The frequency dependence of ϵ_a and ϵ_c can be fitted fairly well by curves based upon one relaxation time each: r_a and r_c. It is found experimentally that $r_a/r_c \sim 10$. Presumably there are no domains and consequently no hysteretic losses associated with domain boundary movements. The losses might be assumed to arise from the anharmonic interactions between the motion of the Ti ions and the other normal modes of nuclear motion. The anharmonicity of the motion of Ti in the a direction will be much larger than that of the motion in the c direction because of the much lower harmonic force constant in the former case. Hence there will be a much larger interaction between the motion of Ti in the a direction and the other normal modes than in the case of the c direction. Consequently we would have $r_a/r_c \gg 1$.

The observed dielectric anisotropy above the Curie point (122°C) in these experiments is still unexplained. It must be remembered that the sample is macroscopically very anisotropic, the thickness (in the c direction) being only a few hundredths of the length and breadth (in the a and b directions). A marked anisotropy of ϵ in the normally cubic crystal may be caused by strains produced in the growth process. Since the thickness is only a few micros, it is not impossible that some surface effects are coming in.

The subjects discussed here will be treated more fully in a forthcoming paper.

[1] H. D. Megaw, Proc. Roy. Soc. **A189**, 261–83 (1947).

[2] G. C. Danielson, private communication.

[3] It is possible that an abnormally high electronic polarizability of O^{-} is largely responsible. See W. Shockley, Phys. Rev. **73**, 1273 (1948).

Natural and Induced Ferromagnetic Resonance

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THE complex permeabilities of several ferromagnetic compounds have been measured over the frequency range 500–28,000 Mc/sec. by the dual impedance wave-guide method.[1] In each case, the magnetic dispersion and absorption have similar resonance characteristics to those observed in γ-ferric oxide,[1,2] with the real component of permeability falling below unity, and the magnetic loss tangent passing through a maximum, at frequencies of 3000–10,000 Mc/sec. The observations agree well with the theoretical formula for a damped resonance

$$(\mu-1)/(\mu_0-1)=\nu_n^2/(\nu_n^2-\nu^2+2i\nu\nu'), \tag{1}$$

where μ_0, μ are the permeabilities at low frequencies and at frequency ν, respectively, ν_n is the natural resonant frequency, and ν' is the damping frequency.

This *natural ferromagnetic resonance* is attributable to Larmor spin resonance in the internal anisotropy and/or strain field H_n of the material.[2] Using the relation

$$h\nu_n=g\mu_BH_n, \tag{2}$$

where μ_B is the Bohr magneton, and taking $g=2$ for an electron spin, the effective values of H_n can be derived from the experimental values of ν_n. Data for typical specimens of three of the compounds investigated are tabulated below.

The *induced ferromagnetic resonance* has also been investigated in these compounds. Kittel[3] has considered the theory of this resonance absorption, which occurs when a large magnetostatic field is applied perpendicular to the microwave field in the ferromagnetic, and he has shown that the simple resonance condition

$$h\nu_i=g\mu_BH_i \tag{3}$$

is valid only for spherical specimens, the relation being modified in other cases by the shape demagnetization coefficients.

Spherical samples, 0.125″ diameter, moulded from mixtures of the powdered compounds with paraffin wax, were located centrally in an H_{01} wave-guide section, $\lambda_{g/2}$ in front of a terminating short. The frequency of operation ν_i was 9721 Mc/sec. A perpendicular magnetostatic field was applied parallel to the narrow side of the guide, and the Q of the wave-guide section was determined, by standing wave measurements, as a function of the applied field. The field H_p at which maximum absorption occurred is given in the table. H_p was found to be independent of the mixture concentration, so that the results may be taken as valid for the solid.

If H_p is substituted for H_i in (3), anomalous values of greater than 2.0 are obtained, similar to those found by other observers on supermalloy[4] and Zn-Mn ferrite,[5] who offered no explanation of the cause of the anomaly. In the table the theoretical values for a free spin are included for comparison, and it will be noted that there is a definite correlation between the magnitude of the internal field H_n, and the deviation of H_p from the free spin value.

Material	ν_n(Mc/sec.)	$H_n(Oe)$	$H_p(Oe)$	H_i	g
Ni-Zn ferrite	6250	2240	2630	3456	2.01
Fe_3O_4	5200	1850	2940	3474	2.00
γ-Fe_2O_3	3850	1370	3170	3454	2.01
Free spin (Theoretical)	0	0	3470	3470	2.00

It is evident, therefore, that the anomalous g values arise from neglecting the effect of H_n. A theoretical relation has been derived for H_i:

$$H_i=(H_p^2+H_i^2)^{1/2}, \tag{4}$$

which is in close agreement with the experimental data. The values of H_i and g derived from (4) and (3) are tabulated.

It is likely that the anomalous g values reported for supermalloy and Zn-Mn ferrite[4,5] are due to internal fields. Although supermalloy is stated to have a low natural anisotropy, the preparation of the thin-sheet specimen used by Yager and Bozorth may have introduced an artificial strain anistropy.

A fuller account of this work will be published later.

[1] J. B. Birks, Proc. Phys. Soc. **60**, 282 (1948).

[2] J. B. Birks, Nature **159**, 775; **160**, 535 (1947).

[3] C. Kittel, Phys. Rev. **73**, 155 (1948).

[4] W. A. Yager and R. M. Bozorth, Phys. Rev. **72**, 80 (1947).

[5] W. H. Hewitt, Jr., Phys. Rev. **73**, 1118 (1948).