36 Channel Peripheral Angio Matrix Coil for 3 Tesla

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Introduction: A novel coil architecture for peripheral angio (PA) imaging at 3 Tesla is presented. The complete new design of this MR-coil consists of 36 integrated coil elements organized in 6 levels along the patient axis.

The PA coil operates with the well-known Mode Matrix technology of Tim (Total Imaging Matrix) [1] and can be combined with all other Matrix coils. Due to the high number of coil elements in one FoV (up to 24), the signals were precombined via Mode Matrix. Two of three available modes are read out at the same time. This corresponds to four mode signals in the x-direction, which allows an acceleration factor of four in the left-right phase-encoding direction. The coil has integrated dynamic switches which assign the required channels dynamically to the selected elements [2]. With the aid of “Hall sensors” this coil can be used for head first as well as feet first applications [2]. Furthermore, the PA Matrix offers an additional plug on the top for the third Body Matrix when performing extended FoV up to whole body imaging.

The dimension of the antenna was investigated in detail to reach an optimal combination of high SNR and high iPAT (integrated Parallel Acquisition Techniques – e.g. SENSE and GRAPPA) performance simultaneously. Examinations with different gap and overlap designs were performed. To show the parallel imaging performance, relative SNR loss maps on phantoms were calculated. Based on these results volunteers were examined.

Methods: The new 3T PA Matrix consists of a total of 36 single coil elements. Therefore, the coil comprises 36 single matching, tuning and detuning circuits and 36 single onboard low noise preamplifiers. The elements are organized in 6 levels along the patient axis (z-direction). A total of 24 PA Matrix coil elements, or a total of 4 levels in head-feet direction, are sufficient to cover a FoV of 500mm. Each level consists of two clusters, one for each leg. Each cluster consists of 3 coil elements. The signals of these 3 elements are internally combined via Mode Matrix to 3 new mode signals – the circularly polarized mode, the “left plus right” mode, and the anti-circular polarized mode [1, 2]. The PA Matrix operates in Dual Mode, combining the 24 elements per FoV to 16 RF channels. So, there are never more than 16 RF channels utilized for one FoV. Only the anti-circular polarized mode (Anti-CP), which carries no information about the middle of the object but rather of the periphery, is neglected. Further, an additional 3T Body Matrix can be connected to the PA Matrix by using a plug that is integrated into the housing of the PA Matrix. The combination of PA Matrix and Body Matrix creates a combined Matrix coil with 8 levels in z-direction and a total of 42 coil elements. The combined array is connected to the MRI system via two 8 channel plugs. A channel switch which resides inside the PA Matrix can select 4 out of these 8 levels from the combined array [2]. With the aid of “Hall-sensors” the direction of static magnetic field is detected [2]. Integrated switches allow head first as well as feet first applications. Furthermore, the Spine Matrix can be used together with the PA Matrix. In head-feet direction all clusters of Body Matrix, Spine Matrix and PA Matrix are equally dimensioned. Thus, different Matrix clusters can be matched up easily against each other.

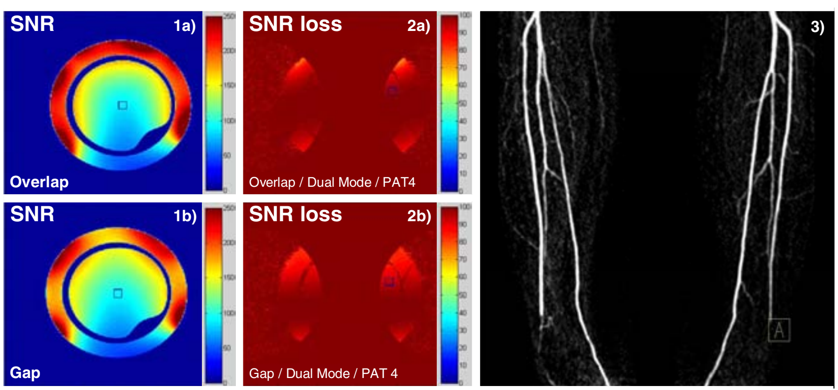
Because of the well-known 3 Tesla challenges for coil design (shortened wave length, increased E-field), unwanted coupling and parasitic capacitances between individual loops and neighboring wires have been minimized. Besides the fact that local coils have to tolerate much higher RF stress at 3T, the Tim Technology™ allows every coil to be placed at variable positions inside the magnet bore. For coils outside the isocentre and close to the end rings of the body coil, the induced RF can be significantly higher than in isocentre position. Therefore, additional detuning circuits had to be implemented and extensive RF stress testing had to be performed to allow patient safety and component reliability.

Results: Investigations were carried out on a 3.0 T Siemens Trio scanner with Total imaging matrix technology.

For the evaluation of the antenna design, an oil phantom (Ø=17cm) surrounded by a loader (Ø=12cm) was scanned with a standard spin echo sequence. Using MatLab™ (The MathWorks, Natick, MA), maps of relative SNR (SNR per unit time) and relative SNR loss (SNR loss factor =1/[g-factor]) were calculated.

In Fig. 1 and 2 the phantom measurements were done in Dual mode operation. This means that two mode signals per cluster are acquired.

Fig. 1 indicates the SNR map for an overlap versus a gap design. Fig. 2 points out the relative SNR loss for an acceleration factor of 2. In the middle of the phantom the gap version shows over 6% less SNR than the overlap version (87.6 to 93.8). The PA Matrix coil delivers 1.5 times more SNR than a Body Matrix coil lying above the legs. In comparison to body coil images the SNR even gains about a factor of 5.3 by using the PA Matrix coil. In the evaluation window of Fig. 2 the SNR loss of the gap version constitutes about 4% more than of the overlap version (93.3 to 97.6).



The SNR gain and the iPAT performance of the new PA Matrix coil were evaluated with a volunteer and with adequate sequences at the University Hospital of Munich. In Fig. 3, a dynamical CE-MRA of the lower leg is shown, which was obtained with the TREAT sequence and GRAPPA (TA=2.9sec, spatial resolution = 1.4mm isotropic, TE=0.8ms, TR=2.3msec, BW=890Hz/Pixel, iPAT=4). The accelerated images show very high SNR and contain no visible artifacts.

Conclusion: Designing 3T PA Matrix coil is a challenge that goes well beyond the task of just retuning the equivalent 1.5 Tesla Matrix coils. Special care has to be taken at the higher frequency in terms of suppression of shield currents and parasitic capacitive coupling between neighboring wire structures.

The number of 36 coil elements is comparable to using 3 Body Matrix coils for each leg. Therefore, a total of 6 Body Matrix coils are needed to achieve the same image quality as with the PA Matrix. It was demonstrated that an optimized antenna is always a compromise between an overlap and a gap design. But for peripheral angio imaging, the overlap version presents the best combination of high SNR and high iPAT performance. The SNR increases significantly by a factor of 1.5 when using the PA Matrix coil in comparison to a Body Matrix coil.

Examinations on human volunteers with acceleration factors of up to four with phase encoding left-right deliver superb clinical images with short TA and high resolution. Furthermore, the PA Matrix coil can be seamlessly combined with other Matrix coils for extended coverage up to whole body applications.

References:

[1] Reykowski A. et al., Proc. ISMRM 12th Ann. Meeting, Kyoto, 2004, p. 1587.

[2] Matschl V. et al., Proc. ISMRM 12th Ann. Meeting, Kyoto, 2004, p. 1586.