Using a mode concept to reduce hardware needs for multichannel transmit array

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Introduction:

NMR imaging at higher field strength (3T and more) frequently shows shading in image brightness which is caused by B_1 inhomogeneity. Therefore it would be desirable to create a more homogenous B_1 field inside a patient. A known approach is the use of a multi channel transmit array [1] [2] [6], consisting of independent controllable antenna elements. The number of independent transmit channels is increasing with the number of antenna elements [3]. The number of TX channels can be reduced, if the relation between antenna elements (rods) and Fourier modes is utilized. In such a configuration the modes with mainly counter rotating field components can be omitted.

Method:

Considering e.g. an 8 element TEM coil [4], the current distribution on the rods can be described as a linear combination of modes. On the other hand, each single mode m is determined by a current distribution on the rods k as $I[k,m] = A[m] \exp(j\, k\, m\, \pi/N)$ with the mode index m (m = -(N/2+1) ..0..N/2), rod index k (k= 0 …N-1) and the number of legs N. Mode +1 is the basic quadrature transmit mode, while the associated receive mode is m = -1.

One motivation to use modes arises from FDTD simulations which showed that the major improvement in B_1 homogeneity comes from a limited number of modes, the contribution of negative modes and mode 0 is negligible. This does even more apply for antennas with more than 8 elements on the circumference. On the other hand using more than 4 modes has almost no influence on the achievable homogeneity.

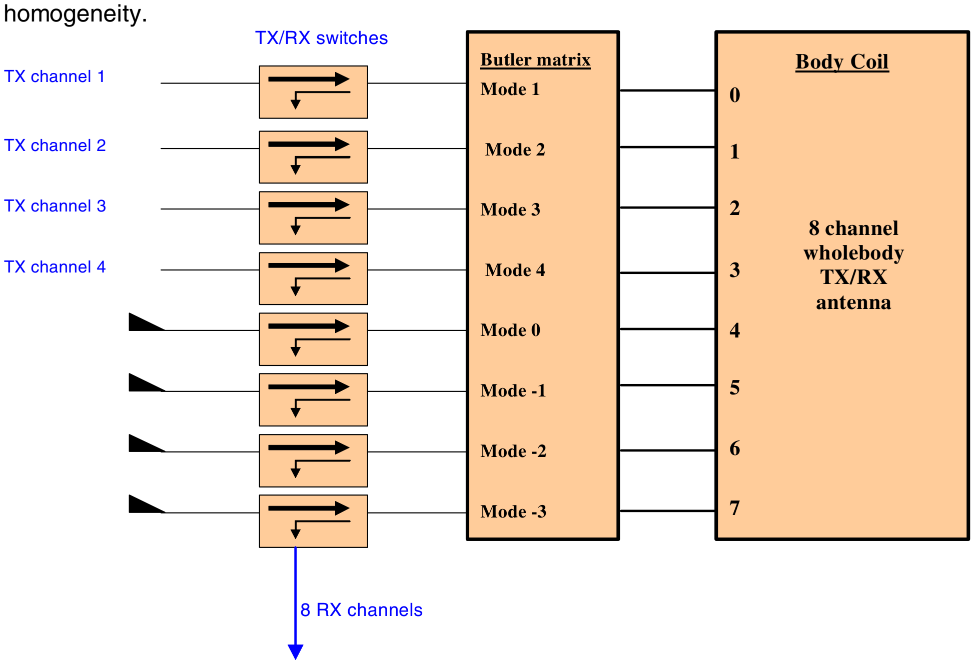

Fig 1: system setup for 3T TX-Array (4 TX channels, 8 RX channels)

Fig 2: 8x8 high power Butler matrix

In a "conventional" TX array solution one RF amplifier would be required for each rod. To reduce the amount of hardware and costs, we favour a setup using a high power Butler matrix [7] in the path between the RF amplifiers and the antenna. The Butler matrix is built of 90°-degree splitters and phase shifters (see Fig. 2) and distributes the input power to the elements of the antenna with the desired phase shifts to produce fields according to spatial Fourier modes. Using this configuration, the number of RF amplifiers can be reduced significantly. An additional benefit of this setup is the intrinsic matching to all RF-power amplifiers in the presence of the load. Similar to reflection cancellation at the transmit input of a quadrature combiner, the reflections at the mode ports of the Butler matrix are typically less than 10%, independent of the loading of the antenna. This minimizes the power derating and gain variation of the amplifiers. Another advantage is the decoupling between the input ports of the Butler matrix, which means ideally there would be no need for T/R switches for the receive mode ports. However with variable loading T/R switches are needed to protect the RX amplifiers. We successfully tested this set up with a degenerate band pass birdcage [5] in a 3 Tesla system. The practical results showed the predicted behaviour.

Conclusion:

A novel setup for a whole body transmit array was designed and evaluated. It employs a high power Butler matrix to reduce the number of RF amplifiers required for effective homogenisation of the B_1 distribution.

References:

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