Double tunable TxRx ^{1}H/ ^{19}F Helmholtz pair for MR imaging and spectroscopy at 11.7T

M. J. van Uden[1], Y. Sun[1], and A. Heerschap[1]
[1]Department of Radiology (667), Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands

Introduction.
For non-invasive imaging of targeted tissues, cells and biological tissue substitutes in living species the application of fluorinated agents are becoming more popular as ^{19}F is a relative sensitive nucleus and images can be obtained without disturbing background signals as seen in ^{1}H MRI. However, compared to ^{1}H nuclei the number of available ^{19}F nuclei is usually limited and thus optimal signal to noise detection is required. Apart from designing contrast agents with a large number of ^{19}F nuclei, this can be aimed for by using the highest possible magnetic field, optimal RF coils and the shortest possible echo time and repetition time in acquisition. Furthermore, for anatomical matching a background ^{1}H MR image is needed. The aim of this study was to realize these MR conditions to enable ^{1}H and ^{19}F MRI of rat leg bone and bone substitutes containing ^{19}F contrast, by:
1.designing and building a Helmholtz pair RF probe that is capable of generating a homogeneous RF-field for ^{1}H and ^{19}F at 11.7T magnetic field
2.performing zero echo time (ZTE) ^{1}H and ^{19}F imaging to capture short T2 species.

Materials and Methods
MR was performed on a 11.7T MR-system (Bruker Biospin, Germany). The RF-coil consists of a Helmholtz pair with two separate, slightly bended, elements with a size of 25 x 35mm. The average distance between the elements is 25mm. Both elements are separately tuned and matched (balanced) and are combined with a home-built lumped element Wilkinson power splitter/divider [1]. Since the elements couple strongly a split in the resonant curve is observed. The elements must be tuned to the lowest frequency [2]. For best performance both nuclei have a separate power/divider. The circuit diagram of the complete coil can be found in figure 1. The circuit in the red box with the solid line is the RF-coil with the 2 similar elements. In the red box with the dashed line the circuit for the power splitter/ divider can be found. This circuit splits the Tx signal into two outputs with half the power and the same phase. During receive the splitter/ divider combines the received signals. Note the mirrored cable connections at the elements to achieve similar phases for both elements. Otherwise the transmit and receive RF-field will partly cancel out due to the 180° phase difference between the elements.

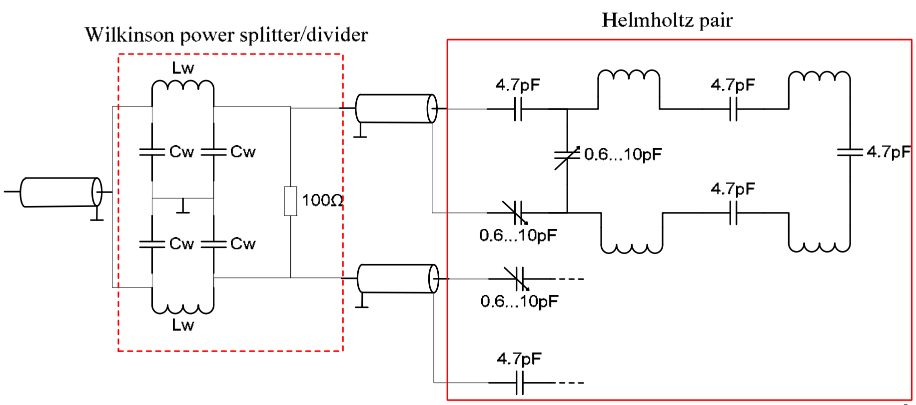

Figure 1:The circuit diagram of the coil and Wilkinson power divider/ splitter. The component values for the divider/ splitter at ^{1}H and ^{19}F are respectively for 22nH and 23.9nH for Lw and 4.5pF and 4.78pF for Cw.

Zero echo time imaging was done with 200kHZ bandwidth, TE/TR=0ms/4 ms, flip angle=3-6^{0}, FOV=45*45*45mm.

Results and Discussion
The new RF-coil was first tested on a bone sample that was put in a 15ml phantom containing a salt solution. In ^{1}H gradient echo imaging with conventional pulses and small flip angles very little signal for the bone is observed, but this image clearly demonstrates the homogeneity of the coil over 3 cm (Fig 2, left image). When ZTE (zero echo time) ^{1}H MRI of the same sample is performed, the bone species with differential tissue contrast becomes visible (Fig 2, middle image). Finally we tested the 1H MRI performance of the coil in an in vivo experiment with the hind limb of a rat in the coil. The ZTE ^{1}H image of an in vivo experiment of a rat leg placed in the new coil also reveals structural details in the bone (Fig 2, right image). Good ^{19}F imaging performance of the probe was also demonstrated by a gradient echo image with conventional pulses and small flip angles, obtained of a 2ml phantom containing a TFA (trifluoroacetic acid)solution (Fig 3, left image). Finally, we obtained a first ZTE ^{19}F image of the same sample (Fig 3, right).

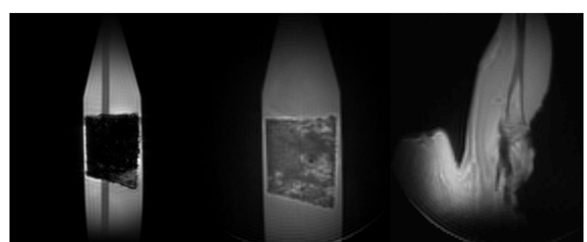

Figure 2: ^{1}H MR images of bone sample in a aqueous salt solution (left: GRE image, middle: ZTE image)and of in vivo rat hind limb(right: ZTE image).

Conclusion
We developed an RF-coil that is capable of generating a homogeneous RF-field large enough to cover a rat hind leg. The coil can be tuned to ^{1}H and ^{19}F for (spectroscopic) imaging of both nuclei. This setup combined with zero echo time imaging can be used to visualize bone and bone substitutes labeled with ^{19}F compounds. Thus regeneration of bone and degradation of these substitutes present at defects can be monitored by imaging both nuclei with overlay of the images.

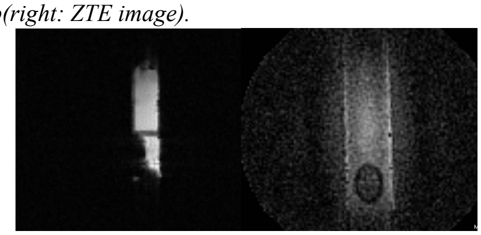

Figure 3: ^{19}F imaging of a 2ml TFA phantom (left:GRE, right:ZTE). The phantom has an air bubble at the bottom.

Reference: 1) Jon B. Hagen, Radio-frequency Electronics, Circuits and Applications. [2] Mihaela Lupu, NMR Probeheads: For Biophysical and Biomedical Experiments. [3] Weiger et al. Ann Meeting ISMRM-ESMRMB Stockholm, 2010