The Absolute Measurement of Resistance and Reactance at Frequencies of the Order 300 mC/second

The characteristic impedance of a parallel wire transmission line can serve as an absolute impedance with which may be compared any unknown impedances. Schmidt[1] has shown the application of this for a partial range of pure resistances and pure reactances. Labus[2] has developed an absolute method for measuring pure resistances at medium frequencies. A theory by Hempel[3] is similar to that of Schmidt with slight extension. Other theories and methods, notably those of King,[4] have been concerned with the comparison of different unknown impedances at very high frequencies.

The formula for the complex current amplitude at any point of a parallel wire line which is terminated in arbitrary impedances, and which has an e.m.f. applied in series with one of the terminations,[5, 6] is used to develop a general theory and a simplified experimental procedure which permit the simultaneous measurement of the resistive and reactive components of any complex impedance in terms of the characteristic impedance of the line. The theories of Schmidt and Hempel are seen to be special cases of the general theory.

The experimental procedure is to connect the unknown impedance as one termination of a parallel wire line, the other end of which is terminated in a low impedance thermocouple. A high frequency e.m.f. is induced in the circuit by coupling to an oscillator, in such a way that the effective e.m.f. acting in the circuit is that induced in the unknown terminal impedance. Observation of the resonance curve of current through the thermocouple on varying the line length, and of the length of the line at maximum current, permits the determination of the magnitude and phase angle of the product of the complex reflection coefficients at the two ends of the line (XY in Pierce's notation). If the unknown impedance is replaced by a large copper disk through the center of which the parallel wire line passes normally, the value of X can be taken as unity and Y can be determined in magnitude and phase angle. Hence the value of X for any unknown impedance can be determined. From the complex value of X and the characteristic impedance of the line the resistive and reactive components of the unknown impedance can be easily and directly calculated.

The method is symmetrical in inductive and capacitive reactances and also shows a form of symmetry for any two impedances whose product is equal to the square of the characteristic impedance.

The accuracy of the method depends on the accuracy of the measurement of line length and other line dimensions. The possible accuracy varies widely over the whole field of resistance and reactance. Measurements at a frequency of 377 mC/sec. indicate an accuracy of about 1 percent for resistance component from a few ohms to a few thousand ohms. Low reactance components combined with resistance components up to several hundred ohms can be measured within 1 ohm or less. Least accurate is the determination of small values of either component when combined with values of the other component of several hundred ohms or

greater. High reactance components with low resistance components can be measured within about 1 percent up to several thousand ohms.

The permeability of ferromagnetic substances can be measured with considerable accuracy if one assumes the validity of existing classical formulas for the effect of permeability on the skin effect and inductance of fine straight wires at these frequencies.

Full details of the experimental method together with measurements made on a number of different forms of impedance and a number of different wire samples are to be published later.

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        March 30, 1938.

[1] Otto Schmidt, Hochfreq. und Elektroak. **41**, 2 (1933).
[2] J. W. Labus, Proc. I. R. E. **19**, 452 (1931).
[3] Werner Hempel, E. N. T. **14**, 33 (1937).
[4] R. King, Proc. I. R. E. **23**, 885 (1935).
[5] G. W. Pierce, *Electric Oscillations and Electric Waves* (New York, 1920), Eq. (30), p. 330.
[6] J. R. Carson, *Electric Circuit Theory and Operational Calculus* (New York, 1926), Eq. (243), p. 133.
    The equations in the last two references are developed by different approaches, but are identical.

Rotational Transitions Associated with Radiation in Water Molecules in Nonpolar Solvents

In our previous report[1] upon the apparent rotational structure in the 1.87, 1.38, and 1.13μ absorption bands of water molecules in carbon disulfide solution we stated that carbon tetrachloride is an unsuitable solvent because of the low solubility of water in this liquid. Some months later we learned that the solubility datum given in the reference cited in the earlier paper is in error, and that the solubilities in carbon tetrachloride and carbon disulfide are, in fact, comparable. We, therefore, repeated our experiment with the new solvent and wish to make this very brief report pending a fuller account which will include, we hope, a study of deuterium oxide.

The 1.87 and 1.38μ bands show the same sorts of structures in the two solutions; the improved plot of the 1.87μ band reveals a long wave portion which had been obscured previously by a deep overlapping solvent band. We believe we can now say with confidence that the bands, shifted toward longer waves in solution, have vapor-like structure with partially developed P, Q, and R branches. However, the intensity of the Q branch is very greatly enhanced over that in the vapor bands. Two alternative interpretations of this enhancement seem possible. First, that there is a marked departure from the usual statistical distribution over rotational states, that $J''=0$ states and consequently $J''=0 \rightarrow J'=0$ transitions predominate. Second, that there is no appreciable alteration of the statistical distribution and hence that $J''>0$ states and $\Delta J=0$ transitions predominate. If the selection rule for gaseous molecules that forbids $J''=0 \rightarrow J'=0$ transitions is applicable here, the second interpretation must be the correct one.

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      March 24, 1938.

[1] Kinsey and Ellis, Phys. Rev. **51**, 1074 (1937).