Evaluation of Extended and Shielded Monopole Antenna Array (ESMA) at 7T

Myung-Kyun Woo[1], Suk-Min Hong[1], Young-Bo Kim[1], and Zang-Hee Cho[1]
[1]*Neuroscience Research Institute, Gachon University, Incheon, Korea*

INTRODUCTION: By modifying the monopole antenna array (MA) for whole brain imaging, we developed extended and shielded monopole antenna array (ESMA) in order to enhance the uniformity of imaging at 7T MRI application. We compared the performance of this new coil with two different types of coils, namely, MA and extended monopole antenna array (EMA). The three coil types were evaluated for the transmit properties, the signal to noise ratio (SNR), and receiver sensitivity.

METHODS: All imaging tests were performed on the investigational 7T MRI scanner (Siemens Medical Solutions, Erlangen, Germany) with a magnet bore of 90 cm (Magnex Scientific, Abingdon, UK). All the coils were tuned to 297.2 MHz (7T) with a human head loading. Fig. 1 shows the schematics and photos of the three coils: 8-ch MA (Fig. 1a, d), 8-ch EMA (Fig. 1b, e) and 8-ch ESMA (Fig. 1c, f). Ceramic capacitors (330 pF) were connected across each divided ground plane to minimize the eddy current. Eight equally spaced monopoles were mounted orthogonal to the ground plane, forming a circle along the acrylic pipe connected to the ground plane [1].

For the ESMA (Fig. 1c, f), a thin layer copper tape was attached to the acrylic boxes and served as the individual shields [2]. Each shield was positioned to start 2cm away from the feeding point and end 0.5 cm past the ending of the monopole. Each channel was located at the center of the acrylic boxes of 5 x 23 x 3.5 cm^3. Each monopole was placed 2cm away from the wall [3]. The MA would be tuned with the monopoles of only 20cm [1]. To achieve a necessary extension for 24cm, three 10 pF ceramic capacitors were inserted into the monopoles for the EMA and ESMA.

Actual flip angle imaging (AFI) sequence (TR1/TR2 = 5, BW = 330 Hz, FA = 30^o) was used for the comparison of flip angle maps. To investigate the SNR and the receiver sensitivity of each coil, the proton density weighted images (TR = 1000 ms, TE = 2.5 ms, FA = 30°) were obtained in sagittal, coronal and axial view. The reference voltage of MA, EMA and ESMA for imaging was 240 V.

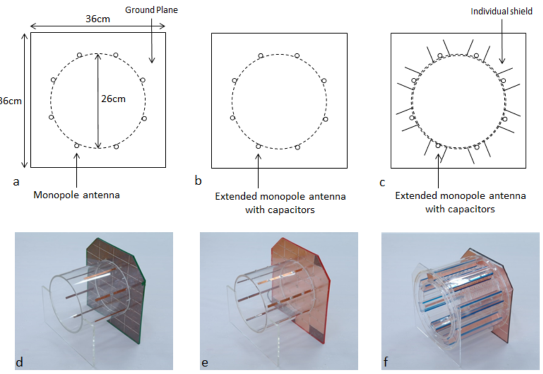

Fig. 1. Schematics (a-c) and photos (d-f) of the 8-channel MA, 8-channel EMA and 8-channel ESMA, respectively

RESULTS: Fig. 2 shows the measured flip angle maps (Fig. 2a), the receiver sensitivity maps (Fig. 2b) and SNR maps (Fig. 2c) of the MA, EMA and ESMA acquired by experiment in sagittal, coronal and axial view, respectively. All of quantification of specific ROI's in the sagittal view is summarized in Table 1.

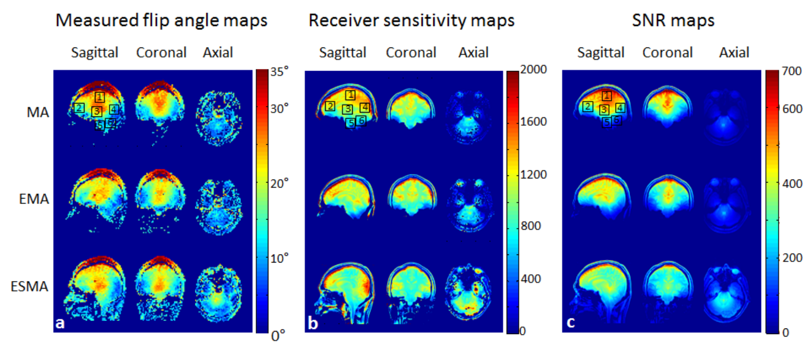

Fig. 2. (a) Measured flip angle maps, (b) receiver sensitivity maps and (c) SNR maps. These showed the transmitter properties, the receiver properties and combined properties in sagittal, coronal and axial view, respectively.

Comparison of sensitivity at ROI-2 and ROI-4 showed an increase of the sensitivity in the periphery in the sagittal view. The sensitivity was 22% and 60% higher at ROI-2 and ROI-4, respectively, than at ROI-1 for the ESMA while 40% and 2% lower at the corresponding locations for the MA. Additionally, the sensitivity at ROI-6 was 21 % higher than ROI-1 for the ESMA while it was 87% lower for the MA. The EMA showed a distribution similar to the MA's; however, its value was lower at the ROI-1 and higher at the ROI-6 than those of the MA. In addition, in the axial view, the sensitivity distributed significantly at the periphery of the brain only for the ESMA compared to the MA and EMA.

In the sagittal view the SNR achieved at ROI-6 was 75% of the SNR at ROI-1 for the ESMA, while it was 24% at the corresponding location for the MA. The differences among the other ROI's were under 35% for the ESMA while at the corresponding locations they were 400% for the MA. Although this ratio was based on the highest area (ROI-1) of each coil, the absolute SNR of the ESMA at ROI-6 was 85% higher than that of the MA. The SNR of the EMA approached the middle point between the SNR's of the MA and the ESMA.

ROI	Measured flip angle (°)			Receiver sensitivity			SNR		
	MA	EMA	ESMA	MA	EMA	ESMA	MA	EMA	ESMA
1 (Parietal lobes)	24.2	21.6	22.1	1294	1136	846	531	419	318
2 (Frontal lobes)	14.0	14.0	15.9	927	1030	1034	225	249	284
3 (Thalamus)	24.0	22.9	23.5	1068	1048	893	435	407	356
4 (Occipital lobes)	15.5	14.7	12.8	1268	1143	1352	338	291	300
5 (Brainstem)	10.8	10.2	15.8	669	740	846	125	131	231
6 (Cerebellum)	10.8	10.7	13.4	689	794	1025	129	147	238

Table 1. Quantification of the specific ROI's taken from a 3 x 3 cm^2 square box at each of the six positions in the sagittal view.

DISCUSSION: ESMA achieved uniform SNR distribution owing to the strength of the complementary performance distribution in transmit and receive condition. ESMA effectively thus addressed the SNR non-uniformity problem associated with the loop array surface coil. ESMA showed strong performance at the parietal lobes as well where shortened wavelengths can cause the degradation of SNR uniformity. This degradation is especially problematic in the case of the loop array coil [4]. The uniform SNR distribution of the ESMA was seen from the anterior to the posterior as well as from the left to the right. The ESMA thus seems well suited for the whole brain imaging with 7T MRI. However, in order to achieve higher SNR and fulfill the possibility of imaging with g-factor, development of high-performing decoupling method is imperative.

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