A Bridged Tee Detector for Nuclear Magnetic Resonance

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The circuit of a bridged tee network for the measurement of nuclear magnetic resonance is described. This circuit was used to measure the field strength of a large air core solenoid. The balance equations for the bridged tee network are:

$$W^2=1/L\left(\frac{C_1C_2}{C_1+C_2}\right),$$

$$R=\frac{L}{(C_1+C_2)}r.$$

The probe contained one ml of No. 20 lubricating oil with B and S No. 17 copper wire wound directly on the proton sample cell to give convenient resonance capacities and a convenient resonant impedance (500 to 25,000 ohms) near the 20-mc working frequency. The simplicity of construction, the general utility, and the adaptability to ordinary laboratory apparatus prove the circuit to be excellent for detecting nuclear magnetic resonance.

I. INTRODUCTION

One of the simplest methods of detecting nuclear magnetic resonance is based upon the loading effect on a coil of wire magnetically coupled to a large number of nuclei and excited at the nuclear resonance frequency of the nuclei in a given magnetic field. As the energy absorbed by the nuclei is usually quite small the circuit employed for detecting this absorption should be as sensitive as possible. To meet this requirement most effectively, it was felt that a bridged tee circuit could be adopted. For this application, the coil would be wound directly around the cell containing the sample and made the inductance of the LC section of the circuit, which could be designed to be in resonance, and the circuit balanced at the processional frequency of the nuclei.

The small change in the Q of the coil brought about by the energy absorption at precession would unbalance the circuit giving a signal across the tuned LC network. This signal could then be made as high as the Q factor of the tuned circuit would permit.

II. DESCRIPTION

The Bridged Tee Circuit

The bridged tee network adapted for the purpose is shown in Fig. 1. The applicable balance equations are

$$W^2=1/L\left(\frac{C_1C_2}{C_1+C_2}\right), \tag{1}$$

$$R=\mathrm{L}/(C_1+C_2)\cdot r. \tag{2}$$

The form of Eqs. (1) and (2) shows that two adjustments are necessary to balance the network. A convenient arrangement is to provide part of R and part of C variable. The circuit is then tunable for different input frequencies.

The Sample

Approximately one ml of No. 20 lubricating oil was enclosed in a $\frac{3}{4}$-inch length of 10-mm Pyrex glass tubing, seal-stoppered at each end.

The Coil

B and S No. 17 copper wire was wound directly on the proton sample cell. The coil was wound so that it would resonate with convenient values of capacitance near the working frequency of 20 megacycles. The resonant impedance of the LC section of the circuit is approximately given by the factor $L/(C_1C_2/C_1+C_2)r$. Since this factor is determined entirely by the coil, this should be wound to give reasonable values of resonant impedance (500 to 25,000 ohms.)

SWEEP COILS

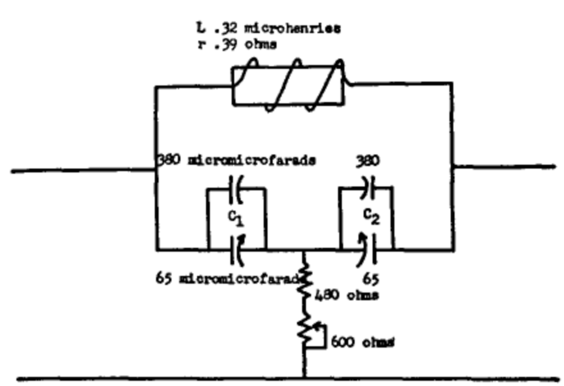

Fig. 1. The bridged tee circuit.

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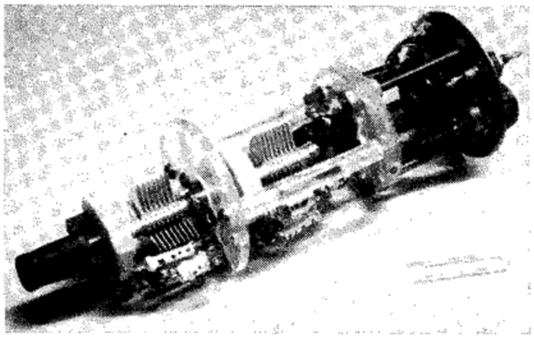

FIG. 2. The bridged tee circuit assembled as a probe.

