Comparison between Linear, Quadrature, and 4-port Excitations from 1.5 T to 4.7 T

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Introduction:
For current MRI system, the two main excitations, which are used for RF coils such as the birdcage resonator [1], are linear and quadrature drives. At low frequency, circuit analysis and the transmission line theory show that the quadrature excitation generates a circularly polarized field, which is more homogeneous than the linearly polarized field produced by linear excitation. Also, the power required for a certain flip angle in a linear drive is twice as much as in the quadrature drive. Therefore, another advantage of the quadrature excitation is the enhancement of signal to noise ratio (SNR) by a factor of $\sqrt{2}$ because as the signal is increased by a factor of 2, the noise is only increased by a factor of $\sqrt{2}$. In this work, these two excitations, in addition to a proposed four-way drive are evaluated in terms of magnetic field (Bi) homogeneity and specific absorption rate (SAR) values in a birdcage coil.

Methods:
The concept of a 4 port drive is similar to the quadrature excitation. The input signal is split into 4 quarters by using a hybrid. A \(\pi/2\) phase shift is applied on each quarter of the signal as shown in Figure 1. The signal coming out of the hybrid is then fed to 4 points on the upper circular ring of the birdcage coil; each of these points is one quarter on the circular ring away from the neighboring point (Figure 1). We simulate this method, in additional to the linear and conventional quadrature excitations using the finite difference time domain (FD-TD) method [2]. The 3-D calculations are evaluated in a high pass birdcage coil loaded with different phantom geometries and anatomically based human head model at 64 MHz (1.5 T) and at 200 MHz (4.7 T).

Results and Discussion:
Figure 2 shows an axial slice of the Bi field distribution and the SAR values inside a cylindrical phantom that has the electromagnetic properties of muscle at 200 MHz. For linear excitation, compared to 90% Bi field homogeneity (the difference between the maximum and the minimum values of the field is 10% of the maximum value) that was obtained at 64 MHz, the homogeneity has dropped to 23%. Also unlike the 64 MHz case, there is no improvement in the homogeneity of the fields from linear to quadrature drive. However, for the 4-port drive, one can observe that the homogeneity of the field has improved to 50% with a better overall homogeneity. As opposed to the conventional quadrature drive, the 4-port drive reduces the tissue-coil interactions leading to more uniform currents on the coil legs and consequently a better Bi field homogeneity. Figure 3a, b shows axial slices of the contour plots of the Bi field for a coil loaded with a phantom that has an octagonal shape and driven in quadrature and 4 ports, respectively. The 4-port drive produces a more uniform circularly polarized Bi field over the quadrature excitation. Unlike the quadrature drive, the fields are symmetrical around an axis with \(\Phi\) of 45° and 135°. In Figure 2, while quadrature excitation has lead to higher SAR peak values compared to that with linear excitation, driving the coil in 4 ports provides SAR distribution with peak values which are significantly less than those with linear or quadrature excitation.

Figure 1. Excitation in 4 ports

Figure 2. SAR (right half) and Bi field distribution (left half) inside a cylindrical muscle phantom at 200 MHz (top: linear excitation, middle: quadrature excitation, bottom: 4-port drive)

Figure 3. An axial slice of a coil loaded with an octagonal muscle phantom showing contour plots of the Bi field

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