A landmark-free MRI scanner concept

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Introduction: Setting up a MRI exam entails a number of steps to be taken by the scan operator, including placing the patient on the table, positioning the receive (Rx) RF coils, and landmarking. Landmarking is typically a manual process, in which the technologist defines the center of the imaging region through optical, mechanical or other means. The scanner then advances this location to the center of the magnet, characterized by the best field homogeneity. While landmarking is not time consuming, it requires additional hardware, and can give rise to failure modes (the wrong anatomy is accidentally landmarked, landmarking hardware fails etc). We demonstrate here a paradigm in which the landmarking operation is automated, relying on no human input; it only relies on existing scanner hardware, an inexpensive Rx coil marker, and the hypothesis that the Rx coil is covering the anatomy of interest. We show that precision better than 1cm can be achieved in finding the Rx coil marker using this approach.

Methods: A rectangular coil, of dimensions 5.5cm x 28cm, tuned to 138 MHz, is connected to the standard transmit/receive chain of a 3T DVMR, GE scanner. Figure 1 presents the S11 of the probing coil acquired on a HP 8753D network analyzer. In our implementation, after the patient is loaded into the table, the table is advanced towards the scan plane, while signal from this probing coil is recorded in an initial prescan step. Due to the (very high) tuning of the probing coil, no signal is received if the resonance of this coil is not perturbed. If the Rx coil covering the anatomy of interest contains a coil marker in the form of a passive RF coil, also tuned to ~138MHz, a splitting of the resonance curve of the probing coil occurs when the probing and marker coils come in close proximity [1]. If the two coils are designed such as, at the maximum splitting, one of the resonances occurs at 128MHz (resonance frequency for the scanner), maximum signal will be received by the probing coil. This will indicate an overlap between the center of the magnet (where the probing coil is located) and the center of the Rx coil (where the coil marker is located, and which also indicates the center of the anatomy of interest). Continuous monitoring of the signal received by the probing coil will show an increase in the signal, followed by a decrease, with the maximum signal obtained when the center of the Rx coil passes through the center of the magnet.

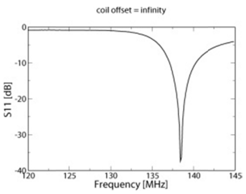

Figure 1: *S11 curve for probing coil connected to the T/R chain of the scanner*

Results: Figure 2 presents the S11 traces obtained on the network analyzer with the probing coil and marker coils -4, -2, 0, 2 and 4 cm apart (5 rows of the left column). Note the splitting of the single, 138 MHz resonance (Fig. 1) in two resonances, symmetrical with respect to the initial one. The closer the two coils are, the larger the splitting becomes (only one of the resonances is captured in the spectral window for the -2 to 2cm region). The right column of Figure 2 presents the NMR signals acquired in the 3T scanner, with the two coils separated by the same offsets as in the left column. The data presented in Fig. 2 was acquired using the head phantom displayed in Figure 3 (left). A second set of experiments, using a torso phantom (shown in right hand side of Figure 3) was also conducted, to verify the impact of coil loading on the accuracy of localization. The integral of the NMR signals acquired in the two experiments as a function of coil offset is presented Figure 3 (center). As expected, minimal to no signal is acquired by the probing coil when the probing and marker coils are far apart; as the probing and marker coils come in close proximity, the signal increases and is maximized when the two coils overlap. Changes in horizontal offsets by 1cm cause a change in the integral of the NMR signal by at least 16%, rendering accurate detection of the marker coil (with precision in the mm range) very feasible. Coil loading impacts the accuracy of localization only to a minimal extent.

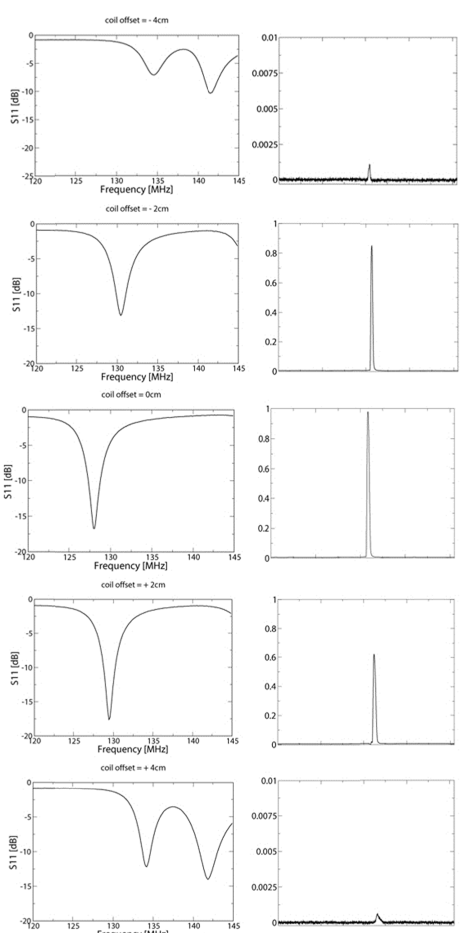

Figure 2: *S11 curves (left) and NMR signals (right) acquired when the probing and marker coils are -4, -2, 0, +2 and +4cm apart (on the z axis).*

Discussion and Conclusions: A study was presented, indicating the capability to detect passive RF coil markers with sub-cm precision using standard scanner hardware. This can be used to automate the landmarking process, and position the region of interest in an MRI exam in the center of the magnet. The concept is expected to work well for the majority of the Rx coils used in MRI exams, including head, knee, breast and posterior torso arrays. For these coils, the coil markers (passive RF coils, tuned high, not influencing the intended tuning/matching of the Rx coils) can be located underneath the Rx coils, and close to the probing coil (embedded in the table, and marking the center of the magnet). The single Rx coil more difficult to locate using this approach is the anterior array of a torso coil; the variable distance between the coil marker and the probing coil may make accurate localization difficult; one can, however, rely on the posterior array (always present when the anterior array is present) for localization in such cases.

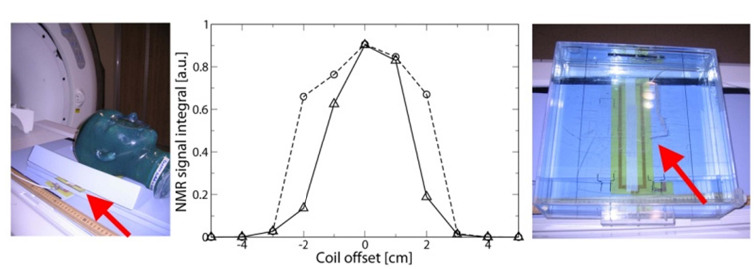

Figure 3: *Location of the probing and marker coils in two experiments (right and left). Integral of NMR signal for the two experiments as a function of (horizontal) distance between the two coils.*

References: 1. Terman F.E., Radio engineers' handbook, McGraw Hill, 1943