Automation system based on piezoelectric motor for tuning and matching miniature monolithic NMR coils

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Purpose:

Miniature high temperature superconducting coils based on monolithic design such as the Multi-turn Transmission Line Resonator[1] (MTLR), exhibit very low internal noise and are particularly attractive to achieve high SNR[2] in MR localized microscopy. However, standard conditioning (tuning and matching) techniques using discrete components[3] are not convenient for these coils due to their small size, monolithic design and low loss feature. In this work, we present a contactless technique for automatically tuning and matching small monolithic NMR coils, such as HTS coils, based on a piezoelectric motor system that achieves high-resolution displacement.

Methods:

The overall automation system is shown in figure 1. The development and validation of the system was done using a MTLR with resonant frequency of 93 MHz comprising two 5-turn copper conductors deposited on both sides of a sapphire substrate (ε = 11.6). Matching was achieved by varying the position of a pick-up loop inductively coupled to the MTLR. Tuning was achieved by varying the distance of a dielectric slice (sapphire) to the surface of the coil[4]. A motion-controlled drive system for a linear piezoelectric motor (PiezoLEGS®, PiezoMotor, Sweden) was developed to control the distances of the pick-up loop and the dielectric slice to the MTLR. This system consists of a Matlab-based graphic user interface (GUI) control software, a driver board and a mechanical set-up. The GUI software monitors the measured data and controls the motor displacement to complete the matching and tuning procedures using automation algorithms. The driver board generates phase shifted signals with controllable frequency to drive the motor, and is equipped with an Ethernet interface for communication. The mechanical set-up uses a linear rod which is frictionally coupled to the motor to displace the dielectric slice and the pick-up loop. The calibration of the displacement of the system was done using manual measurements performed with a mechanical regulator of 20 µm resolution.

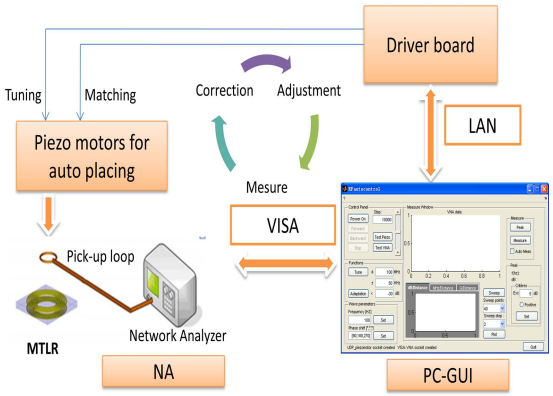

Figure 1: Schematic of the automation system

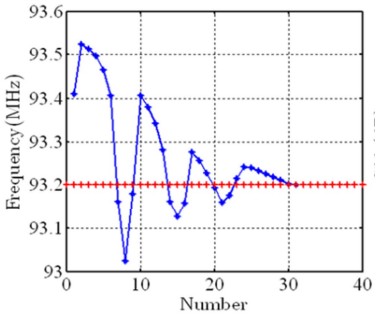

Figure 2: Automatic tuning to a convergent result.

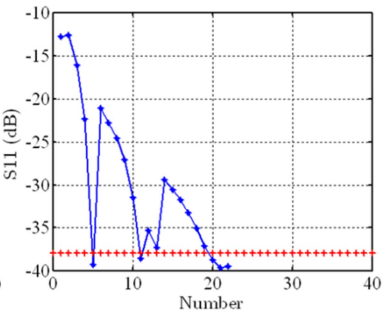

Figure 3: Automatic matching to a convergent result.

Results:

With the developed automation system, displacement resolution of 3 to 10 µm is obtained, depending on the frictional load on the linear movable rod. This displacement resolution corresponds to different tuning resolution depending on the dielectric slice position, for distance smaller than 100 µm: the slope is 2200 Hz/µm, at long distance (above 500 µm): the slope is 86 Hz/µm). Figure 2 shows the system auto-matching procedure for a given target matching level (-38dB). Figure 3 depicts the auto-tuning procedure for a target tuning frequency of 93.20 MHz +/- 10 KHz. With the current automation algorithms, each tuning and matching step takes less than 30 seconds.

Conclusion:

The resolution achieved by this motion-controlled system allows automatic matching and tuning with respect to specified matching level and target frequency with configurable tolerance. As a future work, interlaced matching and tuning procedure will be developed and convergency rapidity will be optimized account for their mutual influence. This remote contactless automatic matching and tuning technique is extremely attractive when coil access is limited (ex. when conditionning HTS MTLR coil in the cryogenic environment).

References:

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