Helix antennas: approaching the target from a different angle

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Helix antennas are a commonly used type of antenna in communication technology. They emit a circularly polarized wave with high directivity. For MRI, these antennas have been tested for travelling wave imaging [1]. However, a more promising application is the use of these antennas as a coil directly on the imaging subject. The helix antenna has the unique property to transmit or receive along the longitudinal axis of the scanner. This unique property enables the coverage of regions that are otherwise hard to address. For example, the helix antenna can be used to aid a birdcage in achieving sufficient B_1 at the apex of the head. At the other end of the body, the helix antenna can be used to increase efficiency/sensitivity for a prostate imaging experiment, where the coil is placed at the perineum.

Figure 1: Helix antenna in communications

General design rules for the helix antenna require that the length of one helix winding equals the wavelength. The spacing between the windings should be one quarter of a wavelength and the full length of the antenna should preferably include at least three windings. The windings generate circularly polarized fields (both B and E fields) that move along the antenna. This results in a circularly polarized propagating wave that is emitted in the longitudinal direction. A high permittivity substrate is used to reduce the signal wavelength (and thereby the antenna dimensions) to feasible proportions. Table 1 shows the antenna dimensions for 3 and 7 T, using high permittivity substrates.

	ε_r inner substrate	diameter (cm)	spacing (cm)	full length (cm)
3 T	40	11.8	9.3	27.8
	80	8.3	6.6	19.7
	160	5.9	4.6	13.9
7 T	40	5.0	4.0	11.9
	80	3.6	2.8	8.4
	160	2.5	2.0	5.9

Table 1: Helix antenna dims.

Figure 2 shows a simulation geometry where the antenna is extended with some extra parts: an external substrate and a shield. These parts are essential as demonstrated by a simulation series (Semcad X, Speag, CH) presented in figure 3 where the antenna is placed on a cubic 0.5 m^3 phantom (ε_r=36, σ=0.45 S/m). The internal substrate is chosen to match the permittivity of the phantom but without losses i.e. ε_r=36, σ=0. Without external substrate (a dielectric cylinder around the antenna) the antenna fails: B_1^+ and B_1^- are equal; circular polarization is not achieved (Fig. 3a). Including an external substrate (15 cm diameter, ε_r=36, σ=0) realizes the expected polarization pattern: B_1^+ is much larger than B_1^- (Fig. 3b). A RF shield around the antenna avoids radiation losses and therefore increases the B_1 field and directivity (Fig. 3c). Although the performance is increased, the wave is no longer fully circularly polarized: some substantial B_1^- arises. This is caused by Eddy currents in the shield. Note that for all images in figure 3, the B_0 field is oriented vertically.

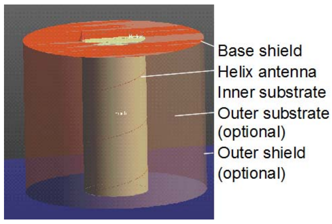

Figure 2: Helix antenna with inner substrate, outer substrate and shield.

Figure 4a shows a simulation setup for a helix antenna on the cranial side of the head at 3T (Ella, Virtual Family). Resulting B_1 distribution is indicated in figure 4b. This setup can be desirable if enclosure of the head by a birdcage coil is not desired or to aid a birdcage coil to achieve sufficient B_1 at the apex of the head. Figure 5a shows a simulation setup with the antenna positioned at the perineum for prostate imaging at 7T (Duke, Virtual Family). Figure 5b shows the resulting B_1 distribution. Note that the resulting B_1 level in the prostate (0.3 μT/√W) is equal to the B_1 level obtained with an external array of dipole antennas (0.28 μT/√W) [2] indicating that the SNR can be increased by 41% when combining the two.

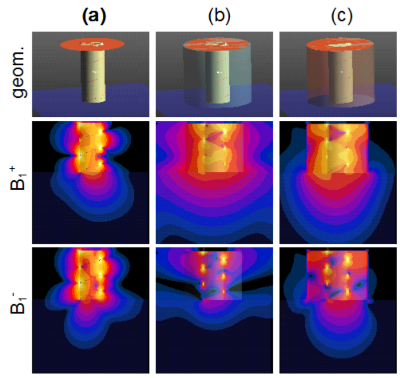

Figure 3: Design exploration (a) Helix antenna with base shield and inner substrate. (b) Added outer substrate (c) Added RF shield

The helix antenna has the unique property of emitting a circularly polarized wave in the longitudinal direction. In combination with dielectric matching to the tissue, it is a powerful candidate for MRI applications like brain and prostate presented here.

References:
[1] Lee and Glover ISMRM 2010
[2] Raaijmakers et al. ISMRM 2013

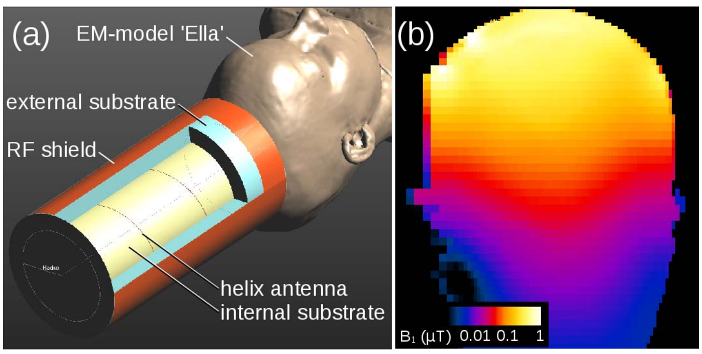

Figure 4: Use of a helix antenna at the apex of the head at 3 Tesla. a) Simulation setup b) B_1 distribution normalized to 1W

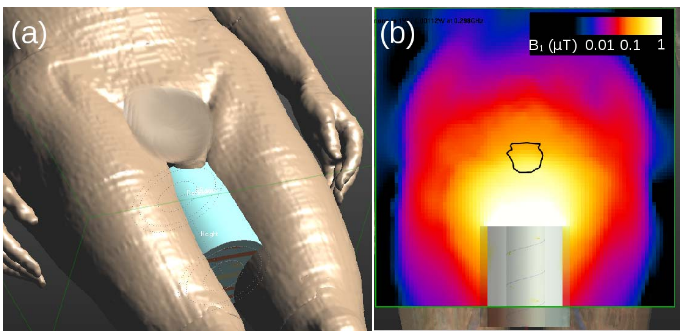

Figure 5: Use of a helix antenna for prostate imaging at 7T a) Simulation setup b) B_1 distribution normalized to 1W. Indicated is the position of the prostate.