# $^{1}$H/ $^{19}$F large coverage homogeneous transmit coil with dedicated multi-element receive coils.

**M. J. van Uden[1], F. Bonetto[1,2], E. ter Voert[1], S. Orzada[3], I. de Vries[2], H. van Laarhoven[4], and A. Heerschap[1]**
[1]Radiology, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands, [2]Tumor Immunology, Radboud University Nijmegen Medical Centre, Netherlands, [3]Erwin L. Hahn Institute for Magnetic Resonance Imaging, [4]Medical Oncology, Radboud University Nijmegen Medical Centre

**Introduction**
Homogeneous RF excitation and reception offers advantages for absolute quantification of metabolites, drugs and cells in vivo. Capecitabine is a drug taken orally for treatment of liver metastasis in colorectal cancer. It is a prodrug that is preferentially converted to active metabolites in tumor tissue and further catabolized in the liver. Since capecitabine and its metabolites contain a fluorine atom it is possible to assess their distribution in healthy liver tissue and in liver metastases by $^{19}$F MRS [1]. Monitoring and quantification of cells, applied therapeutically, in vivo is of major importance to estimate treatment efficacy. It has been demonstrated that combined $^{1}$H and $^{19}$F MRI allows for positive localization of cells and their quantification directly from image data, in a noninvasive way, without using radio-isotopes [2].
Here we present a new coil setup that is capable of creating a homogeneous transmit RF-field for $^{19}$F and $^{1}$H in combination with dedicated receive coils for lymph nodes and for the liver to enable drug and cellular monitoring.

**Materials and Methods**
The coil setup consisted of a transmit/receive Helmholtz pair that can be combined with a $^{19}$F 6 channel flexible liver receive coil or a $^{19}$F 4 channel semi flexible lymph node receive coil. All coils are home built. The Helmholtz pair (size is 47x39cm and 30cm between both elements) can be tuned to $^{19}$F and $^{1}$H frequencies and used series (broadband) detuning. Both elements of the Helmholtz pair were connected to a home-built lumped element Wilkinson power splitter/divider[3] which was connected to a home-built transmit/receive switch with an integrated preamplifier. This transmit/receive switch was used to interface the coil to a 3T MR-scanner (Siemens, Erlangen). For best performance we used a separate power divider/splitter per frequency. The two elements were tuned and matched separately. Because of strong coupling a split in the resonance curve was observed. For the homogeneous mode the elements had to be tuned to the lowest frequency mode[4].Since the elements of the Helmholtz pair were large with respect to the wavelength of $^{19}$F and $^{1}$H at 3T a microstrip transmission line was used. To create a homogeneous current distribution along the complete conductor the microstrip was split approximately every 20 cm with a capacitor of 22pF. This ensured that after every 20cm the reactance was 0Ω. This leads to maximum current on the line. Figure 1 visualizes the principle with the coil below the smith charts. First 10cm microstrip was used, which results in an impedance change (a), second a 22pF capacitor was inserted (b), third a 20cm microstrip was used (c) and then again a capacitor of 22pF, etc. The impedance changes and capacitor values were calculated with the transmission line formulas [5]. Finally the total impedance was kept resistive and inductive so it could be tuned and matched with low loss variable capacitors.

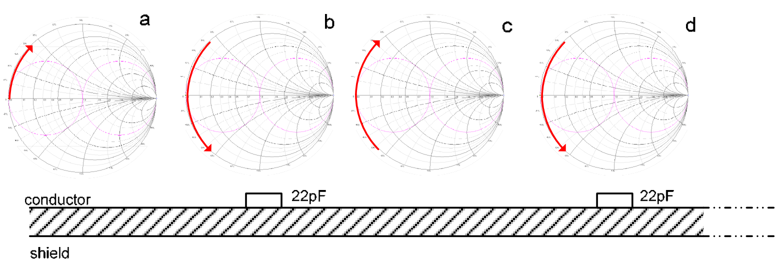

Figure 1: Visualization of the principle of microstrip coils of the Helmholtz pair.

The 'lymph node' coil consisted of 4 circular elements with an diameter of 5 cm arranged in a rhombus (12x14cm). The liver coil (30x50cm)consisted of 6 elements (17x19cm) arranged in a 2x3 matrix. Both coils were decoupled via overlap and preamp decoupling [6]. The liver coil was placed on a 10 liter canister containing a solution with 80ml trifluoroacetic acid (TFA) and positioned in the Helmholtz pair. The lymph node coil was tested on a agar phantom of a salt solution (13 x 22 cm). In the agar gel two plastic tubes containing 100ul of pure perfluoro 15-crown-5 ether placed 2,5cm separated from each other and from the bottom.

