Improvements in Magnetic Imaging Resolution and Positron Emission Tomography using Plasma Antennas

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***Abstract*—**This paper shows various experiments that were done to show advantages of using plasma antennas instead of metal antennas in magnetic resonance imaging (MRI) and positron emission tomography (PET) in conjunction with magnetic resonance imaging. The metal antenna coils were removed from an MRI machine and replaced by plasma antennas in the form of simple fluorescent tubes. The first in vivo imaging was done with plasma antennas in an MRI machine. Of course plasma antennas as fluorescent tubes are not the optimal plasma antenna design for MRI and MRI/PET applications. The problem with metal transmit and receive antennas in an MRI machine is that they interfere with each other. This problem is greatly reduced or eliminated using plasma antennas. In MRI machines combined with PET, the metal antenna coils greatly attenuate the gamma ray paths which are used to locate tumors. Plasma antenna coils greatly reduce or eliminate this problem. Anderson [1] has written a comprehensive book that covers plasma plasma antennas. Supporting references are: [2]-[4]. In addition the plasma can be treated as a metamaterial [5] and plasma antennas are a type of metamaterial antenna.

Keywords—plasma antennas, MRI, PET, MRI/PET, coils, reconfigurable.

I. Introduction (*Heading 1*)

Magnetic resonance imaging (MRI) is currently the gold standard in medical imaging and diagnosis. It is known that matter in a magnetic field on a nuclear scale possesses a property called spin which can be conveniently described by a vector pointing either up or down. A transition between the up and down state is possible if suitable radio frequency energy of the right wavelength is sent into matter. Like all known processes in nature the so-called spin system has now taken up additional energy and wants to go back to its original stable lower energy state. This is realized by emitting energy in form of radio frequency of the same wavelength as those used to excite the spin system. Over time many different antenna types (sometimes called coils in the MRI and MRI/PET jargon) like dedicated devices for head or spine imaging have been developed to satisfy the ever growing demand for better image quality in terms of signal to noise, homogeneity, field of view and conformity to organs under investigation. One of the problems using metal antennas in MRI is that the transmitting and receiving metal antennas interfere. As in all applications, plasma antennas can reduce or eliminate this interference problem. The first tests using plasma antennas in MRI machines and in MRI combined with positron emission tomography (PET) are presented here. We show the first in vivo images using only fluorescent tubes as plasma antennas. In PET, a radioactively labeled sugar with a short half-life time (couple of minutes) is administered to the patient. The sugar will accumulate in areas of the body where high metabolism is taking place, for example in a tumor. When the sugar has accumulated it will start to decay meaning its radioactive isotope will go into another nonradioactive isotope by emitting a positron. This positron then annihilates with an electron and in this process two gamma rays with 511 eV are emitted. If you now have an gamma-ray detector around the patient you can detect these gamma rays and with a bit of statistics can compute where in the body it originated. This will show you tumors as a hot spot on the resulting image. However the resolution of this technique is very coarse, you can see there is a small hot spot but you do not know exactly where it is. That is a problem if you plan to do radiotherapy on a small tumor. You only want to radiate the tumor and not healthy surrounding tissue. Therefore it makes sense to combine the PET with MRI. Currently the MRI antennas are made from metal that is in the line of sight of the PET detector. There is no way around it. Metal can shield or attenuate gamma rays to a great extent. Meaning the MRI coil will shade parts of the PET detector. This is not wanted as you lose information; you might oversee a small tumor this way. If a plasma tube is used it has little or no attenuation than the copper metal. This is an advantage for the PET / MRI as it solves the attenuation problem. We made a simple plot to compare the attenuation we get from a piece of copper with the plasma tube. We think we might even get less attenuation if we had a tube without the phosphor layer. We see that the plasma tube would perform much better than the corresponding metal counterpart currently being used in MRI/PET machines.

II. BASIC PLASMA ANTENNA USED

An off the shelf fluorescent lamp including electronics was obtained from the local hardware store. The lamp does have the following properties:

1. voltage: 220-240 V (power grid)

2. watt: 18 W
3. kelvin: 4000K
4. 50 Hz
5. length: 604 mm
6. diameter: 25. 6 mm (one inch)
7. maker: Philips

The base of the lamp is made of a metal housing. This was removed. The electronics was stripped out of the housing and the cables from the electronics towards the lamp were extended about 5 meters. The lamp was mounted on a base of wood. This setup allows us to keep the electronics out of the stronger stray field of the MRI system thus preventing several ferrites of the electronics going into saturation which will shut down the lamp.

