SIEMENS Parallel Imaging Vendor Update

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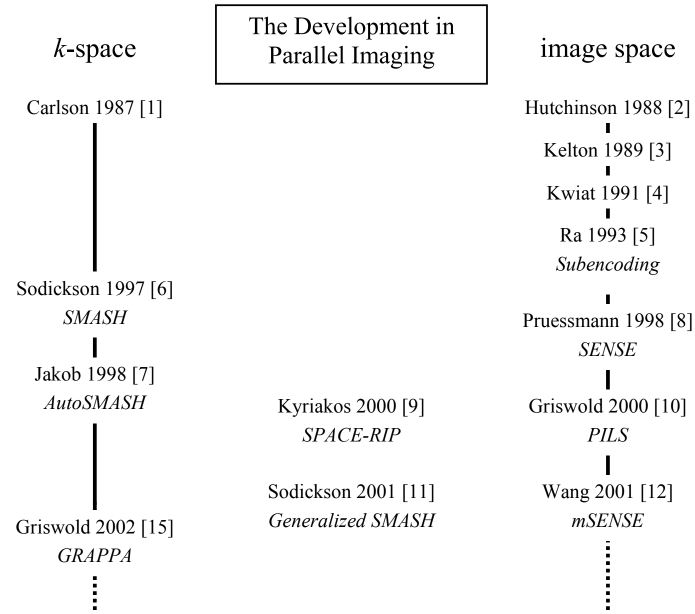
INTRODUCTION:

The first steps towards Parallel Imaging were made from 1987 on [1]-[5]. Since the introduction of the first clinical examples with SMASH and SENSE by Sodickson [6] and Pruessman [8] it still took several years until the first vendor implementations for Parallel Imaging came up. Siemens introduced the integrated Parallel Acquisition Techniques (iPAT) for the MAGNETOM Sonata, Symphony and Harmony scanners in 2001.

Prerequisites for Parallel Imaging to find broad acceptance in the clinical environment are robust and fast image reconstruction, flexibility in spatial orientation, and ease of use. The keys to obtaining these goals are:

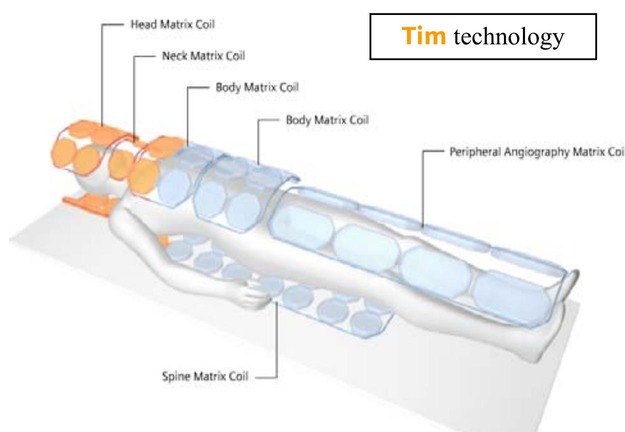
- multiple RF channel technology
- optimized array-coil design
- full product integration (reconstruction, UI, optimized workflow).



ARRAY COILS AND RF SYSTEM:

At the time of introduction of Parallel Imaging the hardware platforms of the commercially available MR systems were not specifically designed for the needs of this new technique. The advantage of Siemens at that time was, that the MAGNETOM systems were already equipped with up to 8 independent RF channels since the year 2000. Additionally, the *Integrated Panoramic Array* (IPA) coil concept, which means that multiple coils can be connected simultaneously, and can be used like one combined array coil, already allowed a flexible usage of Parallel Imaging in multiple directions.

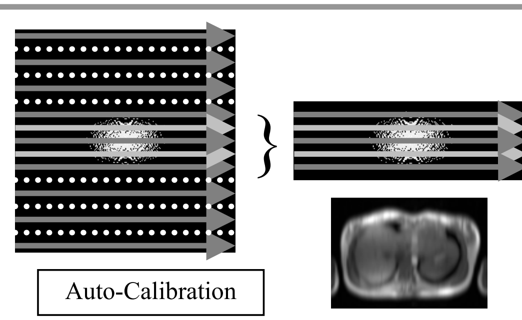
One important design criterion for the next generation of MR systems was to allow full flexibility in whole-body Parallel Imaging. At the RSNA 2003 Siemens introduced the 1.5T MAGNETOM Avanto system with *Total imaging matrix* (Tim) technology. Tim means that up to 76 coil elements can be connected simultaneously, and that coil arrays can be flexibly combined with data acquisition by up to 32 independent RF channels. The 1.5T MAGNETOM Symphony and Sonata as well as the 3T MAGNETOM Trio system will become upgradeable to Tim. Recently, the first MAGNETOM Espree, an open-bore Tim system, was installed at a customer site.



