Automatically tuned and matched RF transceive head coil at 7T

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Introduction

The transmit efficiency and receive signal-to-noise ratio (SNR) of transceive RF coils depends on how well the resonance circuit is tuned to the Larmor frequency and matched to the 50 ohm coaxial cable. Patient size variability changes the load the coil couples with and adversely impacts both tuning and matching, and subsequently the power efficiency and SNR of the coil.[1-3] The loading effects from different human bodies are unpredictable and problematic. Significantly mismatched coils stress other RF components with reflected power like T/R switches and RF power amplifiers. Conventional manual re-tuning and re-matching of coils between dissimilar body types is time-consuming and impractical for clinic applications. Furthermore, at ultra-high fields, multi-channel coils aggravate the loading problem because: 1) the time required for re-tuning/matching is proportional to the number of channels and 2) the loading effects significantly change S_{11} (the reflection coefficient) and the associated RF power efficiency. Previous efforts to automatically tune and match coils focused only on receive coils because transmit or transceiver coils must handle kilowatts, not microwatts of power, a difficult engineering challenge.[4,5] This study offers an electrically driven stand-alone automatic tuning and matching system for RF transmit and/or receive coils.

Methods

Figure 1 shows the 8-channel RF transceiver head TEM coil with the automatic tuning and matching unit. Each channel has an independent tune and match controller making this technique highly scalable. The automation unit consists of an RF power monitor, electrically controlled PIN diode switched capacitor arrays, and the main controller, as shown in figure 2. The RF power monitor samples the reflected RF power through a custom-designed coupler and converts it to a DC signal that an ADC on the main control board monitors. After loading, the values of the high power capacitor arrays (C_{p1} and C_{p2}) are optimized by enabling and disabling individual capacitors with PIN diode switching. The combination of capacitor arrays generates about 256 different capacitances, covering a range from 1pF to 8pF. The main controller sequentially switches the PIN diodes, waits for the next ~15dBm RF pulse used for tune/match adjustment, observes the output of the RF power monitor and repeats this for all possible capacitances. Due to the rapid nature of PIN diode switching, this only takes ~550 ms. Then the optimal capacitances for frequency tuning and impedance matching are set. Every channel is automatically tuned and matched in sequence. To test the durability of the tune and match circuitry, the RF power was incrementally increased to 1 kW. To synchronize the automation controller with the MR console, an RF power amplifier unblank signal was connected to the controller; the MR console did not require additional hardware modification for automatic tune and match capabilities.

Results

In figure 3, every coil element was independently tuned and matched at the Larmor frequency (297.2 MHz) for 7T, (Siemens Magnetom, Erlangen, DE) by this automated procedure after a cylindrical phantom (ε_r=58.1 and σ=0.539 S/m) was loaded. Electrically driven tuning and matching requires only 550 ms per channel. In all channels, automatic tuning and matching function improved S_{11} about 10 dB to 15 dB resulting in less than 1.5% power loss due to mismatch. As previously reported[2], SNR in MR images was improved about 20% to 24% by the automatic tuning/matching with a single element. Each image was acquired using GRE pulse sequence (resolution=1x1 mm, TR/TE=150/6 ms slice thickness=5 mm). The capacitance network of each element showed no instability or signal distortion up to the maximum available 1 kW power. Figure 4 shows uncorrected human head gradient echo images (1x1 mm, TR/TE=200/4 ms, 6 mm slice thickness) obtained with the automatic tuned and matched RF coil at 7T. These images do not have significant defect or distortion.

Conclusions

This abstract demonstrates the feasibility of an 8-channel automatically tuned and matched RF transceiver TEM head coil. This method can be scaled to higher channel count, because each controller is self contained and independent of the console. By eliminating the need for manual adjustments, the time required for tuning and matching was significantly decreased to approximately 550 ms per each channel. This automation technique is novel and applicable to current and future clinical applications and research.

Acknowledgements

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References

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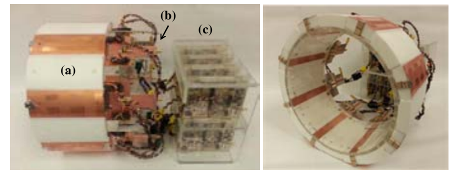

Figure 1. Automatically tuned and matched RF transceive head coil. (a) TEM coil elements, (b) electrically controlled capacitor arrays and couplers, and (c) an automation main unit.

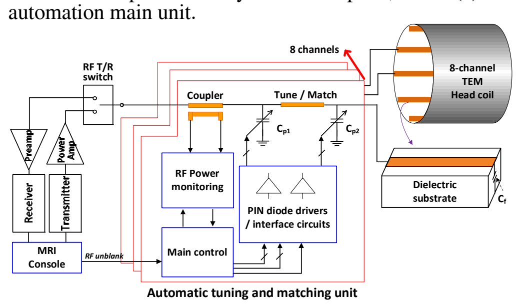

Figure 2. The block diagram of automatically tuned and matched 8-channel RF transceiver coil for 7T.

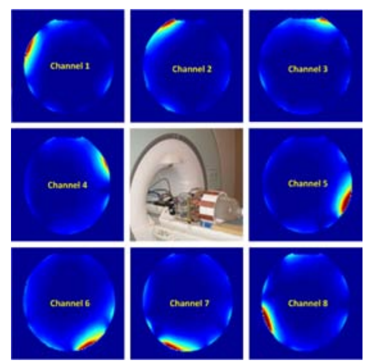

Figure 3. MR experimental setup (center) with a phantom and GRE images of each channel.

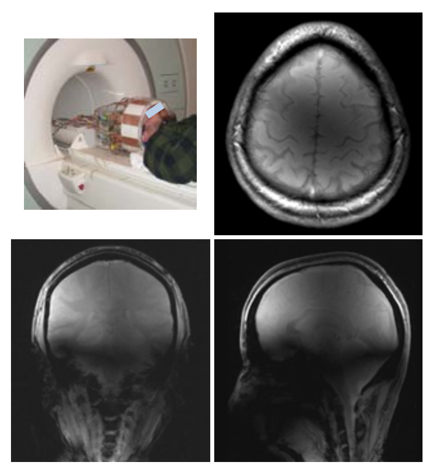

Figure 4. Human head images obtained with the automatic tuned and matched RF coil at 7T.