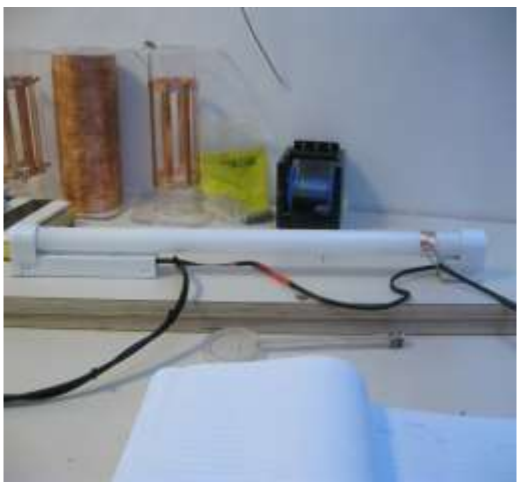

Figure 1: modified plasma lamp on wooden base

as a plasma antenna.

III. PLASMA IGNITION IN A STRONG MAGNETIC FIELD

Initial tests to test if the static magnetic field would have an influence on the plasma showed that not only the electronics needs to be kept sufficiently far away from the MRI scanner but also there is an effect on the plasma itself. It was noticed that moving the plasma lamp at the opening of the MRI system (here are the strongest gradients) the plasma gets deflected and eventually breaks down. If the plasma tube was forced through the gradient field eventually the filament was burned.

The only successful way to ignite and maintain stable plasma found so far depends on the following steps:

1. mount the plasma lamp on the patient table
2. strip the electronics so that the these stay out of the magnetic field (up to half a Tesla seems to be tolerable, not verified)
3. extend the cables so that the plasma tube can be still connected to the electronics also when the tube is in the isocenter of the magnet
4. turn the lamp OFF
5. place the lamp into the isocenter
6. turn the lamp ON

The first image of stable plasma inside a 7 Tesla mri magnet is given in Figures 2 and 3. Abbreviations and Acronyms

Figure 2: First stable external ignited plasma in a 7 Tesla MRI

Figure 3. Plasma antennas in MRI

IV. IMAGING EXPERIMENTS

The plasma can also be ignited by the RF energy from the radio amplifiers of the mri system. These can put out up to 4 kW of power at a frequency of 298 MHz It was observed that as little as 23 W of amplifier output power were enough to light the plasma. As no external power from the power grid is used to ignite the plasma we called this the internal ignited plasma coil. In order to get a more efficient design and thus more signal to noise it was decided to try to feed RF power directly into the fluorescent tube. This was realized with a setup as in Figure 4.

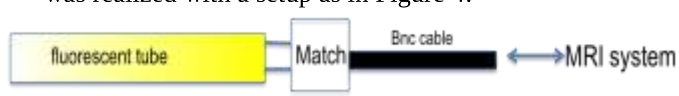

Figure 4: schematic of an internally ignited plasma antenna

The mr table with a banana as phantom is given below Figure 5.

Figure 5: plasma tube coil with banana on mri table

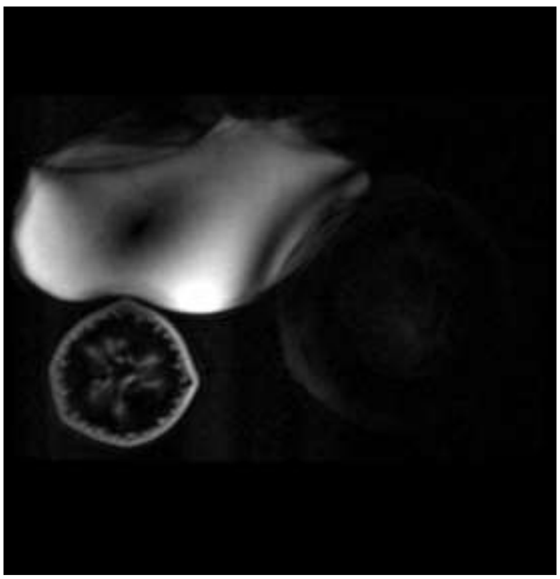

Figure 6: mr image obtained from the plasma tube coil showing a transversal slice through a banana.

V. FIRST INVIVO IMAGES

First images were obtained from the feet and lower legs from a male volunteer. The volunteer lay feet first in the scanner with a linear plasma tube coil between his lower legs.

Figure 7: mr invivo images from a linear plasma coil.

Figure 8. Setup for imaging of the human head with simple fluorescent tubes as plasma antennas.

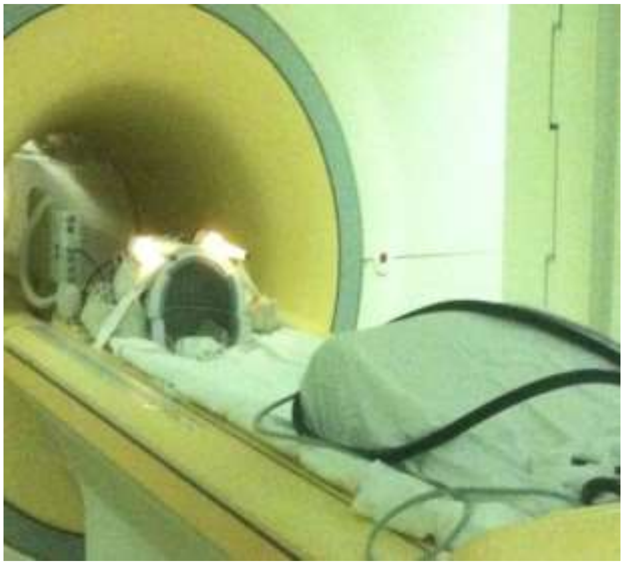

Figure 9. The setup for imaging of the human head in the MRI machine.