Tim coils are designed for Parallel Imaging from head to toe in all 3 spatial directions. The flexible combinations of coil elements and RF channels are enabled by the *Mode Matrix* concept [19]. The resultant scalability allows to use the same full coil setup for all system variants, even those with less than the maximum available number of RF channels.

RECONSTRUCTION – UI – WORKFLOW:

Both image domain (mSENSE [12]) and k-space based (GRAPPA [15]) reconstruction modules are user selectable as a unique feature on the Siemens scanner to offer optimal solutions for each clinical application. As an example, GRAPPA offers an advantage over SENSE when the chosen FOV is smaller than the object size [16],[21] due to its tolerance against wrap-around artifacts, especially in cardiac imaging.



In contrast to the approaches of other vendors the calibration scan to acquire the data for the coil sensitivity maps is integrated into the sequences (*Auto-Calibration*) with the advantage over a separate pre-scan to be less sensitive to patient motion. The additionally acquired *k*-space lines make the image acquisition time slightly longer but on the other hand can help to increase SNR of the final image.

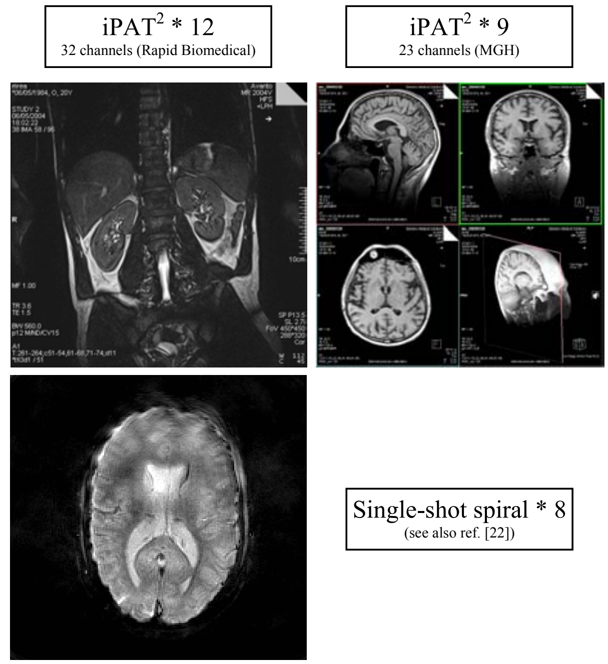
In the Siemens user interface iPAT can be applied in phase-encode direction, as well as in slice-select direction for three-dimensional acquisitions and – to obtain very high accelerations – in phase-encode and in slice select direction simultaneously (*iPAT*^{2}). The *iPAT Assistant* recommends maximum acceleration factors in the individual directions depending on the current selection of matrix mode and coil elements.

DEVELOPMENTS IN THE PIPELINE:

With Tim technology 32 RF channels are available, which makes it very attractive to develop coil arrays with up to 32 array elements, optimized to obtain ultra-high acceleration factors and best SNR. There are several active cooperations with scientists and third-party vendors worldwide.

Our focus for the optimization of iPAT in high-speed time series imaging is on TSENSE/TGRAPPA [13],[18] where an automatic sensitivity calibration can be obtained with no extra time needed for the calibration scan. A similar technique can be used to suppress motion artifacts through a combination of Parallel Imaging and multiple averages [20].

Non-Cartesian *k*-space trajectories offer many advantages for rapid imaging like robustness to motion and flow and benign artifacts when undersampling. A combination of those techniques with iPAT is another important field of investigation. The reconstruction of non-Cartesian imaging with iPAT in reasonable reconstruction times is challenging but can be solved [14],[17],[22].



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