An Integrated Signal-to-Noise Ratio Approach for Phased-Array Coil Health Check

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Introduction and Purpose

As the number of channels increases on commercial MRI scanners, it is getting more difficult to identify individual coil element failures, and collecting reliable SNR data. NEMA method 1 (subtraction method [1]) has been widely used in industry to calculate SNR. However, the subtracted noise in this method is sensitive to other factors such as eddy current-induced ghosting, mechanical vibrations, and external spikes etc. Sources of these artifacts could be external or internal to the system. The motivation for this work was (i) to design an automated software tool with appropriate protocols to identify element failures in a multi-coil array (a.k.a Phased-Array Coil), (ii) to make the method immune to other disturbances, i.e. improving the gage repeatability and reproducibility.

Theory and Methods

When a receive-only multi-channel RF coil is interfaced to the system, depending on the configuration of the coil, either each coil element is routed to a separate receiver, or a group of elements are internally combined and connected to a receiver. In either case, our goal is to detect if any of the receive channels corresponding to one or more coil elements are malfunctioning, and define an absolute number proportional to the SNR to judge the health of the coil elements. To accomplish this we acquire data in two steps (Signal and Noise acquisitions) for each station in the coil. The noise, N(m,n), was acquired by turning off the RF pulse with software control. The intensity of the signal image, S(m,n), was integrated over the entire slice. This helped us avoid placing ROIs to measure signal, thereby improving the robustness. Then the average of the noise image was subtracted from the signal. The resulting signal is divided by the standard deviation of the noise scan (σ) to calculate ISNR (Integrated Signal to Noise Ratio).

$$ISNR = \left(\sum\sum S(m,n) - \left(\sum\sum N(m,n)/MN\right)\right)/\sigma$$

We used a different terminology to differentiate it from the ordinary SNR value. For the protocol we chose a spin-echo sequence being the most stable in terms of signal amplitude and phase (TR=500ms, TE=10ms., BW=16kHz, 8mm slice). As to the image matrix we preferred using a 256x64 to keep acquisition times reasonable but still obtain reliable results. We could statistically show that our results did not vary significantly by increasing the number of phase encoding steps beyond 64 (Fig1). In this figure, since SNR and ISNR numbers are not comparable magnitude-wise, we reported the results in "percent-of-the-mean". For each multi-channel coil, we developed a configuration file to specify the location of slices and the scan plane. The location of the slices was chosen such that maximum number of elements was covered. For example, for an 8-ch head coil, a single axial slice at the isocenter would suffice. However for a CTL coil, multiple runs to cover entire set of elements are necessary. The user interface was designed such that the transition from one test location to the other for all stations (C, T, and L) is executed without any user intervention. The results were presented in a graphical format with the spec limits. The user is also given the option of (i) viewing individual signal and noise images, and (ii) looking at the trend data, i.e. to monitor the health of the RF coil over time.

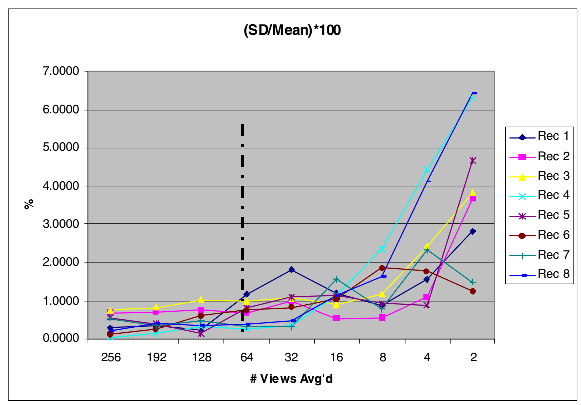
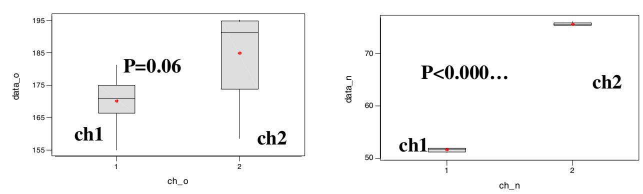


Figure 1: 64 phase encoding steps (or above) provide enough confidence in the measurements.



(A) (B)

Table1: 2-sample t-test box-plots comparing ROI-subtraction method with the proposed ISNR method (ch1 and 2 only) Gage error was considerable reduced from 5% to an average of 0.8 %. These data are from an 8ch-head coil, N=6.

Results

Table 1 shows a comparison of ROI-subtraction measurement method (NEMA) versus ISNR method. The data are from an 8ch-head coil where the 8 elements are arranged in azimuthal direction. For simplicity only channel 1 and 2 data are shown with t-test and the box plots. We also observed that in the ROI-subtraction method the noise fluctuations increase as the ROI size decreases. However ISNR method was shown to be stable, and has considerably improved gage repeatability. With this new method, we can now differentiate small ISNR differences among individual channels / receiver elements, caused by either design differences or preamplifier gain variances in a statistically significant manner.

Conclusion

In the evaluation of multi-channel RF coils, a reliable way to test individual elements is a necessity. In this study, we devised a method to detect the channel failures, and measure a figure-of-merit called ISNR (Integrated Signal to Noise Ratio). We further demonstrated that the tool is immune to most internal and external phase stability disturbances.

References:

1. NEMA Publication# MS-1, 2001.