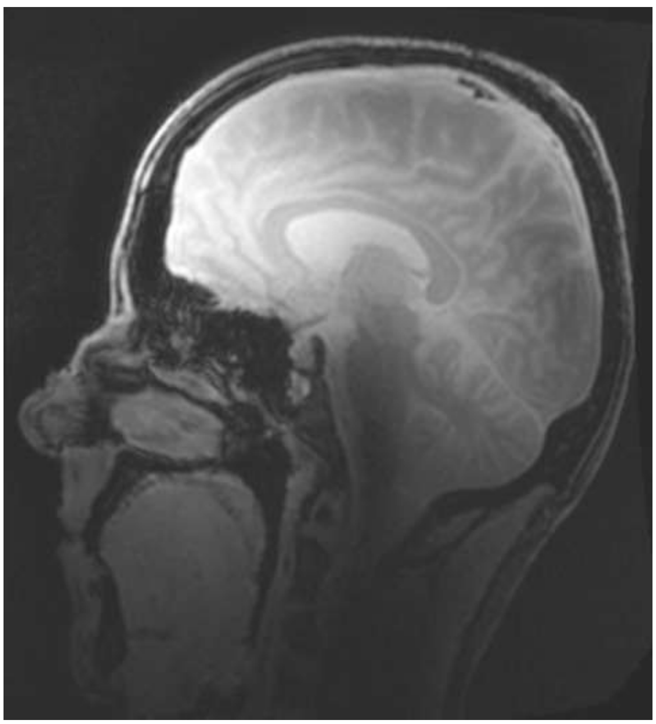

Figure 10. First in vivo image of the human head using fluorescent lamps as plasma antennas in MRI.

VI. Positron Emission Tomography

Currently the MRI antennas are made from metal that is in the line of sight of the PET detector. There is no way around it. Metal can shield or attenuate gamma rays to a great extent. Meaning the MRI coil will shade parts of the PET detector. This is not wanted as you lose information; you might oversee a small tumor this way. If a plasma tube is used it has little or no attenuation than the copper metal. This is an advantage for the PET / MRI as it solves the attenuation problem.

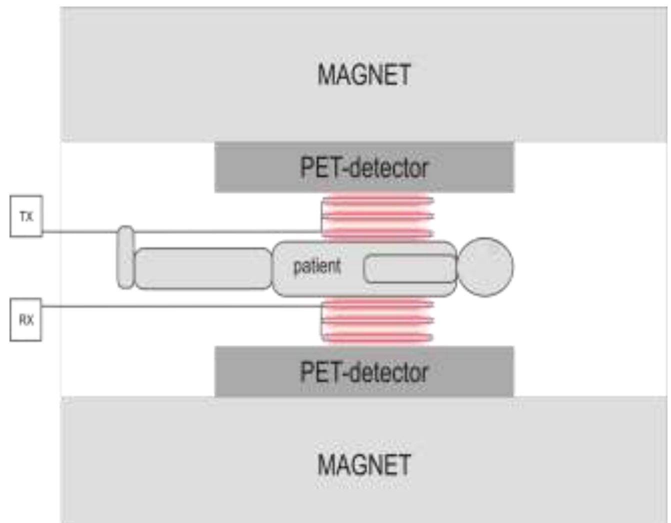

Figure 11. Plasma tubes as transmitting and receiving antenna coil for PET/MRI.

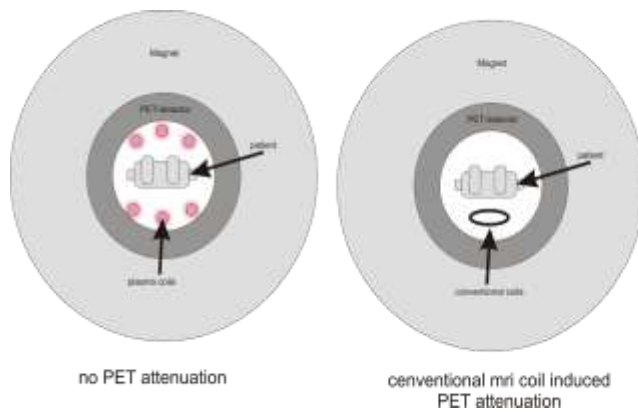

Figure 12. PET-MRI advantage of plasma coils: no or very little PET attenuation compared to conventional coils

VII. CONCLUSIONS

The experiments presented in this report lay the ground for a whole new area of resonator design in magnetic resonance imaging and PET. Many advantages of plasma antennas have not even been tried for MRI and PET. With very simple and cheap florescent lamps it is possible to image human subjects in an MRI machine.

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