Linear phase non-resonant hybrid lumped element / twisted microstrip RF transmit coil

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INTRODUCTION: RF coils that generate transverse magnetic fields with uniform amplitude and linear phase variation across the imaging volume have been shown to be optimal for excitation fidelity in parallel transmission (1) and are useful for reduced SAR slice selective excitation and for gradient-less imaging (TRASE) (2). Such field profiles have been obtained with twisted birdcage coil designs (2,3). Previous work presented a method of using distributed capacitors along the length of a microstrip transmission line to increase the effective electrical length of the line (4). These elements were used to simulate a traveling wave volume excitation coil with linear phase along the axis. The resulting phase variation over a 40cm length, 24cm diameter coil was approximately 168º at 3T frequencies compared to the 60º phase change of the same coil without the distributed capacitors. For this work It was desired to further increase the phase variation along the axis of a volume transmit coil of the same dimensions and at the same 3T frequency. This work presents the design and characterization of a traveling wave twisted microstrip volume coil, based on Finite-Difference Time-Domain (FDTD) simulations.

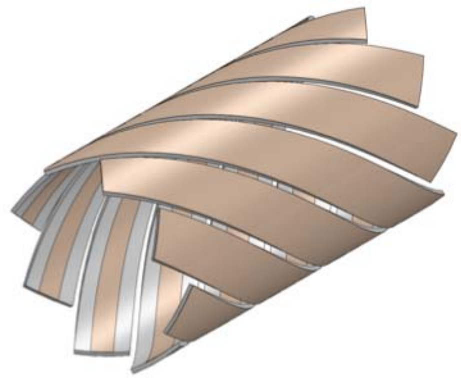

Fig 1: Eight element Twisted Microstrip Linear Phase coil array forming a traveling-wave volume coil with a π twist.

THEORY: Increasing the effective electrical line length of a microstrip transmission line can be achieved with the use of distributed lumped element capacitance placed between the conductors along the length of the line (4). Volume coils made from such elements have increased phase along the length of the coil with minimal Bz-field component (5). Twisting the elements in a spiral manner around the volume surface can increase the phase variation along the length of the coil, but increases the Bz component according to the pitch of the spiral. Combining the two techniques can be used to achieve a greater amount of phase variation along the coil axis. For this work a single π twist is used to determine the feasibility of the twisted microstrip design while limiting the resulting Bz field.

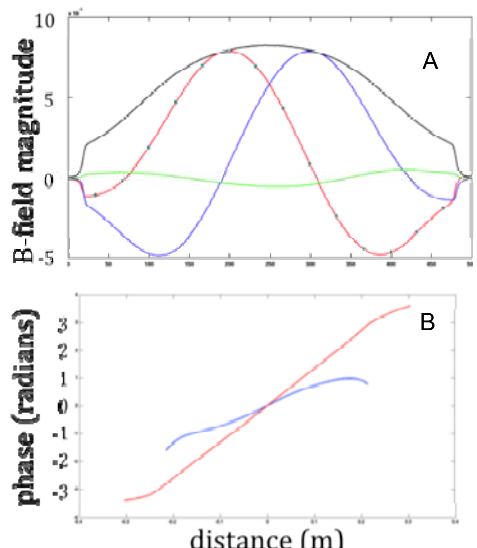

Fig 2: A) Field profile plot along axis of coil. Red/blue/green/black = Bx/By/Bz/|Bxy|. B) Bxy axial phase profile of: red= twisted microstrip, and blue = straight microstrip volume coils.

METHOD: For this work, a volume microstrip coil consisting of 8 individual microstrips around the surface of a 24cm diameter 40cm length cylinder (see Figure 1) was simulated (Remcom Inc.). Each microstrip had a 25mm center wide conductor, spaced 5mm from the 60mm width ground plane, and 54cm long. The Teflon substrate (er=2.4) between the conductors created a characteristic impedance of 34 ohms. Microstrip elements formed a π twist from one end of the cylinder to the other (see fig 1). A circularly polarized B-field was generated using voltage feed sources for each microstrip that varied in phase according to their relative angular positions in the coil. Resistors were used to terminate each line. Each microstrip used 7 evenly distributed capacitors between conductors to increase the phase variation along their length. Simulations were performed using XF simulation software (Remcom Inc.).

RESULTS: Using the parameter capabilities of the XF software, the characteristic impedance of each line was determined to be 37+j2.7 ohms (34 ohm source and load impedances used in simulations). Maximum S21 was achieved using seven 20.3 pF lumped element caps distributed along each microstrip. S21 and S11 were -0.04 and -44 dB respectively, at 123 MHz. B-field profiles (see Fig 2A) show the quadrature Bx and By fields, the low Bz component, and the overall sensitivity profile for the twisted microstrip coil. Fig 2B compares the phase profile along the length of the 8-element straight (5) and twisted microstrip coils. The Twisted microstrip achieves essentially 360º phase variation along its length compared to the 168º of the straight coil. Fig 3 presents an example “deviation from linear phase map” for the twisted coil, showing good phase linearity along the coil axis.

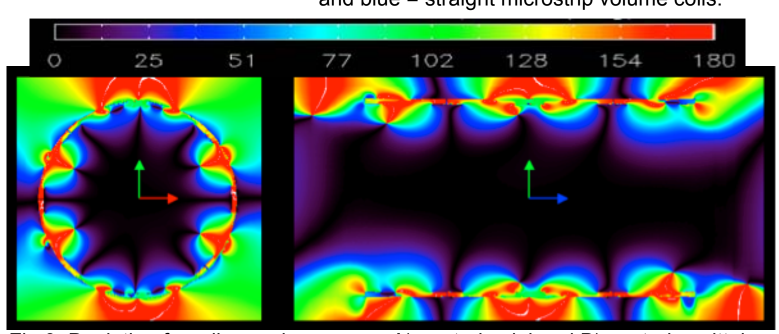

Fig 3: Deviation from linear phase maps A) central axial and B) central sagittal planes. Colorbar indicates degrees deviation from central linear phase profile.

CONCLUSION: This work shows how twisted elements achieve greater linear phase along the axis of a coil designed to have a linear phase distribution through the volume of the coil.

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