# Whole-Body Traveling-Wave Imaging at 7 Tesla: Simulations and Early In-Vivo Experience

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## Introduction

The use of traveling waves guided by the RF shield of the MR scanner has been suggested as a promising method for large FOV imaging and comparatively uniform excitation at high magnetic field strength [1].   At the ISMRM High Field Workshop in Rome in 2008, in vivo traveling wave imaging of the leg [2] and the head [3] was demonstrated.   However, detailed analysis of the distribution of electromagnetic fields throughout the body for an in vivo traveling wave system has not been presented to date.   In this work, we juxtapose full-wave electrodynamic simulations using a human body model with in-vivo human imaging at multiple stations covering the entire body.   The goal of this work is to explore basic principles of signal distribution and energy deposition for whole-body traveling wave MR driven by a patch antenna at 7T.

## Methods

A circular patch antenna with two orthogonal coax feeds matched to 50Ohm was designed for excitation and reception at 297.2MHz. Details of the patch antenna design are provided elsewhere [4], but in brief, the antenna uses a 400mm*400mm square slab with the thickness of 31.75mm as the substrate, a circular patch of copper tape with the diameter of 174mm on the front side, and a the same copper tape covered the whole back area of the patch antenna to form the ground plane. Different cable length is used to achieve a circular polarized field, RF power is split equally with a Wilkinson power splitter and one T/R switch and preamp assembly is used in each line. In the MR system, the patch antenna is placed at the service edge of the bore. The same setup is applied in XFDTD simulation, with a whole human body model in the bore. A sinusoidal waveform with the maximum voltage 400 lasting 2.9e-8 second is used for the excitation, and the coaxial feeds are simplified to wire with lumped elements in the simulation. In human imaging in Siemens MR System, a 2D GRE sequence at the RF pulse amplitude 425V, with TR=20ms, flip angle=40, slice=1, ref. amp=425, phase resolution=128 are used. Moreover, the interaction of the TE11 mode with dielectric material is analyzed to explain the rapid attenuation of the signal from the superficial region to the interior region of the body.

## Results

Figure 1 shows a concatenation of in vivo images at various stations.   The general distribution of signal is consistent with the B1+ distribution shown in Fig 2.   Three basic principles may be adduced to explain the observed attenuation of signal distal to the patch: first, when the traveling wave meets dielectric material in its propagation path, the power is attenuated rapidly because the wave number becomes complex in order to match radial boundary conditions.   This is also observed in Figure 3, which shows B+ mapping when a TE11 wave is propagating in a homogenous dielectric material with nonvanishing conductivity; second, in areas that the body does not fill, the traveling wave can still propagate smoothly, therefore, the signal of the superficial region of the body is still high in the part below the arms; third, when the wave encounters interfaces between different dielectric properties, some power is reflected back, resulting in some standing-wave behavior.   From Figure 4, it can be noted that the SAR maximum is located in the head and the maximal local SAR for simulated 400V drive is 2.595e-004W/kg. The simulation shows that 32% power is dissipated in Tissue and 67.3% power is radiated out. Since the S parameters of the patch antenna changes when the body is placed into the bore, only 74% of the total power is emitted from the patch antenna, and then the net input power is calculated to be 6.88e-4W. Therefore, in order to achieve the limit of SAR regulated by FDA (3W/kg head), the maximal power for a 2D GRE sequence (TR=20ms, flip angle=40, slice=1, ref. amp=425, phase resolution=128) which can be used for human imaging is 500.9W, while we used only 18.7767W in vivo, much smaller than the limit.



Fig. 1: Multistation in vivo traveling wave imaging
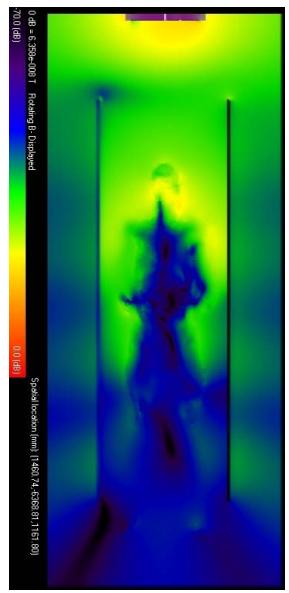


Fig 2: Simulated B1+ distribution
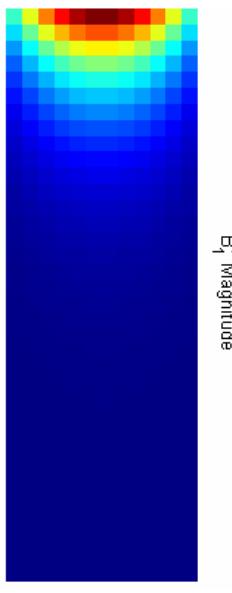


Fig 3: Uniform dielectric simulation
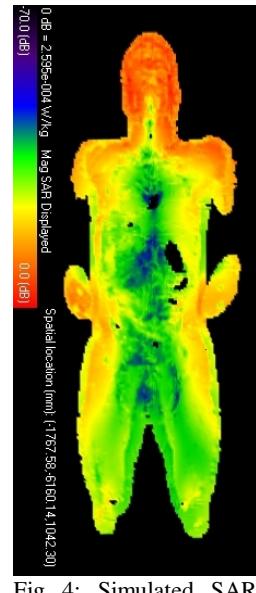


Fig 4: Simulated SAR distribution in a body model

## Conclusions

With the traveling wave generated by the patch antenna, one can generate large-FOV images and relatively uniform excitation, but the signal attenuates very quickly in the interior region, as shown in both simulation and experiment. A large fraction of the power from the patch antenna is radiated out and the system has low transmit efficiency. The simulation shows that SAR is distributed inhomogeneously in the human body model. Based on the SAR value in simulation, the power we used for human scanning is quite low.

## References

[1] D.O. Brunner et al. 16th ISMRM, Toronto 2008. [2] K. Pruessmann, ISMRM 2008 High Field Workshop, Rome [3] N.B.Smith et al, ISMRM 2008 High Field Workshop, Rome [4] B. Zhang et al, ISMRM 2009, submitted.