

A convenient nuclear resonance magnetometer

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By operating in the pulsed mode the system is capable of measuring saturation magnetostriction with a sensitivity of 10^{-8} .

One useful improvement that would make calibration simpler and more repeatable would be to operate the system in a closed-loop mode. In this the signal from the phase-sensitive detector would be fed back to a piezoelectric shifter that would maintain the output close to zero. The voltage applied to the piezoelectric shifter would then be a precise measure of the displacement, independent of the slope of the open-loop calibration curve.

Acknowledgments

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Abstract. A design is given for a low-noise limited oscillator whose inherent sensitivity is then sacrificed for the practical convenience of having remotely controlled varicap diode tuning and small diameter probes. A series of seven probes, each tunable over more than an octave, covers 1.36 to 60 MHz in overlapping ranges.

Mechanically driven tuning is always a problem in NMR magnetometers, it leads to microphonic noise and the size of the capacitor and drive mechanism that has to be built in to the RF head is a nuisance. Varicap diodes have none of these faults and can be remotely controlled by a potentiometer. Unfortunately the only diodes with an adequate capacitance variation available are intended for frequencies below 5 MHz. Their decreasing Q at higher frequencies causes a reduced sensitivity. However, since NMR signal strengths increase rapidly with frequency this can be tolerated if the rest of the circuit maintains its sensitivity. The design uses a transistor version of the limited oscillator (Robinson 1959, 1982) with a low noise figure up to 60 MHz and, using 'medium wave' diodes (i.e. diodes which tune from about 500 pF to 50 pF with 15 V bias) adequate signals can be obtained from the protons in samples 2 mm diameter and 6 mm long. Because the diode Q is rather low there is no point in striving for a high Q coil and, as a result, the coil can be contained within a tube with an outside diameter of only 9.5 mm. At frequencies above 10 MHz even smaller coils and probes would be adequate. The proton resonance range 1.35 MHz to 60 MHz covers the fields (0.03 T to 1.4 T) available with most iron magnets. Figure 1 shows some examples of the signals obtained using 50 Hz field modulation and a magnet with 50 mm diameter poles 12.5 mm apart, at 2, 8 and 18 MHz. Each trace is a stored recording of a single oscilloscope trace and faithfully reproduces the appearance of the signal seen on the oscilloscope.

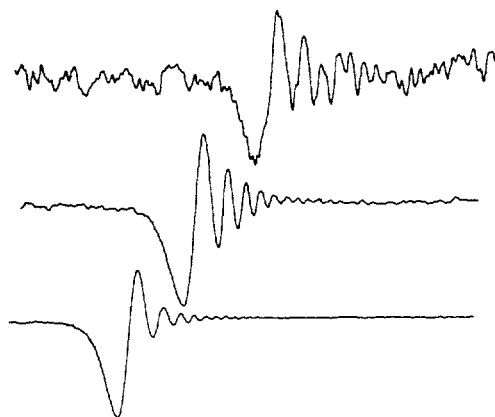


Figure 1. Proton signals at 2, 8 and 18 MHz obtained using a magnet with 50 mm diameter pole faces 12.5 mm apart.

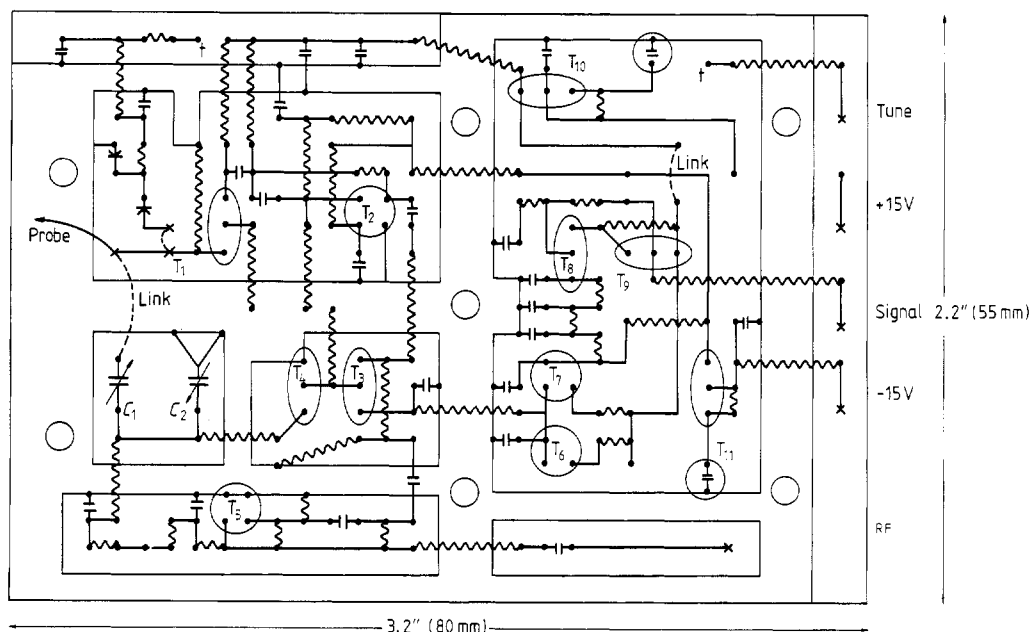


Figure 4. The track side of the PCB. Open circles denote fixing holes, dots denote holes for component leads and crosses denote holes for 1 mm pins. Links in the supply rail and tuning circuit are omitted. The components on the other side of the board are indicated schematically.

thick. Suitable coil windings are (i) 170 turns of 0.12 mm enamelled wire rough-wound, (1.35–3.3 MHz); (ii) 100 turns of 0.2 mm wire in three layers, (2.5–6.8 MHz); (iii) 50 turns in two layers, (4.1–11.5 MHz); (iv) 30 turns in a single layer, (8.4–23 MHz); (v) 17 turns, (11.7–32.5 MHz); (vi) 13 turns, (17.5–52 MHz); (vii) 8 turns, (30–60 MHz).

Operation is simple. Select the correct probe, preferably one where the expected frequency is near the top end of the range where the varicap Q is highest. Set the level output at 1.5 V using C_1 and C_2 at the bottom end of the range and reset $C_1 C_2$ if the level exceeds 3.5 V as the frequency is increased. This may be needed two or three times over the complete diode tuning range.

A suitable tuning arrangement is a 100 k Ω helipot from ground through a 2 k Ω fine tuning helipot to the +15 V rail. It is useful to block DC from the signal output with 0.1 μ F and 1 M Ω and to insert a simple T filter (10 k Ω , 1 μ F, 10 k Ω) in the meter lead to exclude interference.

No claim is made that this system with the varicaps connected is particularly sensitive but it will be seen from figure 1 that the signal is adequate, even from a magnet barely good enough to justify the use of an NMR magnetometer.

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