive and negative effects of data; secondly, it needs to consider how many bits are suitable to represent a data point, because this will affect the accuracy of data and subsequent encoding issues. At the same time, it is necessary to consider the integration; then consider converting decimal numbers into bitstream data; finally, it is supposed to imitate the format of `aac_data` array to transmit the processed sinusoidal data as input signals.

Table 1 The frequency occupancy mode of DRM system

Frequency occupancy mode	0	1	23	4	5
Channel bandwidth (kHz)	4.5	5	910	18	20

Fig. 2 The flow chart of software implementation of each module of DRM transmitting system



For these considerations, the following steps have been taken:

- Step 1: normalize the sinusoidal signal by calling the library function of MATLAB: `mapminmax()`.
- Step 2: observe the normalized data and decide to process it according to eight bits of a data point. The decimal number range represented by eight bits is 0–255. Therefore, the sinusoidal signal is chosen to be multiplied by 255, so that all data are in the range of 0–255.
- Step 3: rectify. There are about four integer functions in MATLAB: `floor()`, `ceil()`, `round()`, and `fix()`. They have different integer rules: `floor`: the smallest integer near $-\infty$; `ceil`: the largest integer near $+\infty$; `round`: the nearest integer (equivalent to rounding); `fix`: the integer near zero. From the perspective of accuracy, `round()` is selected as an integral function.
- Step 4: make the decimal conversion. By calling the library function of MATLAB: `dec2bin()`, a decimal number can be converted into a binary number in the form of a string. On this basis, character data is converted into shaping.
- Step 5: arrange the processed sinusoidal signals according to the format of `aac_data` array, and name the processed sinusoidal signal array as `sin_data`. The data processing of sinusoidal signal is accomplished.

The transmission verification of sinusoidal signal will be carried out. The input signal becomes a sinusoidal data signal (binary number represents). If the transmission is successful, the final decoded sinusoidal data signal (binary number represents) should be obtained by the receiver. It is known that the channel of this transmission is the same as audio transmission. Now, the input signal is recorded as `sin_data`.

`Sin_data` is sent into DRM broadcasting system as input signal of MSC channel. Finally, after channel decoding, an array of `m_sc_data` is captured and binary data in the array of `sin_data` and `m_sc_data` are compared. If the data are identical, the transmission is successful, otherwise it will fail. Therefore, call the library function in MATLAB: `isequal(A, B)`, if the size of A and B is the same, and the elements in the array correspond to the same, then the function returns the logical value: 1; otherwise, return the logical value: 0.

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From the comparison results, it can be seen that the data stream signal can be successfully transmitted by using the channel transmission module of DRM system. Then, the array `m_sc_data` can be considered as a binary array of sinusoidal signals, so the sinusoidal signals should be recovered

```

Command Window
>> isequal(sin_data, m_sc_data')

ans =

     1
  
```

Fig. 3 Comparison results of `sin_data` and `m_sc_data` arrays

```

Command Window
>> isequal(heart_data,msc_data')

ans =

     1

```

Fig. 4 Comparison of data signals before and after transmission

theoretically after signal inverse processing. Read the `msc_data` array, use the `bin2deC()` library function of MATLAB to carry out the binary conversion, and take a piece of decimal data for drawing.

Results and discussion

ECG signal generation

The ECG signals used here are from the MIT-BIH database, which are part of Physionet, a biomedical signal resource website, provided by the Massachusetts Institute of Technology. At present, there are three internationally recognized standard ECG databases: MIT-BIH database provided by Massachusetts Institute of Technology, AHA database of American Heart Association and ST-T ECG database of Europe. MIT-BIH database has been widely used in recent years. The MIT-BIH database provides 48 sets of ECG data in total. MIT uses a custom data format. An ECG record consists of three parts: header file [.hea], storage mode ASCII code characters; data file [.dat], stored by binary, two numbers per three bytes, a number of 12 bits; annotation file [.art],



Fig. 5 Medical image before launch



Fig. 6 Medical images received before launch

stored by binary. The format definition is more complex and the way of reading is the same as the former. Reading the ECG signals of MIT database requires installing WFDB software package (WFDB, wave form database) in MATLAB, and finding the relevant software package in Physionet Web page: WFDB toolbox, and installing it.

ECG signal processing and transmission

The processing method of ECG signal is similar to that of sinusoidal signal. It needs to consider the positive and negative of the signal, the number of digits of data representation, integer, binary conversion and so on. The processing flow is the same as that of sinusoidal signal.

After the above processing, the ECG signals are arranged according to the format of `AAC_data` array of the input signals of the transmitting system, and they are recorded as `heart_data`.

The processed ECG signals are sent into the transmitting system according to the designed channel transmission format, and then transmitted by the DRM system after coding and modulation. The decoded data are obtained by the DRM receiving system. Similarly, the `isequalO` library function of MATLAB can be used to compare the data received before and after transmission. The logical value is “1”, which indicates that the two data are equal and the ECG signal is successfully transmitted.

The above results show that the received and transmitted data are identical, and there is no error code, which proves the reliability of the system transmission.

Medical image transmission

In the case of limited transmission of post-disaster information, DRM system is used to transmit medical imaging

information on the condition of the wounded in the rescue site. When sharing the pressure of rescue, it is more conducive to the diagnosis of the wounded by expert system. Imaging medical information includes ultrasound image, X-ray image, magnetic resonance image and so on. The medical image transmitted is a magnetic resonance image.

The magnetic resonance image is processed according to the way of processing ECG signal. After processing, the format matching arrangement is made according to the format of AAC_data array of the input signal of the transmitting system, which is recorded as MR_data. The following is a magnetic resonance image before launch.

The image data is sent to the transmitting system, which is coded and modulated by the DRM transmitting system, and the decoded data is obtained in the DRM receiving system.

Similarly, the function `isequal()` is used to compare the data signals received before transmission. The logical value of the result is "1", which indicates that the two data are equal and the image signal is successfully transmitted.

Conclusion

The possibility of data transmission by channel is analyzed, and the exploratory scheme of data transmission is designed; then, taking sinusoidal signal as an example, the transmission channel of digital AM broadcasting system is used to transmit and verify the exploratory scheme; subsequently, it is applied to the transmission of medical information. Taking the traditional ECG signal and magnetic resonance image as an example, the transmission is carried out according to the appropriate transmission format and these two kinds of medical information are successfully transmitted.

At present, there are many ways to transmit medical information, such as Bluetooth, network and so on. Compared with these transmission modes, the application of digital AM broadcasting system in the transmission of medical information is not advantageous. However, the application of digital AM broadcasting system in special occasions such as major disasters is focused on. Advanced means are vulnerable to damage. As the simplest and easiest to deploy communication mode, digital AM broadcasting system will provide the fastest information and emergency communication functions for disaster relief and rescue, which is a practical and valuable application.

Compliance with ethical standards

Conflict of interest Author Min Du declares that he has no conflict of interest. Author Jianwei Luo declares that he has no conflict of interest. Author Shuping Wang declares that he has no conflict of interest. Author Shan Liu declares that he has no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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