Multi-Pass Travelling Wave Volume Coil

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Introduction

Up to now most 7T body imaging is performed with local TX/RX arrays despite the existence of the TEM resonator [1] and the advent of travelling wave excitation methods [2]. Travelling wave excitation suffers from power attenuation along the bore and high local energy deposition (SAR), whereas the TEM resonator is no more usable when its dimensions approach λ/2.

In this work we present a novel volume coil concept for high and ultra high field MRI body systems which does not utilize a resonating structure. Instead it excites a large volume with a multi-pass travelling wave combining the travelling wave concept with a principle [3] that has been the basis for both the birdcage [4] and the TEM-resonator [1].

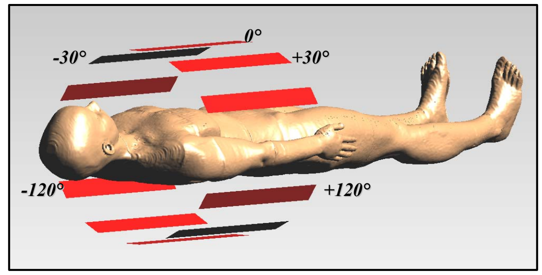

Fig.1: Sketch of simulated model, length of bore shield (not shown) =1220 mm, ∅=630 mm, length of transmission lines=425 mm on circle of ∅=545 mm.

Materials and Methods

In the coil design several parallel transmission lines are placed uniformly around a cylinder at equal azimuthal distances (Fig.1). An incoming wave at the central line (0°, Fig.2) travels in z-direction to its end, where it is split into two equal parts. It is then fed back without interaction with the excitation volume to the beginning of two adjacent lines, azimuthally +-30° apart from the first one. After propagating to the line ends again both waves are fed back to two further lines which they leave at their respective ends. This pattern is repeated and also mirrored in the lower set of transmission lines with a phase shift of π. Finally, four attenuated waves leave the lateral lines, are combined and dissipated in terminating loads. The current magnitudes and phases are controlled by the appropriate lengths and characteristic impedances of the transmission lines to create a homogeneously excited volume.

To theoretically confirm the principle and evaluate the potential as a volume excitation coil, electrodynamic simulations (3-D full wave FDTD–Software SEMCAD X, Schmid & Partner Engineering AG, Zürich, Switzerland) were performed at 300 MHz without and with a human body model (Ella). The simulated coil was 425 mm long with a diameter of 545 mm within a bore shield of 1220 mm length and 630 mm diameter. Dynamic grid sizes were chosen.

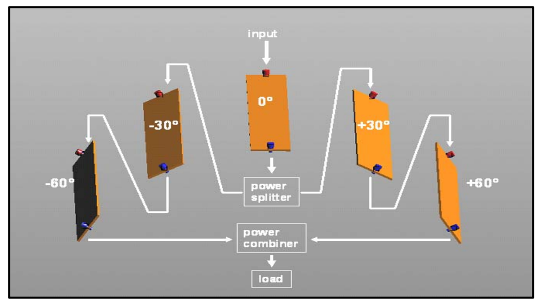

Fig.2: Power flow in upper set of transmission lines. Input is at 0° (head end). The output of this line is equally divided and fed back to drive ports of lines +-30°. Remaining output power from lines +-60° is combined and dissipated in load. Apart from relative phase shift of π, power flow in lower set is identical.

Results and Discussion

Simulation results are shown in Fig. 3-4. Uniform B1+ fields are produced in the XY-plane when the coil is empty (Fig.3). Line plots show B1+ variations of less than 0.5 dB within a radius of 150 mm. With a human body model tissue properties cause minor interference of the B1+ fields, resulting in less uniform (variation +- 5 dB) but still strong excitation areas in the torso (Fig.4 top). The highest B1+ fields and maximum SAR occur in the inner coil volume close to the driving port and at parts of the body closest to the transmission lines (arms and shoulders) with appreciable amounts leaking out towards the head (driven end) and the legs. This was expected because the bore shield acts as a wave guide and causes large excited areas outside the targeted FOV. Absorbing or compensating the fields in these areas would help confine the excitation energy to the coil volume, decrease total body SAR and increase SNR. As RF power is dissipated in the terminating load, power efficiency is lower than with a resonator. In contrast to one-pass travelling wave techniques the multi-pass method presented here seems to have the potential of creating efficient volume excitation with good homogeneity in ultra high field MRI systems in a very simple way - despite its using linear polarization only in the basic concept.

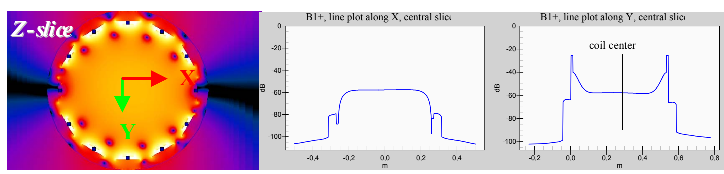

Fig.3: B1+ field map at central z-slice and line plots at z-slice (xy-plane) of unloaded coil; relative dB-scales as in Fig.4.

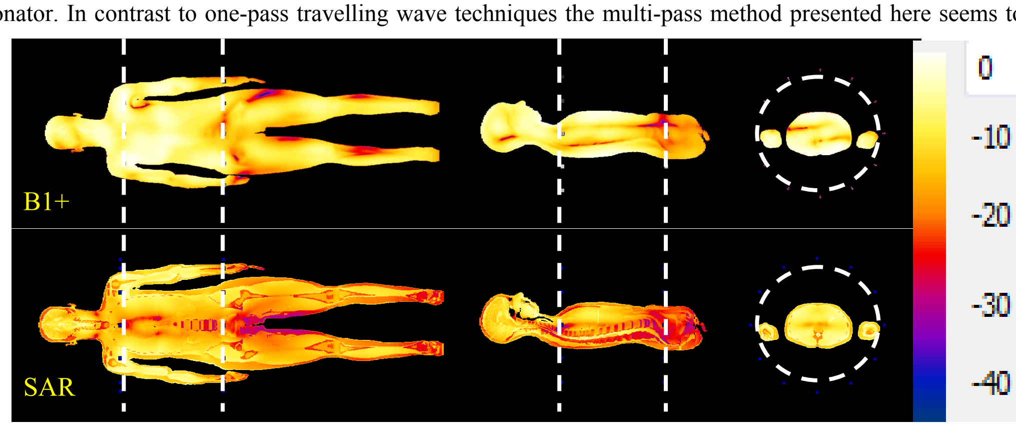

Fig.4: B1+ and SAR maps at central slices; relative scale in dB; dashed lines mark coil limits.

References

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