Three dimensional simulation and magnetic decoupling of the linac in a linac-MR system

Real time image guided radiotherapy has been proposed by integrating an in-line 6 MV linear accelerator (linac) to a magnetic resonance (MR) imager in either a parallel or transverse configuration. In either configuration, magnetic interference in the linac is caused by its immersion in the magnetic fringe fields of the MR imager. Thus in order to minimize the effect of the magnetic interference, investigations on linac performance in external magnetic fields was completed through various simulations.

Finite difference and finite element methods as well as particle simulations were performed in order to design an electron gun and an in-line 6 MV linac waveguide. Monte Carlo simulations provided calculations of dose distributions in a water tank from the derived electron phase space at the linac target. The entire simulation was validated against measurements taken from a commercial medical in-line 6 MV linac, other simulation programs, and theory.

The validated linac simulation was used to investigate linac performance in external magnetic fields. The results of this investigation showed that the linac had a much lower tolerance to transverse magnetic fields compared to longitudinal fields. While transverse magnetic fields caused a global deflection of the electron beam away from the central axis of the waveguide, longitudinal fields changed the optics of the electron gun in a suboptimal way. Both transverse and longitudinal magnetic fields caused excessive beam loss if the field strength was large enough. Heating caused by excessive beam loss in external magnetic fields was shown to have little effect on the resonant frequency of the waveguide, and any change in dosimetry, if it existed, was shown to be easily corrected using the jaws or multileaf collimators (MLCs). It was determined that the low-field parallel configuration linac-MR system investigated did not require any magnetic shielding, so the focus was on shielding the transverse configuration. Using beam loss, MLC motor tolerance to magnetic fields, and MR imager homogeneity as constraints, passive and active magnetic shielding was designed and optimized. Thus through the parallel configuration, or using magnetic shielding, magnetic interference has been reduced to within the linac operational tolerance.

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