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DOTmedbusiness NEWS

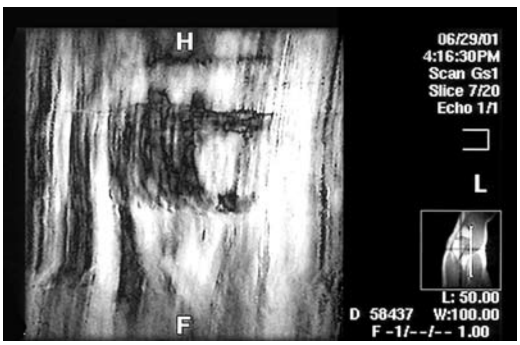
Confronting challenges to urban-based MRI facilities

By Joel Kellogg

MRI systems can be negatively impacted by electromagnetic interference generated by a variety of sources including moving metal, subways, electric buses, transformers, and electric lines. Typically, EMI sources will impact gradient echo sequences, functional MRI (fMRI), and spectroscopy. While OEMs and end-users will try to avoid situating in areas impacted by EMI, it can be very difficult to find "quiet" sites in densely populated urban areas.

The challenge: electromagnetic interference

Areas such as New York City represent an extreme challenge for OEMs and users attempting to site EMI sensitive equipment. Failing to identify a solution for a site with large environmental EMI disturbances decreases the usefulness of an MRI system. Sensitive sequences like fMRI will be impacted and the images produced will suffer. Additionally, gradient echo imaging sequences can be impacted resulting in degraded images that show signs of image ghosting.



Gradient echo knee image. Image suffers from ghosting caused by large Quasi-DC EMI levels.

Solutions: evaluating cost, performance, and convenience

Essentially, there are five possible solutions for a site experiencing EMI disturbances. The first three are generally not options. They would consist of identifying a new site free of disturbance, operating a hobbled MRI or abandoning the project altogether.

Shielding solution

Of the more reasonable options, the first would be to implement a passive shielding design around the MRI in order to reduce the EMI levels inside the MRI suite. A passive shielding solution involves using magnetic shielding material — typically, some sort of steel — to reduce the EMI. Unfortunately, the shielding properties of these materials are very poor when attempting to address EMI disturbances generated by quasi-DC sources such as subways and moving metal. Often, these solutions come with a price tag in the hundreds of thousands of dollars. Further, it is difficult to guarantee the performance of these shields as there are additional technical challenges. For example, the shielding can be rendered completely ineffective if it becomes saturated due to elevated DC magnetic fields. Inevitably, either a portion or all of the passive shielding around an MRI will become saturated rendering the magnetic shielding ineffective for reducing quasi-DC EMI. In order to create an effective passive shield, the shield would need to be designed in layers with the layers closest to the MRI designed to contain the Gauss fields and the layers furthest from the MRI designed to reduce the EMI disturbances. This would require the layers closest to the MRI to provide much higher Gauss containment than is typically required. In most installations, only the five Gauss must be contained from public areas per FDA recommendations, but in this case, the initial shield for Gauss containment would most likely need to provide one Gauss protection or better to avoid saturation of the outer. Further, the outer layer would need to be comprised of a very high permeability material such as "mu-metal." These materials tend to be very expensive.

Magnetic active cancellation system solution

The second option would be a magnetic active cancellation system. A magnetic active cancellation system typically includes a magnetometer, controller, amplifier and compensation coils. The magnetometer is utilized to monitor the environmental EMI. The controller interprets the data provided by the magnetometer and determines the level of magnetic field cancellation required. An amplifier then drives current through a set of compensation coils, which provide an opposing cancelling field. A magnetic active cancellation system, unlike passive shielding, can provide high levels of attenuation at frequencies less than 100 Hz.

Determining the best solution for an MRI facility

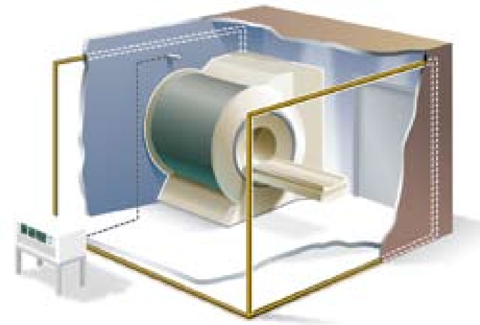
There are pros and cons to passive and active shielding solutions. Passive shielding requires significant construction and can be extremely expensive when utilized for quasi-DC EMI issues. Due to the construction methods required for passive solutions, an owner may have to accept that the volume of the room may decrease substantially due to the passive shield requirements. Further, passive shielding systems are designed and installed to meet a specified attenuation level. As a result, the passive shielding may become insufficient if the environment changes for the worse. Passive shielding, however, does not require maintenance nor rely on electronics that could potentially fail and result in MRI downtime or limited functionality of the MRI.

