Signal combination Mode Matrix Calculation on Considering Multiregion SNR

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Introduction: The concept of "Mode Matrix" has been proposed in reference [1]. It's mainly geared towards parallel imaging techniques which require array elements stacked in phase encoding direction [2-4]. The pre-combining signals use Mode Matrix to scale the number of necessary RF channels as a function of the acceleration factor. In this work, we provide a new method for Mode Matrix calculation without considering the array distribution.

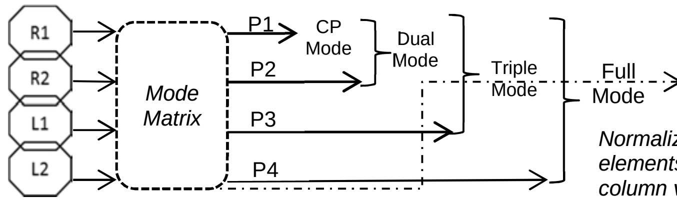
Method: The method can be applied to any coil array with at least 2 elements, an explicit example is given for N=4. The step by step process of the propose method is described as follows.

<u>First</u>: We need to construct a matrix which could transform physical signals from 4 elements into 4 virtual modes [Fig1]. Signals should as possibly concentrate in front modes in order to scale output channels flexibly. It's necessary to take account of such signal attenuation through body and try to optimize the SNR in deep region of interest (ROI). Taking abdominal coronal scan for instance, the central slice usually has lowest signal and was considered as the reference plane for optimization (Fig. 2). It notes that slices on the bottom are not selected as a reference since they are always close to other coil elements (e.g. spine).

<u>Second</u>: Some small regions along the coil array distribution direction are roughly selected (Fig. 2), the number of regions doesn't have to be equal to the number of the coil elements. Assuming our scenario fulfills the requirements for stochastic process analysis and eigenvalue decomposition [5], an optimal weighting vector could be calculated to maximize the SNR for each region respectively. In Fig.3, **OA**, **OB** and **OC** are independent optimal weighting vectors corresponding to three regions depicted in Fig. 2.

<u>Third:</u> The key to the calculation of weighting vector for signal output P1 (CP mode) is to balance the signal intensity among region 1-3. SNR optimization for each region is straightforward but at cost of the possible SNR reduction on other two regions. In this study, we take **OA** as an initial value, since region one has highest priority (center of FOV) and gradually rotate it into **OB** within AOB plane to obtain an optimal weighting vector **OA1**, which could balance the SNR for region 1-2. Then we rotate **OA1** gradually into **OC** to optimize weighting vector **OA2** similarly. Therefore the SNR variation among all regions is taken into account in this case. Additional constraints can also be easily predefined to further optimize the calculation respect to different application. In our example the **OA1** was calculated with the constraint that the SNR from region1 should be no less than 96% of the optimized value [Fig 4 left], OA2 was calculated with the constraint that SNR 1 reduce no more than 10% and SMR 2 reduces no more than 30%.

<u>Forth:</u> Vector OA1 is first column of Mode Matrix which stands for combine weighting vector for P1 [Fig1]. Other vectors for the matrix could be estimated according to the following criteria: (1) all vectors must be normalized; (2) each vector must be orthogonal to the others. However it cannot guarantee a uniqueness solution even if all criteria are met. In practice, a particular solution is set temporally and then same regional optimization process described in the third step is taken to generate signal P2 ("Assumed CP mode" in temporal 3 channels). It seems we have 3 new channel signal to optimize the CP mode signal



$$\begin{bmatrix} a1 & b1 & c1 & d1 \\ a2 & b2 & c2 & d2 \\ a3 & b3 & c3 & d3 \\ a4 & b4 & c4 & d4 \end{bmatrix}$$

Normalized Matrix for 4 elements transformation, column vectors are combine weightings respectively forP1, P2 P3 and P4, each column is orthogonal to the others

Fig 1 *Block diagram of 4 Channels Mode matrix with optional modes "CP", "Dual", "Triple" and "Full"*

