MRI Console Electronics

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INTRODUCTION

The "MRI console" controls all components of the MRI system, including the magnet (and shims), the gradient coils, and the RF coils, acquires the MRI signals detected by the RF coils, and processes the acquired data to create the MR images. The MRI console has three main components: the host computer, the pulse programmer (PPG), and the RF transceiver.

HOST COMPUTER

The host computer plays three important roles: controlling the time-critical PPG, acquiring a large quantity of MR signal data, and reconstructing the MR images. In the early days of MRI development, minicomputers were exclusively used as the host computers, with the DEC VAX being the most popular system. Smaller computers such as SUN workstations then came into use. With the development of high-performance personal computers (PCs), PC hosts are now widely used with Windows, UNIX (Linux), or a specialized real-time operating system. Interfacing the host computers to the PPG and the RF transceiver is a critical issue. The choice of either the PC's internal bus (PCI/PCIe) or a standardized interface (Ethernet, USB, or other high-speed interface) critically affects the architecture and overall performance of the MRI console.

PULSE PROGRAMMER (PPG)

The PPG is the core unit of the MRI console. It must output sequences of long control words (64~256 bits) in the time unit of 10 – 1000 ns with no time jitter, and update them for every repetition time (minimum ~0.1 ms). The PPG supplies 3CH gradient waveforms, arbitrary RF pulse shapes (in both amplitude and phase), (time-varying) shim currents, transmitter gate pulses, data-acquisition triggers or clocks, and other timing-control signals. Although most clinical MRI systems do not supply details of their PPG architecture, various approaches to PPG design have been reported by many research groups. They have included digital signal processors [1], microcontrollers [2], field programmable gate arrays [3,4], and the PC itself [5].

RF TRANSCEIVER

Analog RF transceiver systems were used in early MRI systems. Because the structure of an analog transceiver is simple and intuitive, MRI beginners should learn about analog transceivers before considering digital transceivers. The major difference between these two types is the conversion frequency used in the ADC and DAC. For an analog receiver, the ADC conversion frequency is around the Nyquist frequency of the MRI signal (up to several 100 kHz) in the rotating frame. For a digital receiver, the conversion frequency is four times the intermediate frequency (~10 MHz). Modulation and demodulation (i.e., signal detection) of the RF signal are performed digitally (numerically) in a digital transceiver. The advantages of the digital transceiver include freedom from DC offset, good IQ balance (i.e., ghost-free), good RF phase reproducibility, and a wide dynamic range for the signal.

PORTABLE MRI CONSOLE

If a 3CH gradient driver and an RF transmitter are installed in a mobile rack together with the MRI console, the MR measurement system can be made portable. By combining such a portable MRI console with small permanent magnets, portable MRI systems can be constructed and used in many MRI applications [6,7].

References

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