The parameters of the coil used in the circuit were as follows: $L=0.32$ microhenrie, $Q=128$, $r=0.319$ ohms, $N=5$ turns, $1=0.8$ cm, $d=1.1$ cm.

Other Parameters of the Circuit

The fixed part of both C_1 and C_2 was 65 micromicrofarads, the variable part of both was 380 micromicrofarads. The fixed part of R was 480 ohms, the variable part, 600 ohms.

Assembly of the Circuit as a Probe

The air core of the solenoid whose field strength was measured using this circuit[1] was 2 inches in diameter. The components had then to be assembled within a brass cylinder of a diameter slightly less than this. For this purpose, Lucite was used to support the components rigidly within the housing. This material was chosen for its excellent mechanical damping qualities which are necessary where nonmicrophonic support is required. Thus, the proton sample cell with its coil was mounted, by means of a disk of Lucite, centrally with respect to the axis line of the air core and with its own axis perpendicular to the latter. Other components were mounted appropriately within the brass housing. Both sides of the variable capacitors of the bridge circuit are necessarily ungrounded in the probe. The shafts for adjusting these capacitors which extend out one end of the housing were, therefore, insulated.

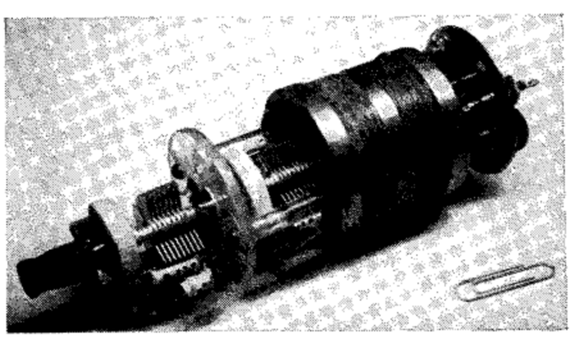

FIG. 3. The probe with sweep coils in place.

[1] Waring, Spencer, and Custer, ONR Contract N6ori216 T. O. 1, Technical Report No. 4 (1950).

In addition to the components described above, a set of sweep coils was rigidly mounted within the probe housing. These coils were provided to carry the total field at the sample cyclically as much as 10 or 20 gauss above and below the critical field. Since the field created by these coils should be of reasonable homogeneity at the sample, they were wound on a brass sleeve and rigidly mounted, concentrically within the probe cylinder, so that each was equidistant from the axis of the sample cell. Both the incoming and the outgoing sweep coil wires were capacitatively by-passed to ground at their point of entrance to the probe housing by ceramic capacitors of 0.0001 microfarad capacity. The probe is illustrated in three stages of construction in Figs. 2–4.

III. SUMMARY

The bridged tee circuit described was demonstrated† to be capable of giving precise values of magnetic field strength.

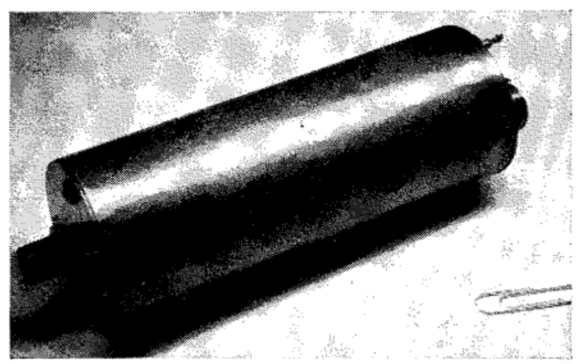

FIG. 4. The complete probe assembly.

The circuit is flexible in that the coil of the circuit may be used separate from the other components. A very small probe results which may be used for measuring otherwise inaccessible fields. In addition, the bridged tee would be well suited for analyzing shapes of nuclear magnetic resonance signals.

The bridge may be used with a variety of associated equipment. Inexpensive signal generators and radio receivers may be employed with good results.

The simplicity of construction, the general utility, and the adaptability to ordinary laboratory equipment proves the bridged tee circuit to be excellent for detecting nuclear magnetic resonance.

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