# A 3-Axis Phase Gradient Array for RF Encoded MRI using the TRASE Method

Jonathan C. Sharp[1], Qunli Deng[1], Scott B King[2], Vyacheslav Volotovskyy[2], and Boguslaw Tomanek[1]
[1]National Research Council of Canada, Calgary, Alberta, Canada, [2]National Research Council of Canada, Winnipeg, Manitoba, Canada

**Introduction:**
TRASE (Transmit Array Spatial Encoding) is a novel MRI method in which the spatial encoding is achieved by repeated refocusing by 180° pulses, where all $B_1$ transmit fields have the form of a phase gradient (1). Figure 1 illustrates the encoding principle. In the simplest case, application of 180° pulses using alternate positive and negative phase gradient fields results in 1D encoding. Some possible applications of this new form of encoding include low-cost MRI (due to the elimination of the B0 gradient system) and microscopy.

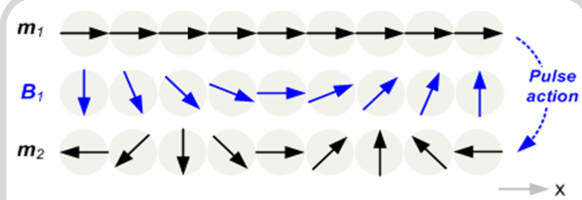


**Fig.1**: Refocusing by a linear $B_1$ phase gradient results in k-space encoding of transverse magnetization.

**Purpose:**
The purpose of this work is to develop full 3-axis encoded RF imaging apparatus and techniques. We have previously demonstrated 2D encoding using a coil array capable of producing any one of 4 phase gradient transmit fields (+X, -X, +Y, -Y). In this work we present a 3-axis encoding transmit coil array and experimental results.

**Methods:**
A previously-described 2D-encoding coil (3), providing encoding for the X and Y axes, was combined with a double spiral birdcage array (1), providing encoding for the Z axis. The X & Y coils were of identical design, constructed at 90deg with respect to each other to allow encoding of orthogonal axes. The apparatus for each axis (X or Y) consisted of a Helmholtz-type coil and a Maxwell-type coil. Phase gradient polarity was selected by the phase of the RF drive to the Maxwell coil. Array outer dimensions were (42cm, 42cm, 28cm), providing 4deg/cm phase gradients over an imaging FOV of 15cm. The twin spiral birdcage coils were of much smaller size (10cm diameter cylindrical former), but provided a stronger phase gradients of 12.5deg/cm. All experiments were performed on a 0.2T magnet (8 MHz), operated by an NRC TMX MRI console (2). A single RF channel was used with PIN diode controlled RF switches and phase shifters (for the X & Y coils). While the elements required for producing a phase gradient on a selected axis are energized, all other coils are actively disabled by PIN diode circuitry.

**Results:**
To test the operation of all array elements, and the production of all 6 fields, 2D-encoded images in all 3 orthogonal planes were collected (Fig.2). For 2D-encoding the parameters were as follows: 800us pulse length, 200 echoes, 399 echo trains. The XY image shows the circular tube cross-section, while the other 2 view show the conical profile of the end of the phantom tube.

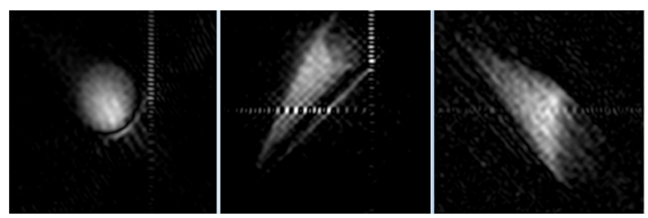

**Fig.2:** *Three 2D-encoded images, demonstrating the 3-axis encoding ability. Planes: XY, XZ, XY. Phantom: cylindrical tube with conical end, 30mm diameter; 40mm height).*

**Discussion:**
Since some coil elements in the array are not geometrically decoupled, the quality of active decoupling achieved (in the presence of RF transmit signal) is critical for optimum array performance. With improved isolation between the Z-coils and XY coil elements a pulse length reduction down to at least 500us should be achievable. Due to the mis-match between the Z and X,Y gradient strengths and FOVs this is not an optimum design, however it is proving useful as a platform for development of fully $B_0$-gradient-free imaging techniques.

**Conclusions:** A 3-axis RF encoding phase gradient transmit array has been constructed and tested. This will allow the development of fully 3D-encoded TRASE sequences including slice or slab selection (1) and 3D-volume encoding.

**References*:*** ***(1)*** *Sharp JC & King SB. MRI using Radio-Frequency Magnetic Field Phase Gradients. Magn. Reson. Med. 63:151-161, 2010;* ***(2)*** *Sharp JC, Yin D, Bernhardt RH, Deng Q, Procca AE, Tyson RL, Lo K, Tomanek B. The integration of real and virtual magnetic resonance imaging experiments in a single instrument. Rev Sci Instrum. 2009 Sep; 80(9):093709.* ***(3)*** *Sharp JC, Deng Q, Volotovskyy V, Tyson R, Yin D, Bernhardt R, King SB, Tomanek B. Imaging without Gradients: First In Vivo MR Images using the TRASE RF Imaging Method, 20th ISMRM, 2012.*