Radio Frequency Shielding for a Linac-MRI System

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Introduction: Image-Guided Radiotherapy involves the use of an imaging modality to minimize planning treatment volumes required to deliver a specified radiation dose. A major problem in the radiotherapy process involves patient movement during treatment and day-to-day organ movement. The use of MR images with exquisite soft tissue contrast aims to reduce the irradiated normal tissue volume around the cancerous tissue by tracking and/or adapting to current position, shape and size of the tumour. The 6 MV linear accelerator (linac) integrated with a 0.22 T MRI system in our facility has demonstrated image acquisition during linac irradiation [Fallone et al. 2009]. One of the challenges associated with linac-MRI integration is the broadband radio frequency (RF) interference from the linac's RF pulse modulator and from the brushes in DC motors used to drive the multileaf collimator (MLC) leaves. Unless shielded, this interference is readily picked up by the RF imaging coil with deleterious effects on image quality (e.g. SNR reduction of up to 80% [Fallone et al.]) The purpose of this work is to determine the efficacy of shielding RF noise generated by the linac and an MLC during MRI data acquisition.

Materials and Methods: Gradient echo images (TR=300 ms, TE= 20 ms (linac studies), TE = 35 ms (MLC studies)) of a standard aqueous $CuSO_4$ phantom were acquired at 0.22 T (~ 9.3 MHz) to study the MLC and linac shielding. For the MLC studies one jaw of a commercial 52-leaf MLC (Varian, USA) was placed 70 cm from the RF coil within the system's RF cage. MR images were acquired with the MLC stationary and then with thirteen of the twenty six leaves continuously moving. The MLC motor assembly and cabling were shielded using copper, copper tape and Aluminum foil. Shielding the linac interference required using filters at all additional entry points in the RF cage which were required for linac operation. Images were acquired with the linac in standby and while the linac produced radiation. The radiation was blocked just before the coil with a lead brick to eliminate any radiation induced effects in the coil. The signal to noise ratio (SNR) and the presence of spikes in k-space data were used as indicators of shielding effectiveness. The linac modulator noise was readily visualized above the noise in the k-space data by using an appropriate window and level.

Results: Figure's 1 and 2 show the acquired MR images during the MLC study (A and B) and the linac study (A and B) respectively. Figure 3 shows the acquired k-space data while the linac was operating. Figure 3 images at the left and right are the acquired k-space data for Figure's 2A and 2B respectively, and Figure 3 (middle) is an acquired k-space with insufficient RF shielding for the linac.

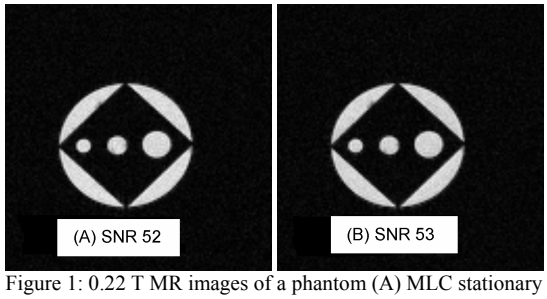

Figure 1: 0.22 T MR images of a phantom (A) MLC stationary and 70 cm from the MRI coil (B) MLC functioning at 70 cm from the MRI coil.

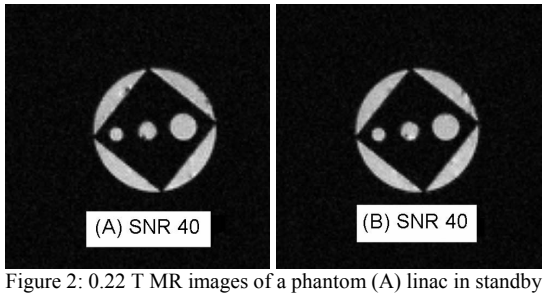

Figure 2: 0.22 T MR images of a phantom (A) linac in standby (B) linac producing 6 MV radiation.

Discussion: One of the challenges associated with the integration of a linac with an MRI system is broadband RF interference from the linac modulator and from the DC motors of the MLC. A linac produces pulse trains that result in a "line" of spikes in k-space data when incomplete or improper RF shielding exists. With proper shielding no spikes are visible and no degradation in image SNR occurs. The MLC motors can be shielded such that there is no experimental difference in the measured SNR with the motors running compared to when stationary. The difference in SNR in Figure's 1 and 2 is due to the slightly different imaging sequence parameters and optimization of signal for each independent study.

Conclusion: We have demonstrated that appropriate shielding of the linac-MRI system is necessary to avoid degradation in the quality of MR images acquired during linac operation. Images showed no degradation in measured SNR with and without the linac pulsing. A current clinical MLC can be shielded so that no degradation in SNR occurs.

References:

Fallone B.G., Murray B., Rathee S., Stanescu T., Steciw S., Vidokovic S., Blosser E. and Tymofichuk D. "First MR images obtained during megavoltage photon irradiation from a prototype linac-MR system" *Med. Phys.* **36** 2009 pp 2084.

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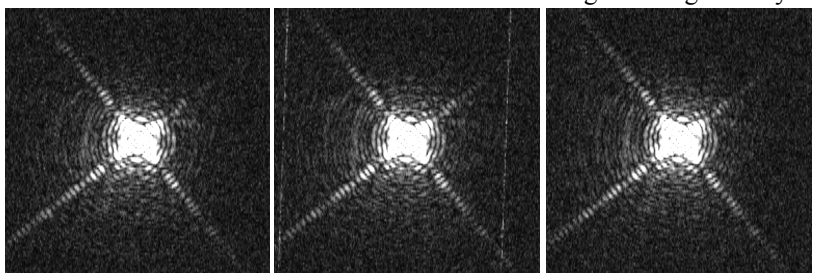

Figure 3 (Adjacent): Acquired k-space data from a rectangular cuboid phantom. (Left) linac in standby (no external RF noise production) (middle) data with incomplete RF shielding illustrating the acquisition of "lines" of spikes in k-space during the production of radiation (right) complete RF shielding with the linac producing radiation (the radiation was blocked just before coil).