RESEARCH NEWS

Medical diagnostics

MRI images: more efficient, quieter and faster

Magnetic resonance imaging has become an indispensable tool for medical diagnostics. Using metamaterials – printed circuit boards whose properties can be systematically adjusted – can increase measurement sensitivity by a factor of five. Metamaterials can also make scans faster and quieter. Researchers at the Fraunhofer Institutes for Digital Medicine MEVIS and for High Frequency Physics and Radar Techniques FHR are working together to make examinations more pleasant for patients.

Magnetic resonance imaging – MRI for short – lets doctors image and examine the brain, spinal cord, internal organs, muscles and joints layer by layer. This technology exploits the fact that certain nuclei in the body can be very slightly magnetized. It can even depict organ movements, such as the beating of the heart. But as impressive and revealing as this imaging may be, for patients, the procedure is often unpleasant – after all, it is loud in the bore.

Up to five times better measurement sensitivity

Getting an MRI could soon become more pleasant for patients. Teams of researchers from the Fraunhofer Institutes MEVIS and FHR working on a Fraunhofer project succeeded in boosting the sensitivity of MRI machines under certain circumstances many times over. "If the MRI works with high-frequency coils that are placed on the patient's body, depending on the question, we can improve the dynamics by up to 20 percent," says Dr. Thomas Bertuch, the team leader at Fraunhofer FHR. "If the coils installed in the MRI machine are used, the measured signal can even be increased fivefold." For doctors, this means that the structures on the MRI images can be discerned in far greater detail.

The research teams achieved this great increase in sensitivity with special metamaterial disks that are designed to be laid on the part of the body to be examined during an MRI scan. "These metamaterials are not materials in the traditional sense, but circuit boards populated with special structures and tracks that make it possible to design materials with effective properties – including materials that do not occur in nature," says Bertuch.

While the electromagnetic field used to excite the atoms in the body needs to be quite strong, the signal these atoms send back – the basis for the MRI measurement – is

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extremely weak. If the metamaterial tracks are designed with this in mind, they can optimally concentrate the receive fields to increase measurement sensitivity.

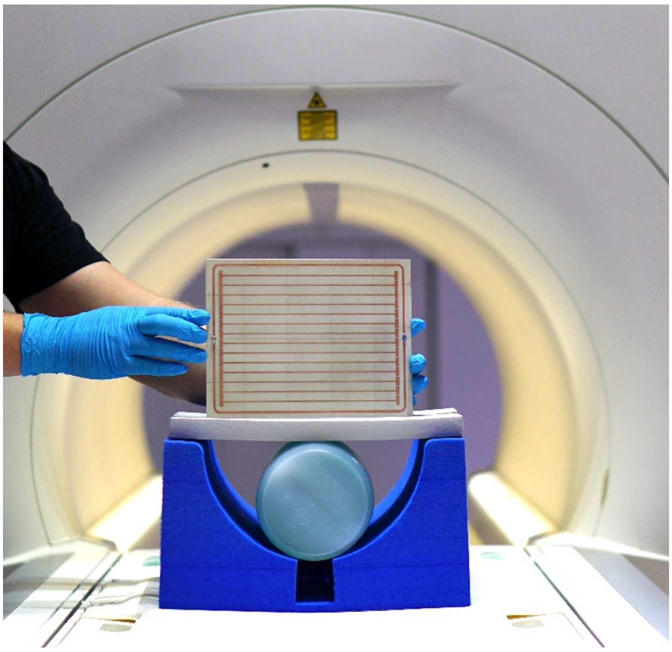
One challenge the researchers faced here was that the reflected signals have the same wavelength and frequency as the excitation signals. Since the excitation signal is already very strong, it is not desirable to boost it even more. To circumvent this obstacle, the researchers devised a trick: they integrate non-linear components, such as diodes, into the metamaterials. If the field is strong, these components detune the disk's resonance frequency in such a way that no amplification occurs. If, in contrast, the field is weak, the signal receives the desired boost. The researchers have already measured a variety of metamaterial disks in the Fraunhofer MEVIS MRI machine and established their amplifying effect. Additional measuring equipment is available at these two Fraunhofer Institutes – including a measurement system that enables them to precisely evaluate the ambient magnetic field and how it changes as a result of the metamaterial disks.

Quieter and faster

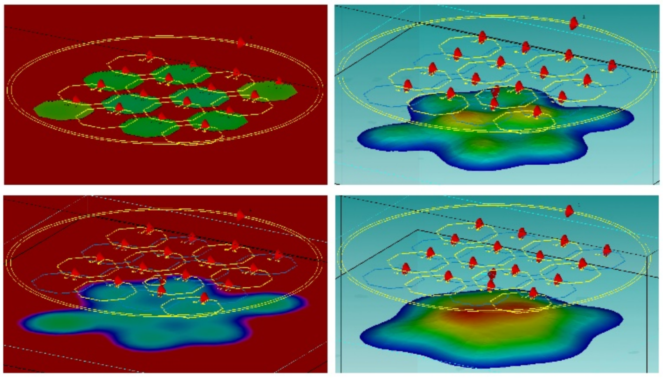
Anyone who has ever lain in an MRI machine knows that it is not only the cramped space, but above all the loud noise that causes patients stress. Determining which part of the body is sending back which signal usually requires a magnetic field whose strength varies with position – the gradient field. Switchable coils dynamically overlay this field on the strong permanent magnetic field, and this causes the loud noise. "The loudest noise during measurement is usually produced when the images are recorded," says Prof. Matthias Günther, deputy director at Fraunhofer MEVIS. "We are working on using metamaterials to completely eliminate this source of noise."

To this end, researchers involved in the Fraunhofer project use a metamaterial array system. The signals from the various body regions strike different "pixels" in the array system, so it also serves to localize the signals. The first prototype is due to be completed in spring 2021, with the researchers planning to improve it in later steps. However, examinations will not be completely silent: there is currently nothing that can be done about the noise generated when the magnetic field is switched to obtain special image information, such as blood flow or diffusion effects, but it can be made much quieter than the noise produced by the imaging.

And if additional magnetic field switching for imaging can be eliminated, the process also becomes much faster. "According to theoretical calculations, our technology should enable us to complete scans up to one thousand times faster. Only when the experiments have been done will we know just how fast that will be in practice," says Günther. Patients would then be able to enjoy much faster and quieter examinations.



Picture 1: Experiments with the metamaterial disk in a magnetic resonance scanner identified as much as a fivefold increase in measurement sensitivity.



Picture 2: Phase images at two different depths (left) and magnitude images of the magnetic field (right) for different resonance patterns in a metamaterial array.