Contribution of the inherent traveling wave in 7T to large FOV imaging

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Introduction

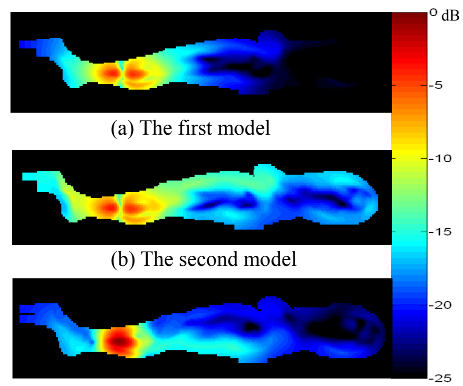
As the traveling wave has become a hot topic in high field MR as a promising method for large FOV imaging since ISMRM 2008, a lot of applications of traveling wave in imaging have been discussed. For example, one explanation for the large FOV imaging of the leg with a z-oriented small loop (Figure 1a) is that the leg takes the role of waveguide and extends the FOV. Nevertheless, since the conductive interface in the 7T scanner, consisting of the cryostat, gradient coil and RF shield, allows TE11 mode propagating, all excitations should create a TE11 mode in the interface, which we called the inherent traveling wave in 7T. Therefore, it needs to understand the traveling wave contribution even in the conventional transmission and reception methods in order to make use of it. In this work, we performed full-wave electrodynamic simulations with a body model to explore the contribution of the inherent traveling wave to the large FOV imaging with a conventional excitation method.

Methods

Since the conductive surface always exists in the system during the experiment, it is hard to evaluate the contribution of the conductive interface to the large FOV imaging experimentally; therefore, we resorted to the 3D commercial FDTD software, CST Microwave Studio (Computer Simulation Technology, Darmstadt, Germany), to analyze its contribution. In CST, six models were built to understand the wave behavior in the conductive interface. In the first model, a loop (5cm in diameter and 6mm in width) driven with a current port is placed beside of the low leg of human model, the normal direction of the loop is parallel to the coronal direction of the body model, with the whole system is placed in the free space; the second model has the same configuration as the first one, except that the whole system is placed in a constant diameter conductive cylinder. The diameter of the cylinder is 680mm, which allows TE11 propagating inside at 7T according to Maxwell's function. In the third model, the position of the loop is changed to face the body in the cylinder. The B1 mappings of the leg in these three conditions are compared. Moreover, to confirm that it is TE11 mode propagating in the conductive cylinder, we removed the body model to avoid the complicated wave behavior due to the body in the above three models to form the fourth, fifth and sixth models, respectively. The magnetic field vectors and B1 mapping of the three cases without body model are compared.

Results

Figure 1(a) and 1(b) show the B1 mapping of the leg in the first and second models respectively. From the result, it can be seen that the FOV is extended and the SNR is boosted when the conductive cylinder presents, especially in the area away from the loop, which is very clear in the ratio map of these two cases, as shown in Figure 2. Figure 1(c) shows the B1 mapping of the leg in the third model, which is the general setup in MR system. This setup has the best SNR in the region close to the loop, and compared with 1(a), its FOV is extended along z, but not as much as 1(b). The wave behavior is clearer at the unloaded cases. Figure 3(a) is the simulation result of the fourth model, from which it can be seen that the signal decays as it propagates away from the coil, while in the conductive cylinder in the fifth model, the B1 mapping shows standing wave pattern, as shown in 3(b); when the normal direction of the coil is in transversal plane, corresponding to the sixth model, the B1 mapping also has a standing wave pattern, as shown in Figure 3(c), although its strength is weaker than 3(b). From 4(a), it can be seen that without the conductive cylinder, the near field complies with Biot-Savart law, and the far field radiates out; when is the cylinder presents as shown in 4(b), H field in the cylinder has the TE11 mode pattern, and the near field still comply with Biot-Savart law; 4(c) shows the case that the normal direction of the coil is in a transversal plane, it is also TE11 in the conductive interface, but its strength is much smaller than 4(c). This is because the H field of the TE11 mode at the edge points along z direction, when the coil is placed in the x-y plane, according to the right-hand law, the magnetic field induced in the coil also points to z direction, thus this position is the most efficient to excite TE11 mode. If the length of the cylinder is infinite, the magnitude of the B1 mapping should be equal in the z-direction; however, the cylinder in the practical application can not be infinite. As a result, we can still see the standing wave pattern as shown in Figure 3(b). Methods such as impedance matched at the end of the cylinder have been suggested as a solution to remove the standing wave effect.



(a) The first model

(b) The second model

(c)The third model

FIG1 B1 mapping of the leg with a single loop

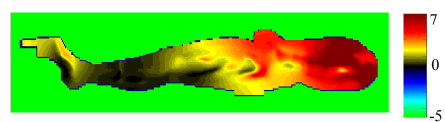


FIG2 Ratio of the Fig 1(b)/1(a)

Conclusions

The conductive interface of 7T system works as a cylindrical waveguide, it allows the modes whose cutoff frequencies are lower than the 7T resonant frequency propagating in it, so as to extend the FOV and boost the SNR of the imaging. Even with the conventional excitation, there is traveling wave propagating in the conductive interface. In order to effectively excite the working mode, the position of the excitation should be that the current distribution in the excitation and the H field pattern comply with the right-hand law.

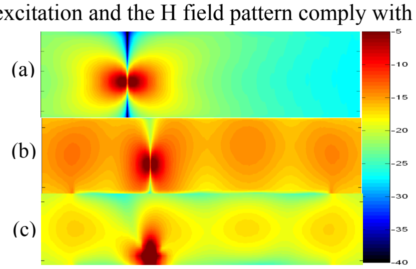
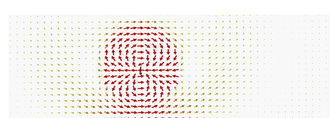
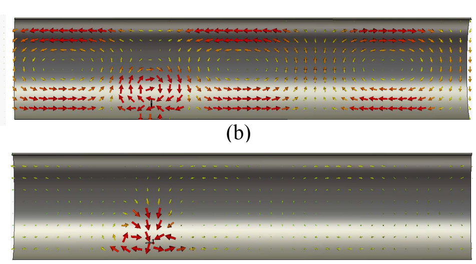


FIG3 B1 mapping in (a) the fourth model; (b) the fifth model; (c) the sixth model



(a)



(b)

(c)

FIG4 H field vectors in (a) the fourth model; (b) the fifth model; (c) the sixth model

References

[1] D.O. Brunner et al. 16th ISMRM, Toronto 2008. [2] N.B.Smith et al, 17th ISMRM, Hawaii 2009. [3] B. Zhang et al, 17th ISM RM, Hawaii 2009.