Magnetic Resonance Imaging Hardware

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Despite the fact that Magnetic Resonance Imaging (MRI) is a mature technology, now present in most hospitals, its development has not slowed to any significant extent over the past three decades. This is probably due to the interplay between academic and industrial research, driving the continuing development of new methods and hardware, with ever increasing biomedical applications. We will, first, review the basic hardware components necessary in an MRI scanner, namely: the main magnet necessary to polarize the nuclear spins, considering the permanent, electromagnet and superconducting technology; the shielded magnet room, used to reduce the interference of external noise; the gradient coils and the driving gradient amplifiers, necessary for spatial localization along the three dimensions; the radio frequency (RF) coil (including surface, volume and array coils), used to transmit the 90°/180° RF pulses and to detect the FID/Echo signals; the RF pulse generation hardware, including the RF power amplifier; the detection chain, including the low noise pre-amplifiers; the TX/RX switches necessary to separate the Transmit (TX) and Receive (RX) phases of the MRI acquisition; and the transmission lines, used to connect and shield the high frequency hardware components. In particular, we will focus on the RF detection chain that in the past decade has undergone radical changes thanks to the development of multi-channel TX/RX MRI systems and travelling wave detection. Then, we will present the latest advancements in MRI hardware and discuss a selection of biomedical applications, ranging from ultra-low field (kHz) to ultra-high field (GHz). Special attention will be provided to the use of multiple-tuned RF coils suitable for the concurrent detection of proton (1H) and other X-nuclei nuclear spin (13C, 23Na, 31P). Finally, we will discussed the development of multimodality imaging methods, where MRI is being integrated with EPR, MEG or PET systems, to take advantage of wider molecular imaging contrast mechanisms and/or ultra-fast acquisition times, both suitable for functional studies in animal models and humans.