Frequency Division Multiplex for Phased Array Receive Coils

J. Iannotti[1], S. Go[1], K. Dufel[1], B. Platt[1], and E. Fiveland[1]

[1]General Electric Global Research Center, Niskayuna, NY, United States

I. Introduction

Phased array surface coils are widely used to improve image SNR [1] and acquisition speed [2]. The number of coil elements has increased from 4 to 128, with an emphasis on a larger number of coil elements for increased parallel imaging acceleration. The increased number of channels also increases the number of necessary interconnects, cable baluns and receivers. With 32 to 128 element coils, cable management and bulk are obstacles to patient-friendly, large element count coils. We propose and demonstrate a method for combining multiple channels into one coaxial cable by utilizing Frequency Division Multiplexing (FDM). In this approach, signals from each coil are up-converted into a unique frequency. These unique frequencies are combined and transmitted down a single cable where then separated into individual channels, dramatically reducing a multitude of cables.

II. Experimental methods

All experiments were performed on a 1.5T GE SIGNA MR scanner. Three 8.25cm diameter circular elements were constructed, assembled and tuned as a test phased array coil (Fig. 1). Each coil was connected with a $\lambda/2$ cable to a standard preamplifier. The same test array was used for both the baseline and FDM tests. For the baseline tests, the test array was connected to the receiver cabinet using individual cables for each coil element in a normal manner. For the FDM tests, the output of each channel after the preamplifier module was connected to a custom circuit that up-converted the signal from 64 MHz to different frequencies in the PCS (Personal Communication Service) band. For our experiment, the signals from the three coil channels were up-converted to 864, 1064, and 1264 MHz, respectively (Fig. 2). These frequencies were chosen such that the harmonics and intermodulation products generated would not degrade image SNR or introduce additional image artifacts. The up-converted signals were then combined and transmitted through a single coaxial cable to the receiver cabinet. At the receiver cabinet, the signals were separated and down-converted back to 64 MHz before being sent to the individual receiver inputs for each channel. A 2D multi-slice fast gradient echo (FGRE) pulse sequence was used for the imaging tests (10mm slices; 30° flip angle; 256x256 matrix; TR = 68 ms). Images were obtained with a standard quality assurance (DQA) phantom and a uniform $CuSO_4$-doped phantom. Baseline images were first acquired through three conventional MR channels. A second set of images was acquired using through our FDM system with unity gain (0dB). In this setup, the entire FDM system was treated simply as a lossy cable section. Magnitude images were compared, for each approach using measured SNR in small regions-of-interest (ROI). SNR from the multi-slice image data was measured in slices 5mm, 15mm 25mm, 35mm, and 45mm from the phased array coil surface (Fig. 3).

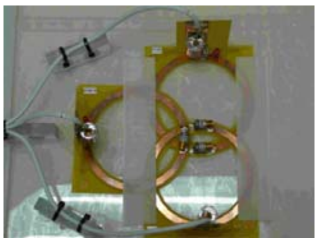

Fig. 1. Three-element Phased array

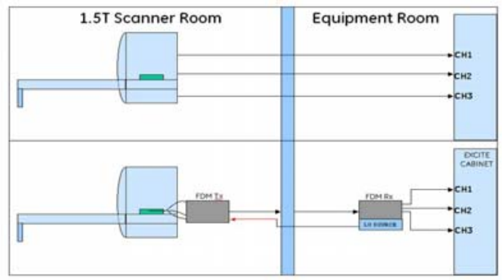

Fig. 2 top: baseline configuration and bottom: FDM configuration

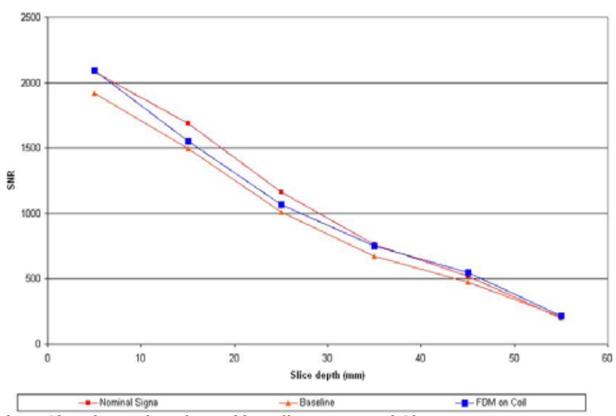

Fig. 4 Signal to noise plots of baseline, FDM and Signa system

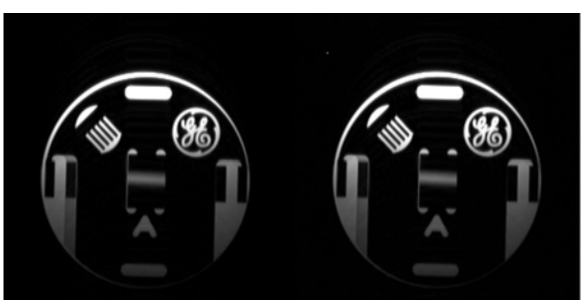

Fig. 3 left: baseline image and right: FDM image

III. Results and Discussion

Images taken with the three-channel FDM system were comparable to baseline images (Fig. 3). SNR of the FDM images showed less than 5% variation difference with respect to the baseline images. Cross talk between channels was insignificant with 65dB channel-to-channel isolation. Phase stability was ensured with precision LO sources. Furthermore the system is designed such that any phase variation introduced during the up-convert process was cancelled out by the down-convert process.

IV. Conclusions

We have demonstrated the feasibility of using FDM technology for mutli-channel phased array coils. In this proof-of-concept, no degradation in image SNR was observed despite the additional circuitry introduced for the up- and down-converting steps. These results points the way for improved designs for 32, 64, and 128 channel coils with reduced weight, bulk and complexity. This was an essential step to realizing patient-friendly high channel count RF coils.

References

1.Roemer PB, Edelstein WA, et al. MRM 1990; 16: 192-225.
2. Sodickson DK, Manning WJ. MRM 1997; 38: 591-603.