

# The MRI Eigencoil: 2N-Channel SNR with N-Receivers

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**Synopsis** MRI Eigencoils were constructed at 1.5T using an inline hardware combiner attached to the standard Siemens 8 Channel Head Array, producing the same SNR and parallel imaging benefits of the 8 channel receiver system using only 4 receive channels. In some cases, the SNR of a 2N channel array can now be obtained with only N receivers, maximizing SNR and minimizing g-factor for a given number of receivers, while reducing data flow rates and computation time by a factor two.

## Introduction

In the past several years, the demand for increased SNR over large FOV's has resulted in the development of 6 to 8 receiver channel MRI systems. The advent of parallel imaging techniques greatly strengthened the need for multiple channels. Given that the demand for ever increasing numbers of receivers may continue to outstrip the ability to deliver such systems, it is important to get the most benefit from the receiver channels available. This abstract reports upon investigations into the ability to achieve 2N channel performance using an N channel receiver system.

## Theory/Methods

It has been known that the standard Sum-of-Squares (SoS) reconstruction can be optimized for up to 30% higher SNR by employing the noise correlation matrix in the reconstruction [1,2]. That is,  $S_{opt} = \mathbf{s}'\mathbf{N}^{-1}\mathbf{s}$ , where  $\mathbf{s}'$  is the conjugate transpose of  $\mathbf{s} = (s_1 \dots s_n)$ . It follows that with eigenvalue/vector decomposition of the Hermitian noise correlation coupling matrix,  $\mathbf{N} = \mathbf{K}'\mathbf{K}$ , the optimal combination can be expressed as  $S_{opt} = \mathbf{s}'\mathbf{K}^{-1}\mathbf{K}'^{-1}\mathbf{s}$ . If we define  $\hat{\mathbf{s}} = \mathbf{K}'^{-1}\mathbf{s}$  as our new signal vector, then  $S_{opt} = \hat{\mathbf{s}}'\hat{\mathbf{s}}$  which is just a SoS operation in the new basis. Due to some basic symmetry existing between the n-elements of an array and therefore  $\mathbf{N}$ , there may be some degeneracy between the eigenmodes. The number of degenerate eigenmodes (d) means the n-element phased array has degree  $m = n - d < n$ . Degenerate eigenmodes can be linearly mixed (preserving there eigenvalue) to produce new eigenmodes with most of the SNR concentrated in one of the two modes, leaving almost all the SNR contained in m-channels. This, of course, is the principle of Quad/Antiquad pairs now extended to higher degrees. Images were collected on a Siemens 1.5T Symphony 8 channel scanner using the Siemens 8-Channel Head Array [3], with elements equally separated by  $\pi/4$  around the head. The Eigencoil<sup>TM</sup> was formed by inserting an m-degree  $\mathbf{K}'^{-1}$  hardware combiner inline between the output of the Head Array and the system interface.

## Results

Straight eigenvalue decomposition of the 8-channel Head Array (residual inductive coupling removed) produces what can be interpreted as the linear modes of an 8-pole birdcage resonator, a phased array coil of degree=5 (three-fold, double degeneracy). With a proper hardware phase combination of the degenerate modes, the three pairs of linear "birdcage" modes were converted to Forward/Reverse polarity pairs (2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup> columns of Fig.1), labeled with their respective phased modes ( $n =$  array element number). The 5 Forward polarity pairs contain most of the SNR. Also, one or both of the non-degenerate modes (1<sup>st</sup> column of Fig. 1) have low SNR and can also be discarded, forming the 4- and 3-Channel Eigencoils of Fig. 2.

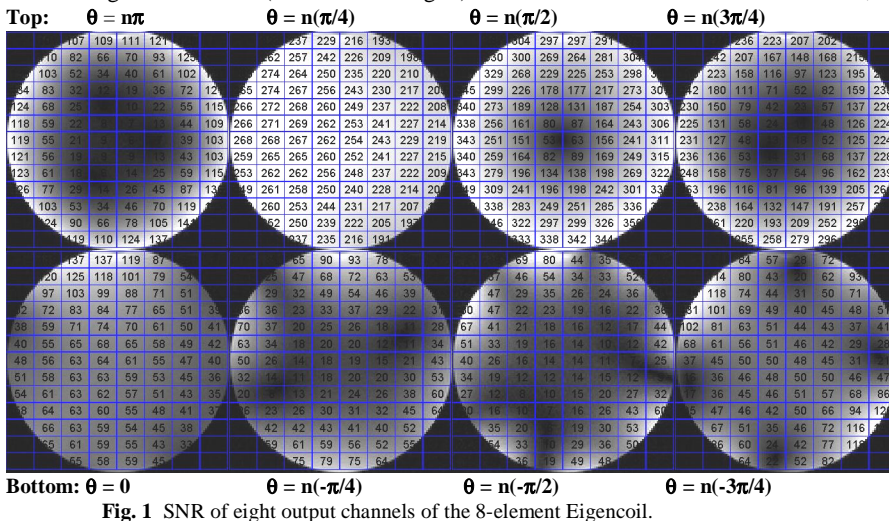


Fig. 1 SNR of eight output channels of the 8-element Eigencoil.

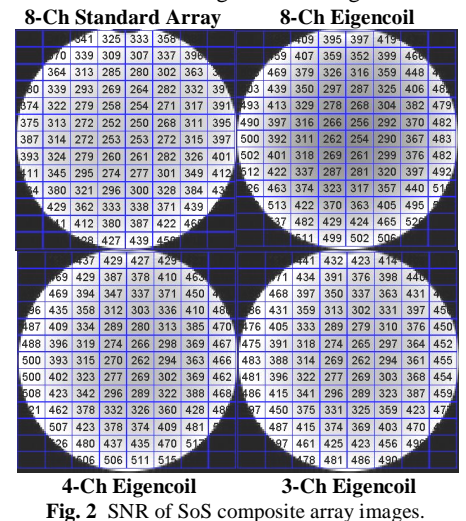


Fig. 2 SNR of SoS composite array images.

## Conclusions

Using Eigencoils, SNR losses associated with the standard SoS algorithm can be minimized (30% gain here) and more importantly, the optimal SNR of the 8-Channel Eigencoil can be achieved in as few as 3 receiver channels. Done in hardware, SNR's equivalent to a 2N-channel array can be achieved using for instance N channels (even N - 1 channels in this case) dependent on the degree-m of the Eigencoil array. Extrapolating these results, it seems apparent that for certain symmetries, it is possible to obtain 16-channel array SNR on an 8-channel system, reducing data flow rates and computational time by a factor of two. Because all the eigenmodes are orthogonal with a diagonalized noise correlation matrix, the Eigencoil is ideal for parallel imaging, minimizing g-factor for a given number of receivers and reducing computation time.

## References

[1] Roemer, P.B., et al., Magn Reson Med 16:192-225, 1990; [2] Varosi, S.M., et al. ISMRM Proc. p. 768, 2002; [3] King, S.B., et al., ISMRM Proc. p. 1070, 2001.