The X-space formulation of the magnetic particle imaging process: 1-D signal, resolution, bandwidth, SNR, SAR, and magnetostimulation.

Journal: IEEE Trans Med Imaging

Publication Year: 2010

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PubMed link: 20529726

Funding Grants: Magnetic Particle Imaging: A Novel Ultra-sensitive Imaging Scanner for Tracking Stem Cells In Vivo, Human Stem Cell Training at UC Berkeley and Childrens Hospital of Oakland

Public Summary:

The magnetic particle imaging (MPI) imaging process is a new method of medical imaging with great promise. In this paper we derive the 1-D MPI signal, resolution, bandwidth requirements, signal-to-noise ratio (SNR), specific absorption rate, and slew rate limitations. We conclude with experimental data measuring the point spread function for commercially available SPIO nanoparticles and a demonstration of the principles behind 1-D imaging using a static offset field. Despite arising from the nonlinear temporal response of a magnetic nanoparticle to a changing magnetic field, the imaging process is linear in the magnetization distribution and can be described as a convolution. Reconstruction in one dimension is exact and has a well-behaved quasi-Lorentzian point spread function.The spatial resolution improves cubically with increasing diameter of the SPIO domain, inverse to absolute temperature, linearly with saturation magnetization, and inversely with gradient. The band width requirements approach a megahertz for reasonable imaging parameters and millimeter scale resolutions, and the SNR increases with the scanning rate. The limit to SNR as we scale MPI to human sizes will be patient heating. SAR and magnetostimulation limits give us surprising relations between optimal scanning speeds and scanning frequency for different types of scanners.

Scientific Abstract:

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