Magnetic active cancellation, on the other hand, does not require significant amounts of construction. Typically, the construction is limited to the installation of cabling for the system coils. These coils can be installed at the time of the RF shielding installation and concealed behind the interior finish walls. Additionally, a magnetic active cancellation system can be retrofitted into a room. Finally, magnetic active cancellation typically costs less than passive shielding and provides much better performance than passive shielding at frequencies less than 100 Hz.

Implementing magnetic active cancellation

Magnetic active cancellation is a unique solution to EMI issues as it does not employ traditional shielding materials such as steel, copper or aluminum. The system utilizes Helmholtz coils to generate a canceling field to an EMI disturbance. In order to effectively install a cancellation system, it is important to understand the EMI issue for a particular site and what the impact will be on the MRI. Provided that the RF shielding meets the magnet vendor's requirements, RF should not pose an issue. EMI on the other hand, can create some interesting issues that can be difficult to identify. When a site is within the magnet vendor's EMI specifications, there should not be an EMI issue, but a site that is out of specification will pose some unique challenges. For example, it is not always enough to simply reduce the magnitude of the EMI at the site. A proper assessment of the EMI will determine if there are significant gradients (the rate that the disturbance changes over distance) generated by the EMI. The gradients can sometimes be more problematic than the magnitude of the EMI. Therefore, when employing any solution for EMI it is important to first perform a proper evaluation of the site to determine the magnitude of the EMI in the B_0 direction (main direction of the MRI's magnetic field) and the gradient across the bore of the MRI. While a magnetic active cancellation system may work well in many applications, there are applications where it is necessary to customize the coil design in order to effectively reduce gradients associated with an EMI issue.

Once it has been determined that a magnetic active cancellation is the appropriate solution for an EMI issue, a set of coils will need to be installed in the MRI suite. It's best to install the coils during the RF shield installation as the cable can be installed behind interior finishes. If an EMI issue develops later and a facility can't or chooses not to open interior walls to conceal coils, the coils could be mounted in an exposed coil tray.

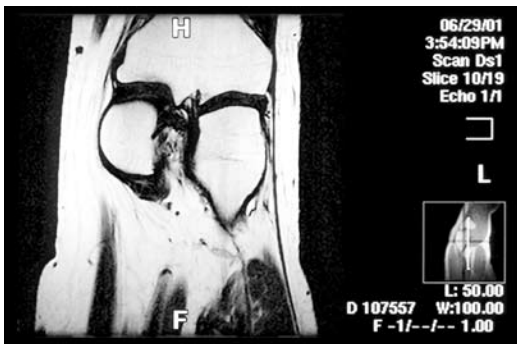


Example of a common magnetic active cancellation system configuration for high field, close bore MRI.

After the MRI is in place and has been brought up to field, the magnetic active cancellation system can be set-up, calibrated and tested. A proper magnetic active cancellation system will account for the natural EMI attenuation from the MRI's magnetic field.

The result from eliminating electromagnetic interference

The actual benefits of the system will vary and are dependent upon the specific EMI conditions for a site. For example, disturbances that only slightly exceed the MRI specifications may only create issues with functional MRI sequences, but much larger disturbances may begin to impact spectroscopy and gradient echo sequences.



Previous knee images taken after implementation of a magnetic active cancellation system.

Conclusion

When faced with an EMI challenge, an owner has options available to resolve the problem that do not involve abandoning the site. In these situations, it is critical for the owners to identify a company that will provide a professional assessment of the situation and work closely with the owner to identify the best possible solution for that specific application. The owner and solution provider should consider the costs, flexibility, versatility and reliability of a given solution before making a decision. With some care and attention to details with the appropriate assistance of a knowledgeable EMI solution provider, an owner can turn a challenging site into a productive, fully functioning MRI imaging suite.

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