WWB (IMS) Wednesday 08:00 – 12:00 BCEC Room 152
RF Design Components of Magnetic Resonance Scanners
Half-day workshop reviewed by MTT-17, IMS09

Organizer(s):
Robert Caverly, Villanova University; MTT-17, IMS TPC.
William Doherty, Microsemi-Lowell Corp.

The tutorial will present material covering the RF design practice used in Magnetic Resonance Scanners with presentations on hardware component design. The workshop will be geared for RF and microwave engineers wishing gain insight into technology as a means to move this important medical imaging forward. The tutorial topics range from brief review of magnetic resonance phenomenon, the need for high field scanning and its related RF components in the VHF region, the need for and design of tightly controlled RF pulse sequence generation, and high efficiency pulse transmitters for faithful reproduction of these well-defined pulse sequences. The tutorial will continue on the weak received signals by reviewing high gain, low noise amplifiers for the MR scanner receiver front end along with the transmit/receive coils as part of the MR transceiver system.

Speakers:
1. Robert Caverly, Villanova University
"An Introduction to MRI"

This introductory session will review some of the fundamental physics governing the processes involved in magnetic resonance imaging. The focus will be on those physical phenomenon directly involved with the excitation and resulting RF radiation from the target nuclei. The relationship between RF frequency and elements that make up various tissues as well as the necessary static and gradient magnetic fields will also be reviewed. The need for specialized wave shapes and the faithful reproduction of these shapes at high powers will also be reviewed

2. Matthew R. Cummings, Cummings Electronics Labs
"Practical RF Electronics for MRI/NMR Transceivers"

This talk explores the functional and performance requirements for MRI/NMR transceivers, and presents real-world strategies for implementing successful designs. Receivers for MRI/NMR must exhibit excellent dynamic range and stability to preserve image quality – all while operating in an electrically noisy environment that is often in close physical proximity to high-voltage transmitter electronics. In addition to presenting a typical modern NMR digital transceiver in block diagram form, this talk will discuss specific implementation and selection considerations for key components, including: signal-level amplification, mixers, filters, data conversion and digital-signal processing devices. It will also include a review of the design challenges typically encountered, as well as examples of image quality issues resulting from transceiver performance degradation and interference.

3. Ron Watkins, Stanford University Department of Radiology
”Concepts in MRI RF Transmit”

Topics in this lecture

• Basic NMR spin interactions

• System Block Diagram and Major Hardware

• Time base and excitation

• RF Power Amplification

• Transmission lines, splitters and Switches • Volume Transmit Coils (antennas)

• SAR, Safety and Power Monitoring

4. Fritz Raab, Green Mountain Radio Research Company
“High-efficiency transmitter for magnetic-resonance imaging "

This prototype high-efficiency HF/VHF transmitter for magnetic-resonance imaging (MRI) is based upon the Kahn EER (envelope-elimination-and-restoration) technique (Figure 1). The transmitter includes capability for generating stored signals as well as digitizing and amplifying low-level RF inputs. The present design is capable of being configured for operation from 10 to 128 MHz and producing a 175 to 200 W output with 70 to 80-percent efficiency. It has a bandwidth of 250 kHz and an envelope rise time of 1 us.

5. William Doherty, Microsemi and Ron Watkins, Stanford Univ. Dept. of Radiology
“RF Design Components of Magnetic Resonance Scanners”

PIN Diode Switching and Limiting Issues for High Field MRI Scanner Coils W. E. Doherty, JR., Microsemi Corp and Ron Watkins, Stanford University, Department of Radiology From an EE point of view, switches are SPST, SPDT, DPDT (transfer switch), etc and are realized as lumped element or distributed line topologies, depending on the particular frequency bands being used. An MR engineer tends to describe & design MR coil switches in terms of the circuit function: RF blocks, detune, disable, limiters (LNA protection). The purpose of this paper is to make these two perspectives compatible and to discuss the devices and networks available to the designers of high, medium, and low field MR scanner coil switches. Lumped element / distributed lines / topologies – quad, pi, etc 1 x 1, 1 x 2, 2 x 2 (transfer switch) networks MR coil switching functions: blocks, detune, disable, limiters (LNA protection)

6. Patrick Ledden, Nova Medical
"Radio Frequency Detectors for Human Magnetic Resonance Imaging"

This talk will focus on the some of the unique aspects required for the design of Magnetic Resonance Imaging array detectors and associated hardware. As with radar and other RF/microwave antennae applications, arrays of MRI detectors can be used for improving the spatial and time resolution of MRI technology. Unlike typical far-field antennae, MRI detectors are based on resonant loops that inductively couple through their nearfields to the oscillating magnetic field of the MRI spin signal. These detectors have a number of specific requirements in terms of non-magnetic design, adequate isolation from the electric and magnetic fields of nearby detectors, ultra low-noise performance, and safety. Examples will be shown of recent developments in the field such as array coil design for the latest generation of ultra-high field human MRI scanners.