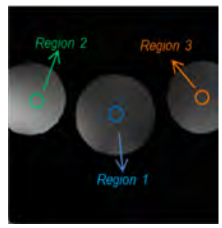


Fig.2 *regions selected For SNR optimization*

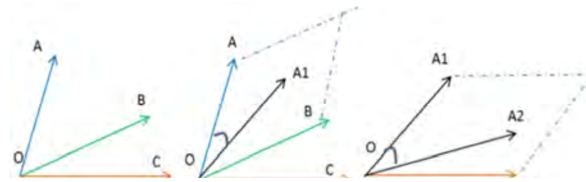


Fig.3 *Illustration combine weighting vector for P1. OA, OB and OC are optimized weighting vectors for region 1-3 respectively.*

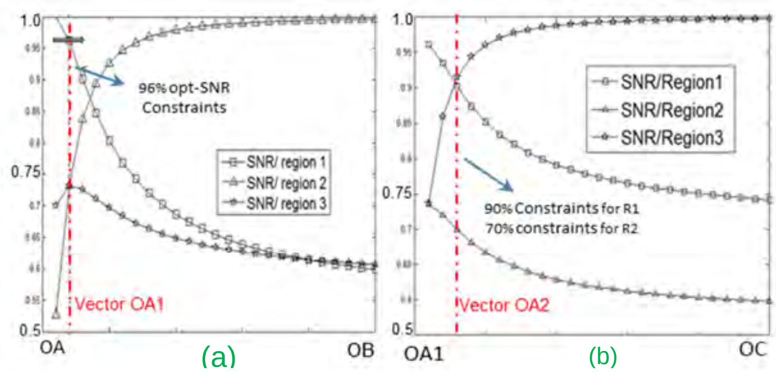


Fig.4 *weighting vector calculation based on the SNR balancing among different regions; (a) start from* ***OA****, optimized SNR of region 2 with the constraint: SNR reduction of region 1 less than 4%, end at* ***OA1****; (b) start from* ***OA1****, optimized SNR of region 3, constraints: region 1 SNR reduction less than 5%, region 2 SNR reduction less than 4%, end at Vector* ***OA2***

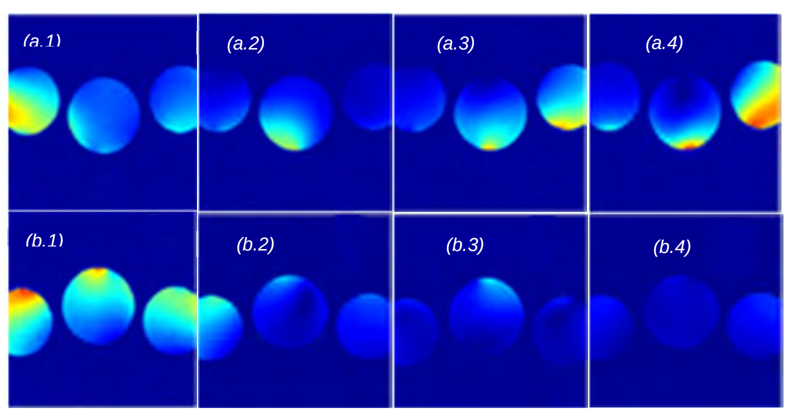


Fig.5 *The comparison of phantom results, (a1-a4) are images from original 4 coil elements, (b1-b4) are images after Mode Matrix transformation, from left to right: P1, P2, P3 and P4.*

Result and Discussion: Phantom tests were performed on a commercial 1.5 T scanner (MAGNETOM Aera, Siemens Healthcare), equipped with a 4-channel (arranged in line) coil array. Signals before using the proposed Mode Matrix show obvious dependence on coil position (first row in Fig. 5), signal dispersed on all channels. After mode matrix transformation, signals are more concentrated in the first mode (Fig.5 b-1) and the other modes can be discarded respect to practical requirements for parallel reconstruction, which resulting in low requirement for receiver channels while maintaining acceptable signal level.

Reference:

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