Single-feed quadrature coils as transceiver array elements for improved SNR and transmit efficiency

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INTRODUCTION: Quadrature or circularly polarized (CP) coils are desired in MR experiments due to their improved MR sensitivity (by 40%) and reduced excitation power (by half) compared with linear coils. This is particularly true in parallel imaging and parallel excitation where the reception/excitation acceleration demands highly efficient receive and transmit. Conventionally quadrature coils are driven from two feeding ports. In surface coils, which usually serve as resonant elements in parallel imaging coil arrays, the quadrature mode is usually formed by using two loops orthogonal to each other. Their bulky structure limits their application to designing parallel imaging arrays. Soutome and co-worker proposed a method for single-feed birdcage coil and demonstrated its feasibility at 1.5T (1). In this work, we propose a method to generating quadrature modes by single-feed surface coil for high field MR applications. This method is based on the single-feed CP microstrip patch resonator technology. To demonstrate the concept, a single-feed quadrature coil array with two elements was designed and evaluated by using FDTD simulation and bench test.

METHOD: The simulation study on the single-feed CP surface coil with a square ring shape (2) was performed using FDTD algorithm. The coil was designed for proton at 7T. With dimensions shown in Fig 4 and substrate permittivity of 13.1, the calculated resonance frequency of 297.7MHz was obtained by computing the S11 from the input port, a point near the inner square on the diagonal (Fig 1). The square ring microstrip is a completely distributed structure and capable of high frequency operation. Circularly polarized B1 fields generated by the single-feed microstrip resonator were evaluated numerically. With the guidance of simulation results, a coil array with two quadrature resonant elements was built on a piece of TMM 13I material with the thickness of ¼" (Rogers Corp., Chandler, AZ). Bench test was performed using a network analyzer to evaluate the resonance frequency, decoupling between elements and CP performance.

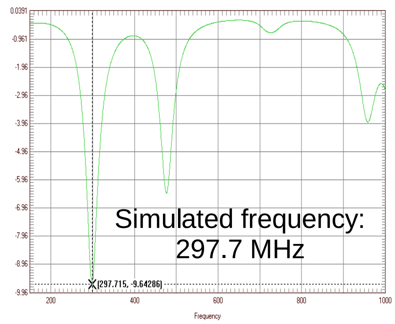

Fig 1 Simulated S11 plot from a nearly square shaped single-feed CP microstrip resonator by FDTD algorithm.

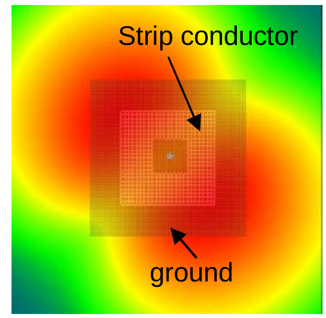

Fig 2 B1 map of the nearly square shaped single-feed CP microstrip resonator by FDTD algorithm.

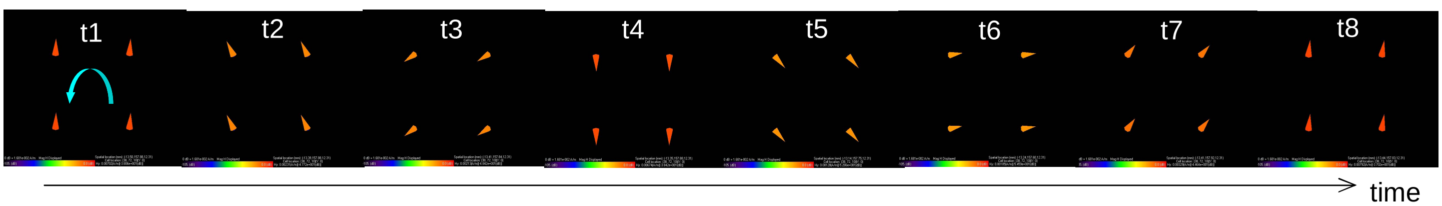

Fig 3 Magnetic field vectors of the circularly polarized mode generated by the proposed single-feed surface coil. The direction of the arrows denotes the direction of the magnetic fields. The vector direction change with time from t1 to t8 (about a period T) clearly shows the circularly polarization behavior.

RESULTS: Circularly polarized magnetic field B1 was calculated. Fig 2 shows the CP B1 plot in a plane 3cm above the single-feed CP resonator. The direction change of the magnetic field vectors was recorded within about 1 period, clearly showing the circularly polarization behavior of the fields (Fig 3). A feeding coaxial cable was directly connected to the CP at the feed point shown in Fig 4. The resonance frequency measured 299.8 MHz, yielding less than 1% accuracy compared with the simulated frequency (297.7MHz). Without matching circuitry, the S11 reached to -37dB, well matched to the system 50 Ohm (Fig 5 left). In the case of array, Fig 5 (right insert) shows the S21 measurement between the two resonant elements. Although the two elements were only 3cm apart, the measured decoupling was -27 dB or better, indicating a sufficient isolation for parallel imaging applications.

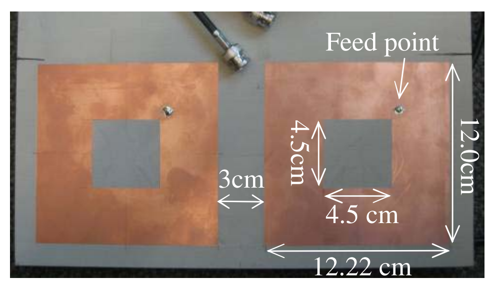

Fig 4 The proposed single-feed quadrature coil array with two elements. The resonance frequency measured 299.8 MHz. With a gap of only 3cm between the two loops, the decoupling was achieved -27 dB.

CONCLUSIONS: Single-feed quadrature microstrip resonators were demonstrated for ultrahigh field MR applications. The technique proposed is advantageous and feasible for designing parallel imaging coil arrays with better reception/excitation efficiency. The single-feed quadrature coil arrays may benefit the parallel excitation applications due to their reduction of the required RF transmit power.

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REFERENCES: (1) Soutome Y, et al, ISMRM 15, 1057 (2007); (2) Garg R, Microstrip Antenna Design Handbook (2001).

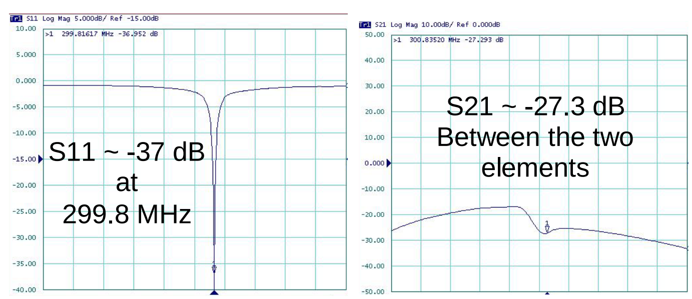

Fig 5 Measured resonance frequency of each single-feed CP element and decoupling performance between the two.