**Results and Discussion** The coils were tested on a 3T clinical MR system. A phantom setup with 5 bottles of salt solution were positioned in the Helmholtz pair (TxRx mode) without receive coils. An $^{1}$H gradient echo image with conventional pulses with small flip angles shows that the Helmtholtz pair generates a homogeneous RF-field (Fig 2). Since the frequencies of $^{1}$H and $^{19}$F are close to each other this is also true for $^{19}$F. When combined with the 'liver' receive coil the $^{1}$H image of the canister, shown in figure 3 shows a signal decrease in the middle of the phantom. As a similar image was obtained with the system body coil this is likely caused by the high conductivity of the phantom fluid, but could also be due to less performance of a detune circuit. Subsequent 2D $^{19}$F spectroscopic imaging revealed fluorine signals in the phantom (spectral maps overlaid on background image in figure 3). The left image shows the 6 receive channels combined and the right image is a single receive element. The lower SNR in the bottom left corner of the left image is caused by the position of the receive coil, which was a bit turned to the right with respect to the phantom.

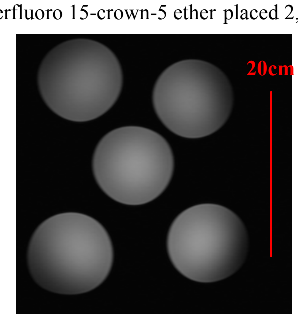

*Figure 2: $^{1}$H imagemade with the Helmholtz (TxRx mode.)*

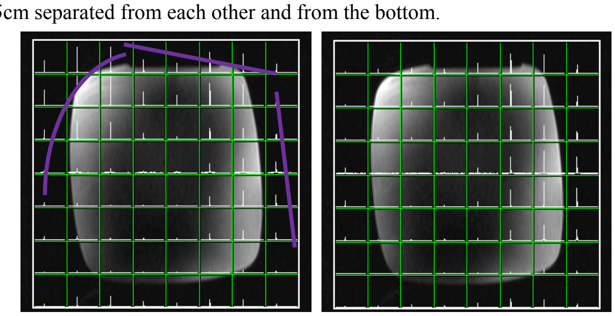
*Figure 3:background $^{1}$H images of 10l canister with spectral overlay. Left) 6 channel combination and coil positioning (purple lines), right)single element.*

To test the 'lymph node' receive coil it was positioned between the Helmholtz pair together with the agar phantom. With this setup a $^{19}$F FLASH image (Fig 4, middle) and 2D $^{19}$F spectroscopic imaging were acquired. From the spectroscopic imaging a metabolite color map was produced (Fig 4, right). The $^{19}$F image as well as the metabolite map shows slightly more signal at the position of the lower phantom, which might be caused be an inhomogeneous receive field.

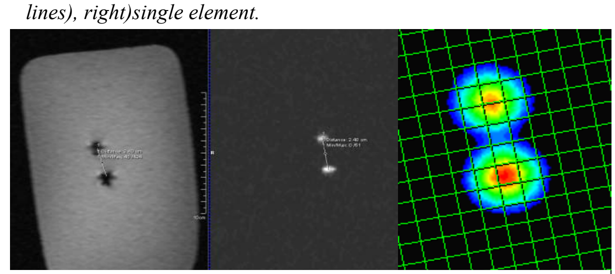
*Figure 4: left) $^{1}$H gradient echo image, middle)$^{19}$F FLASH image, right)$^{19}$F metabolite map*

**Conclusion:** We developed a large Helmholtz pair for the human body that is capable of generating a homogenous RF-field at $^{1}$H and $^{19}$F frequencies and can accommodate dedicated multi element $^{19}$F receive coils with optimum SNR for liver and lymph node applications.

**References:** [1] Klomp et al. NMR Biomed 20 (2007). [2] Srinivas et al. Trends Biotechnol. 28 (2010); [3] J. Hagen, Radio-frequency Electronics, Circuits and Applications. [4] M. Lupu, NMR Probeheads: For Biophysical and Biomedical Experiments [5] H. Wheeler, "Transmission-line properties of a strip on a dielectric sheet on a plane", IEEE Tran. Microwave Theory Tech., vol. MTT-25, 631 (1977). [6]The NMR phased array, PB. Romer et al, MRM, Vol. 10, Issue 8 (1997)