Single Optical Fiber Transmission for Multi-channel MRI using FDM Method

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Introduction:

A several proposals of using optical transmission to replace RF coaxial cable for MRI have been reported to avoid the RF interference among array channels [1-6]. However, in practice when the number of channel goes to 32 or more, the overall cost for whole optical system will be very high. The large amount of electronic parts will be difficult to be integrated to the array coils. This is because each channel requires its own optical transmission and receiving circuits [6]. In this work, we present a single optical fiber to transmit multiple MR signals using frequency division multiplexing (FDM) method.

Method:

The block diagram of a single fiber analog optical link for MRI transmitter and receiver system is shown in Fig. 1. The direct digital synthesizer (DDS) and mixer are used to accurately convert the RF signal with the resolution of 0.04Hz and a 180 MHz system clock. Using FDM method [7, 8], RF signal of each channel is down converted to the low frequency and assigned to its own frequency band with 200 KHz bandwidth. Then all these multiplexed signals are combined together and sent to the optical link through impedance matching circuit. In the optical transmitter, the input RF signal is converted to optical output by a 1mW, 1330nm Fabry-Perot (F-P) laser diode. The automatic power control (APC) is used to eliminate the laser output variation due to the temperature shift. In the optical receiver, the input optical signal is converted back to MR signal by a photo diode (PD) which performance of linearity is from -112 to 2 dBm. The optical transmitter and receiver are connected by a single mode optical fiber using FC/APC connectors.

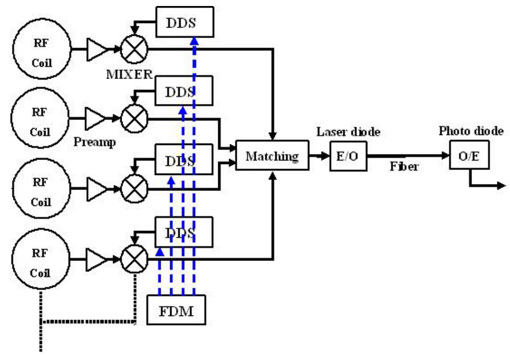

Fig1. Block diagram of the digital optical transmission

Results and Discussion:

The prototype of single optical transmit link is shown in Fig.2 (a). This link includes amplifier, protection and automatic power control circuits. The prototype of the two channel FDM PCB board is shown in Fig. 2(b). The two channel standard 64 MHz sinusoidal signals are input to the board. The expected two different frequencies (200 KHz and 400 KHz) signals are obtained as output which can verify the FDM function. Normally, at high frequency High Q band-pass filter is difficult to be designed and implemented. However, after the signals are down converted, the band-pass filters are relatively easy to be designed and implemented. The measured data show that the SNR of the mixed signal remains above 95% of that using the traditional method. The bench tests also show that the linear region of the optical link is from input power of -75 to -20dBm. The power gain begins to compress about 1dB when input power is -18dBm shown in Fig. 3. The dependence of the link power gain on low modulated frequency system is measured from 100KHz -20MHz with the constant input power of -25 dBm. In this region the link power gain can maintain 10dB within 0.2dB fluctuation. However the bandwidth is not limited in optical system (GHz) and can be easily expanded by using wider bandpass filters. Theoretically, the SNR requirement of this link is not important because these multiple RF signals are amplified by those very low noise preamps before they are sent to the optical link.

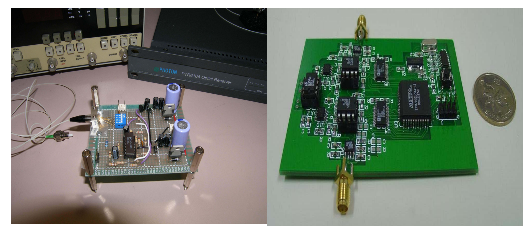

Fig. 2 (a) Optical link, (b) MRI two channel FDM

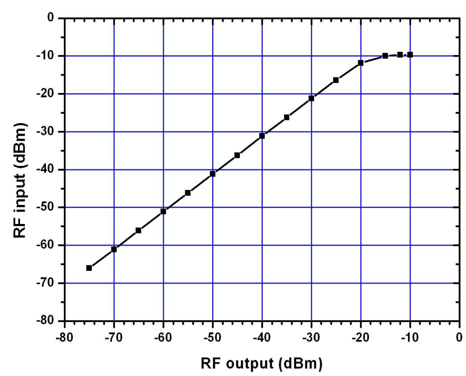

Fig. 3. Linear region of the optical link

Conclusion:

Using a single fiber optical link for the multi-channel RF array can significantly simplify the optical transmission and receiving system, especially for the RF channel number goes to 32 or higher. Because of using FDM method, all the RF channel signals can be combined as one channel to be converted to the optical signal. This design can significantly cut the cost of using many individual optical transmit links and optical receivers for multi-channel array RF transmission.

Reference:

1. G.P. Koste, et al, ISMRM, 411 (2005); 2. C.H. Cox, Analog Optical Links, Theory and Practice, Cambridge Univ. Press,2004; 3. J.Yuan, et al, ISMRM, 2031 (2006); 4.J.Yuan, et al, ISMRM,322, (2006); 5. J.Yuan, et al, ISMRM,1036, (2006);6. J. Yuan, et al, JMR, 130-138 (2007);7. J.Wei, et al, ISMRM, 220 (2006); 8. J. Wei et al, JMR, 358-363 (2007).