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Prior to the advent of the microwave circulator, the majority of electron spin resonance spectrometers employed waveguide hybrid or "magic" tees as the bridge element. They provide reasonably good isolation, 40 - 50 dB, over the complete waveguide bandwidth. Coaxial hybrid tees which cover the entire radio frequency spectrum have become available recently[1]. Isolation of 45 dB is common and bandwidths to several octaves can be covered in single units.

These hybrids provide an extremely simple and versatile method for assembling nuclear magnetic resonance (nmr) spectrometers for operation at virtually any frequency. Figure 1 shows the disposition of components required to assemble an nmr spectrometer around a hybrid. Radio frequency drive is supplied from a signal generator to the hybrid, and the bridge unbalance is detected by a suitable receiver. The sample coil, L, is resonated by the series combination C_1C_2; the ratio is adjusted to provide an impedance match to the coaxial cable connecting to the third arm of the bridge. The second arm of the hybrid is either terminated in the characteristic resistance of the hybrid or connected to a variable impedance load which can provide for finer balancing. Reactive elements in this arm introduce an additional frequency dependence.

To adjust the system the oscillator and receiver are set to the same frequency, the second arm is terminated in Z_o, and the capacitor

C_1 is adjusted to minimize the receiver output, thus resonating the tuned circuit to the oscillator frequency. C_2 is then adjusted to further minimize the leakage. The procedure is repeated until no further reduction in leakage can be achieved. If the isolation of the hybrid has previously been established by terminating arms 2 and 3 and noting the attenuation introduced between oscillator and receiver, it suffices to continue the balancing until this isolation is achieved. Commercially available wideband modulator-mixer units provide a versatile radio frequency/phase detector[2], whose performance frequently surpasses those constructed ad hoc in the laboratory. The phase detector may be eliminated and absorption or dispersion selected by small purposeful unbalancing of the bridge by C_2 or C_1, respectively.

The system offers the advantages of the usual bridge arrangement, in that transmitter and receiver are well decoupled so that the system noise level is determined largely by the receiver noise figure. By comparison with the induction spectrometer[3], which achieves isolation geometrically, it suffers from the frequency sensitivity of the bridge balance[4] and the 6 dB reduction in signal arising from the division of both transmitter power and reflected signal power at the hybrid. Crystal control of the transmitter is necessary if the maximum sensitivity is to be achieved. We have observed a significant degredation in performance traceable directly to 60 Hz frequency modulation of high quality signal generators. The use of coaxial circulators, which are becoming increasingly available at lower frequencies, would restore the signal loss arising from the power divisions in the hybrid.

The simplicity of this spectrometer--only the sample resonant circuit need be constructed--recommends it for nmr measurements over a wide frequency range, for low temperature experiments where it is desirable to have only a single cable entering the cryostat, and for situations in which the ultimate in sensitivity is not required. We currently use this arrangement for field-frequency control of a high resolution nmr spectrometer at 60 mHz and anticipate using it widely for measuring and mapping the fields in superconducting solenoids. Liquid He^3 appears to be the sample of choice for this purpose, for it yields strong nmr signals with very narrow lines.

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1. Adams-Russell Co., Inc., Waltham, Mass.; Anzac Electronics, Inc., Norwalk, Conn.; Merrimac Research and Development, Inc., West Caldwell, N. J.
2. Aertech, Mountain View, Calif.; Hewlett-Packard Co., Palo Alto, Calif.
3. F. Bloch, W. W. Hansen and M. Packard, Phys. Rev. 69, 127 (1946).
4. D. T. Teaney, M. P. Klein and A. M. Portis, Rev. Sci. Instr. 32, 721 (1961).

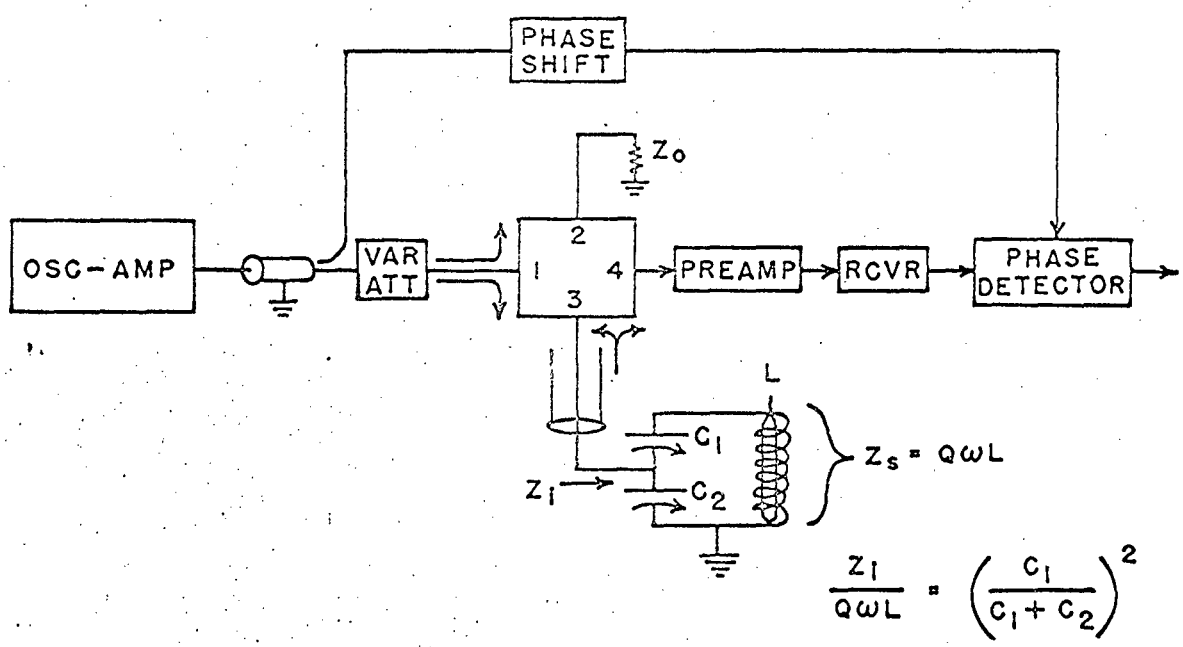

Fig. 1

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