Baluned-Hairpin-(BHP)-Resonator for Field Monitoring

Thomas Riemer[1]

[1]*Insitute for Medical Physics and Biophysics, University of Leipzig, Leipzig, Saxony, Germany*

Introduction

"Spatiotemporal Magnetic Field Monitoring for MR" and its benefit for image reconstruction was introduced in 2008 by Barmet et al. [1]. Recent applications of field monitoring address the "Real-Time Feedback for Spatiotemporal Field Stabilization in MR Systems", Duerst et al. [2], and show that "Feedback Field Control Improves Linewidths in In Vivo Magnetic Resonance Spectroscopy", Wilm et al. [3]. Basis for the spatiotemporal field monitoring is the placement of "NMR Probes for Measuring Magnetic Fields and Field Dynamics in MR Systems", De Zanche et al. [4], within the magnet. These NMR based field probes should not distort the homogeneity of the static magnetic field they are place in and they should possess a homogeneous static magnetic field within the field probe's sample for highest SNR and long lasting FID. The design given by [4] and an improved implementation by Barmet et al. [5], is based on a small sample capillary containing the monitor solution susceptibility matched to the tightly wound copper solenoidal probe coil. This probe setup is immersed in an elliptical epoxy former which is also matched to the copper susceptibility. Thus the air/copper-boundary is transferred sufficiently far away from the field monitoring NMR sample to result in a sufficient homogeneous static magnetic field over the field probe's sample. A much more "Simple NMR Probe for Magnetic Field Plotting" was proposed by Unger and Hoult in 1999 utilizing the fact, that an "infinitely" long cylinder aligned with the static magnetic field does not distort that field [6]. They bent a copper wire of 0.88 mm diameter to a hairpin like shape of 50 mm length and an inter wire distance of 1 mm. This setup resulted in a 15 Hz linewidth for a water sample in a 9.4 T magnetic field. As outlined in „NMR PROBEHEADS FOR BIOPHYSICAL AND BIOMEDICAL EXPERIMENTS", Mispelter et al. [7], a well designed NMR probe should have a balanced electric potential over the detector coil which requires a balanced match and a balun to interface the detector to the unbalanced coaxial feeding lines used in NMR-spectrometers. It is the aim of this contribution to describe a new hairpin design that incorporates the **b**alun within the **h**air**p**in (BHP-) resonator.

Figure1: *Sketch of the baluned-hairpin-(BHP)-resonator built: Three silver plated copper wires of 0.4 mm diameter were placed in parallel in plane with an inter wire distance of 0.4 mm in a thin walled Teflon tube cylinder of 75 mm length, 8.5/7.5 mm o.d./i.d. and closed with two 2 mm thick Teflon caps tightly fitting the Teflon tubes with three 0.4 mm holes drilled for taking up the copper wires. Ten 0.5 mm holes with an spacing of 5 mm were drilled perpendicular to the planar three straight wire balun resonator to take up a 200/330 µm ethanol containing capillary for position dependent field measurement. The BHP-resonator was tuned and matched to 300.13 MHz (7.05 T magnet) with two AVX-trimmers 5-30 pF, 3.2x4.5 mm size (C_T, C_M).*

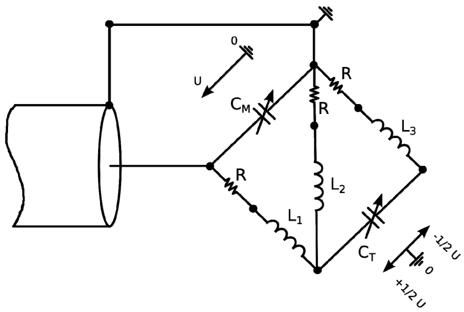

Figure 2: *Schematic of the planar three straight wire balun resonator: The asymmetric feed line is attached to the planar three straight wire balun resonator in an asymmetric fashion over the Capacitor C_M. The Lines L_2 and L_3 connected by the tune capacitor C_T constitute the NMR detector and exhibit the desired symmetric potential distribution.*

Methods

A BHP-resonator as sketched in Fig. 1, with its schematic given in Fig. 2, was built for a 300 MHz widebore NMR spectrometer. For z-axis dependent field measurements an ethanol containing 200/330 µm i.d./o.d. sample capillary was placed in one of the ten 5 mm spaced holes of the teflon cylinder holding the ethanol sample in place between L_2 and L_3. A simple pulse acquire ^{1}H NMR spectrum was recorded for each of the ten capillary positions.

Results

The z-axis dependent frequency offsets observed in the BHP-resonator nicely resembles the field plot given by the manufacturer delivery protocol for the used 7.05 T superconducting magnet (Fig. 3). In addition does the observed ^{1}H signal linewidth resemble the linewidth expected for the gradientfield extracted from the manufacturer delivery protocol (Fig. 4).

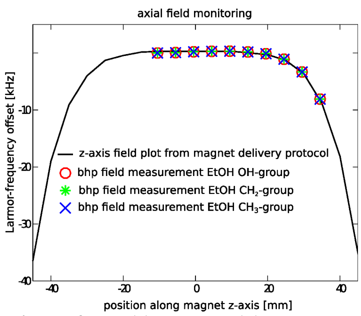

Figure 3: *Field monitored by offsetting the 200/330 µm (i.d./o.d.) sample capillary at the 10 holes drilled in the resonator tube.*

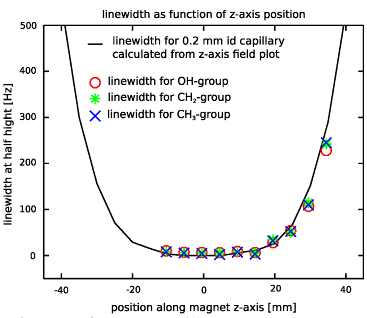

Figure 4: *Linewidth as function of position dependent field gradient: The linewidth at half height ranges from 6.5 Hz in the homogenieous region of the magnet to 245 Hz in the fringe field of the magnet.*

Discussion

The linewidth of 6.5 Hz achieved with the BHP-resonator is comparable to the linewidth of 15 Hz reported by Unger and Hoult for their hairpin setup taking into account the higher field and the bigger sample capillary diameter and it is comparable to the 7 Hz linewidth reported by De Zanche for the suszeptibility matched solenoid[4]. In addition to that the BHP-resonator is as simple to build as the hairpin-resonator and much less demanding than the suszeptibility matched solenoidal designs. Since the potential symmetriezation within the detection coil made up of L_2 and L_3 is mediated by the new third line L_1, a single capacitor is sufficient to match the BHP-resonator to the desired feeding line impedance. Which reduces complexity and costs.

Conclusion

Starting of the "Simple NMR-probe for Magnetic Field Plotting" proposed by Unger and Hoult a NMR-probe for field monitoring was developd, that includes the balancing element within the resonator without compromising the static magnetic field homogeneity. Hence the BHP-resonator can directly be connected to a coaxial feeding line with asymmetric potential.

References

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