Digital Wireless Transmission for MRI Signals

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Introduction

In recent years, several proposals of using wireless transmission for MRI have been reported to avoid the interference between array channels [1-3]. Amplitude modulation (AM) and single sideband (SSB) analog wireless techniques have been applied to design transponders for RF coils [4]. Compared to this analog transmission technique, digital transmission has advantages of better noise immunity, more stability and flexibility, and is code error free. In this work, we have designed and implemented a digital transmission system based on WLAN 802.11b standard, which can reach the speed of 11Mbps with 2.4G band.

Methods

Fig.1 schematically describes our digital wireless transceiver circuit. Before wireless transmission, MR analog signals are digitized by an A/D converter (ADC), which is controlled by digital signal processor (DSP). And these digital signals are transferred to an 802.11b wireless module.

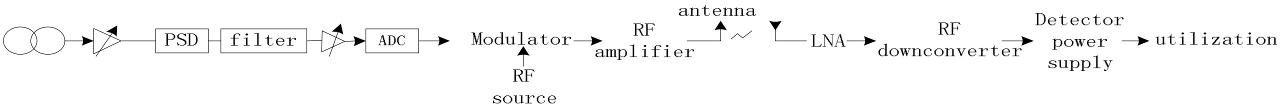

Fig. 1 Digital wireless transceiver for MR signals

For digital wireless transmission, assume the MRI image pixel size is 128×128, and each pixel contains 4 bytes to describe the image gray scale. For each image, it contains 1M bits (real and imaginary part together). If we assume one image per second normally, then the transmission data rate is 1Mbps. However, in order to accommodate framing, overhead, and checksum for the wireless link, the higher data rate more than 1Mbps may be necessary. Typically, throughput is about 70% to 75% of peak data rate. Therefore, the required data rate for the wireless link is roughly 1.4Mbps. For this data rate, the differential quadrature phase shift keyed (DQPSK) modulation technique is used, which can transmit data up to 2Mbps and its null-to-null bandwidth radio is 2MHz. There are four different modulation schemes according to the transmission rate in IEEE 802.11b. Except for DQPSK, complementary code keying (CCK) with data rate 5.5Mbps or 11Mbps can be applied also. On good connections the bit error rate (BER) should be required below 10^{-9}. To achieve a 10^{-9} BER, the required energy per bit relative to the noise power (E_b/N_0) is 13dB for DQPSK, 6dB for CCK (5.5 Mbps) and 10dB for CCK (11Mbps) [5]. For MRI application, communication range of tens of meters is desired. The free space path loss at maximum 30 meters for indoor propagation is 80dB and fade margin is 30dB. Then the specifications of link budget are as follows in Table 1:

Modulation	DQPSK	CCK (5.5 Mbps)	CCK (11 Mbps)
Transmission data rate	2 Mbps	5.5 Mbps	11 Mbps
Bandwidth	2Mbps	11 Mbps	22 Mbps
E_b/N_0	13dB	6 dB	10 dB
SNR	13dB	3 dB	7 dB
Sensitivity	- 92dBm	-90dBm	-85dBm
Transmitter power	18dBm	20dBm	25dBm

Table. 1 Specifications of link budget based on 802.11b

Results and discussion

Fig. 2 shows distribution of real part of a spin echo signal drawn from the center K-space line in one slice for brain imaging. These data are collected with our MRI wireless transmission system to test the feasibility of wireless transmission. The whole experiment was done on the 0.3T XinaoMDT low-field vertical MRI system. In the experiment, a commercial receive-only head RF coil designed for low-field MRI system is used and the input of the pre-processing circuit is connected to the output of the preamplifier after the RF coil. The synchronization of the transmission system with the MRI scanner is realized by using the system synchronization clock, which also controls the digital sampling.

The complete images need both real and imagery parts. However, imaginary parts of imaging signals can not be generated just through some simple algorithms after AD conversion. Because it is difficult to decide the sampling rate of sine wave and cosine wave in one cycle to make real and imaginary signals synchronous. The synchronous imaginary part of MR imaging signals could be completed in hardware for the real part circuit simultaneously.

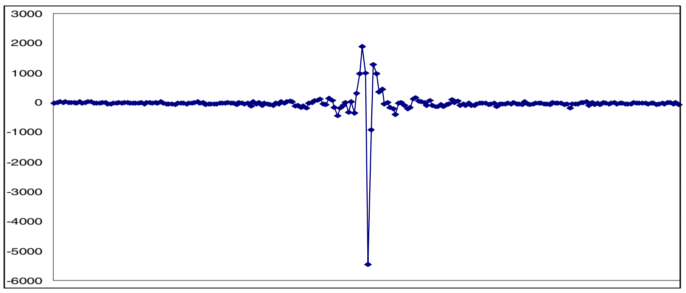

Fig. 2 The distribution of the real part of a spin echo signal drawn from the center K-space line in one slice

Conclusion

A digital wireless transmission link based on 802.11b for MRI application has been designed and implemented, which can eliminate cables for multi-coil array, therefore avoid the interference among these channels. The link budget has shown that the sensitivity of the wireless receiver is high enough to detect the weak MRI signals. The DQPSK and CCK modulation methods can support normal MRI data transmission with rate of 2Mbps. A spin echo signal has been detected successfully on a 0.3T MRI through our digital wireless transmission link.

References

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