MRI Compatible (2.4GHz) Bluetooth Communication System: Isolating and Eliminating Electromagnetic Noise

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Background: The basis of MRI is measuring the magnetic spin of nuclei (NMR) or electrons (EPR). The magnetic field travels from the location of the spin to the RF coil in the form of an electromagnetic (EM) waves. MRI rooms are surrounded by Faraday cages to prevent external EM noise from interfering with the MRI acquisitions. Practical needs for electronics in the MRI room require the use of waveguides, filters, and shielding to ensure the elimination of EM noise at the magnetic resonance frequency (63MHz @ 1.5T H[1]).

Motivation: The need arose to use a keyboard and mouse inside of the MRI room and have them communicate with an external computer to perform cardiac stress tests with a MRI compatible treadmill. A wireless system was in place, but introduced detectable image noise. A standard RF noise test provided on the SIEMENS Avanto system revealed significant RF interference over a wide range of frequencies (Figure 3).

Materials and Methods: To eliminate mouse and keyboard communications as sources of EM noise, a new wireless system was designed using the Bluetooth communication protocol (Figure 1 and 4). Flexible aluminum tubing was used to isolate the USB cable which could carry external noise and noise from USB circuitry's fundamental frequency or harmonics. The Bluetooth transmitter circuitry was isolated in an aluminum housing. Any noise on the cable carrying the Bluetooth signal from the transmitter to the antenna was assumed to be eliminated with on board filtering. A network analyzer was used to measure the frequency components of the Bluetooth signal. Non-magnetic components were used throughout the design process. The tips of the USB cables had a small amount of ferromagnetism. Ferromagnetic plates in the keyboard were replaced with aluminum substitutes. AA batteries were identified with non-ferromagnetic cases that reduced magnetic attraction by roughly 90% over most commercially available AAs. RF noise tests and a high bandwidth imaging sequence were used to determine whether noise was effectively eliminated by the new system.

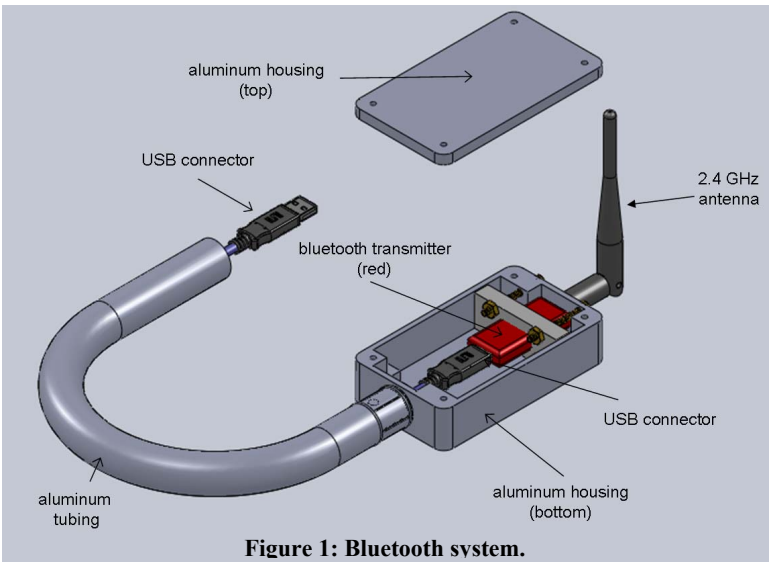

Figure 1: Bluetooth system.

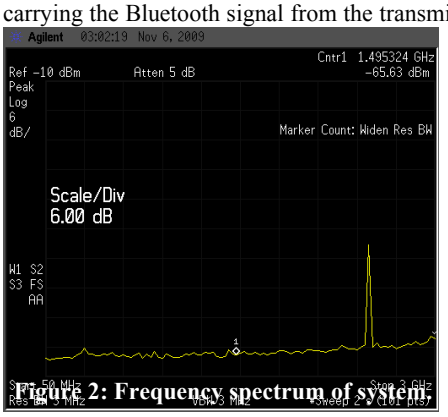

Figure 2: Frequency spectrum of system.

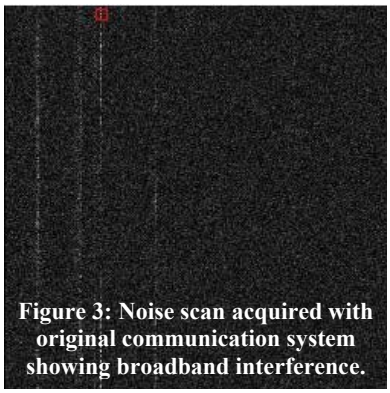

Figure 3: Noise scan acquired with original communication system showing broadband interference.

Results and Conclusion: Knowing the device was FCC certified and test results from ETSI provided by the manufacturer placed upper limits on noise of -58.2 dBm for frequencies 1.705 - 30.0 MHz, -56 dBm for frequencies 30 to 1000MHz, and -44.3 dBm for all other frequencies outside of the 2400 to 2483.5 MHz operating range of the Bluetooth device. The network analyzer revealed no significant noise outside the Bluetooth operating range (Figure 2). The MRI RF noise test revealed no RF interference with the shielded Bluetooth system in operation. Additionally, the SNR measured in images acquired using a high bandwidth EPI perfusion sequence was unaffected by the operation of the device. The new device enables wireless operation of mouse and keyboard in the MRI room without introducing RF interference in the range of frequencies spanned by the MRI receiver system.

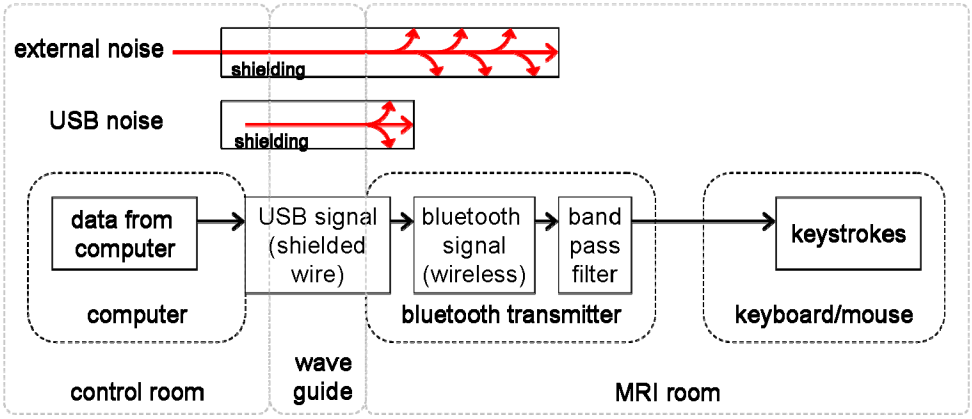

Figure 4: Overview of new Bluetooth system.