Note on the High Frequency Dispersion in Nickel Zinc Ferrites

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As is known,[1] ferrites show a dispersion of the initial permeability μ_0 at a frequency which is intimately related to the low frequency value of the initial permeability. Snoek[2] explained his phenomenon as a gyromagnetic resonance of the electron spins. Rado, Wright, and Emerson[3] found two regions of dispersion in a ferrite material, "Ferramic *A*." The lower frequency of dispersion which according to Snoek's formula corresponds to the value of the initial permeability, has been described by these authors as a resonance of the domain boundaries, whereas the resonance at 1300 Mc/sec has been ascribed to spin rotation.

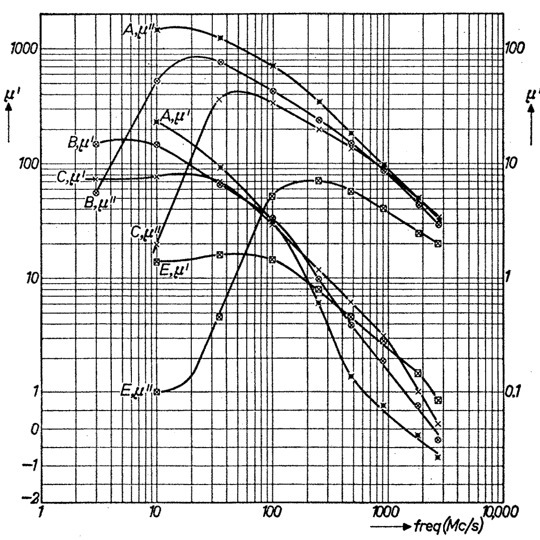

FIG. 1. The real and imaginary part of the initial permeability, μ' and μ'', respectively, as a function of frequency f for samples of NiZn ferrite with varying Ni−Zn ratio

Ferrite	NiO	ZnO	Fe_2O_3
	Chemical composition in mole percent		
A	18	32	50
B	25	25	50
C	32	18	50
E	50	—	50

In order to investigate whether two regions of dispersion occur in NiZn ferrites (Ferroxcube IV), we have measured the complex initial permeability ($\mu_0=\mu_\prime-j\mu''$) from low frequencies up to about 3000 Mc/sec. The measurements have been carried out on ring cores in a coaxial line resonator as described elsewhere,[4] and care has been taken to avoid dimensional resonance effects.[5] Figure 1 gives the results of the measurements

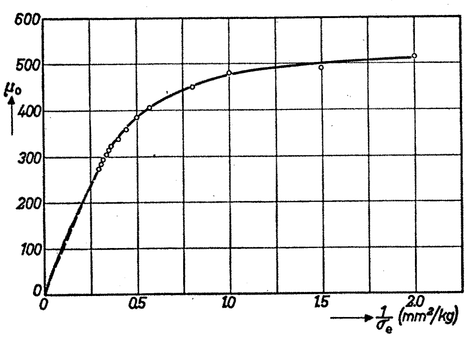

FIG. 2. The initial permeability μ_0 of a rod of NiZn ferrite (chemical composition in mole percent 18 NiO, 32 ZnO, and 50 Fe_2O_3) as a function of externally applied tension σ_e.

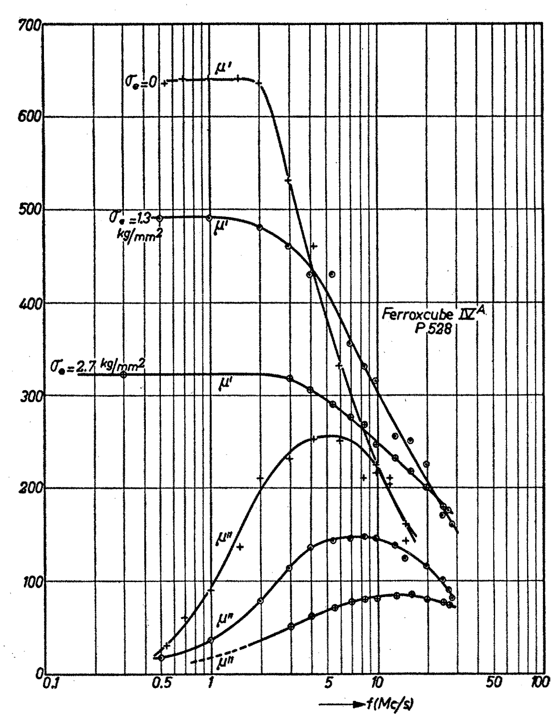

FIG. 3. The real and imaginary part of the initial permeability, μ' and μ'', respectively, plotted against frequency for different values of externally applied tension σ_e. Chemical composition of the ferrite is that of ferrite *A* of Fig. 1.

[1] J. L. Snoek, *New Developments in Ferromagnetic Materials* (Elsevier Publishing Company, Inc., New York, 1947).
[2] J. L. Snoek, Physica 14, 207 (1948).
[3] Rado, Wright, and Emerson, Phys. Rev. **80**, 273 (1950).
[4] van der Burgt, Gevers, and Wijn, Philips Tech. Rev. **14**, 206 (1952).
[5] Brockman, Dowling, and Steneck, Phys. Rev. **75**, 1298 (1949).

for NiZn ferrites with varying Ni—Zn ratios on a logarithmic scale, so that all the results can be compiled in one figure. For each ferrite only one region of dispersion is found, *viz.*, that which has been reported previously.[6] Moreover, the negative values of $\mu'-1$ at high frequency must be due to a resonance phenomenon.

If this resonance is related to the simultaneous rotation of the electron spins in a Weiss domain, it must still occur in ferrites in which boundary displacements cannot contribute to the initial permeability. This condition is fulfilled for NiZn ferrites under external tensile stress, if the direction of the stress coincides with that of the magnetic field. For the NiZn ferrite with chemical composition in mole percent 18 NiO, 32 ZnO, and 50 Fe_2O_3, the internal anisotropy is sufficiently small that the energy $\frac{3}{2}\lambda_s\cdot\sigma_e$ can be made predominant. λ_s denotes the magnetostriction constnat and σ_e the external stress. This becomes clear from Fig. 2 in which for a rod of this ferrite, μ_0 is plotted against $1/\sigma_e$, from which it may be seen that above $\sigma_e=2.5$ kg/mm² the relation between μ_0 and $1/\sigma_e$ becomes a straight line, as is to be expected.[7] We have measured μ' and μ'' *vs* frequency at different values of the tension (Fig. 3). For $\sigma_e=0$ the same magnetic spectrum should be expected as that found for a ring-shaped specimen of the same chemical composition (Fig. 1). It must, however, be borne in mind that the rod has been formed by an extrusion process whereas the ring was formed by pressing. The permeability μ_0 decreases when stress is applied, and at the same time the frequency f_{res} at which the μ'' curve has a maximum shifts to a higher value, according to Snoek's relation:

$$\tfrac{1}{2}\cdot f_{\text{res}}(\mu_0-1)=(2/3)\cdot\gamma I_s.$$

Since under a tension of $\sigma_e=2.7$ kg/mm² the greater part of the spins can be assumed to be oriented perpendicular to the direction in which μ_0 is measured, the factor 2/3 in Snoek's formula must be omitted. This experiment on a NiZn ferrite is in agreement with the view that the dispersion in these ferrites is related to a rotation process.

We wish to thank Dr. G. W. Rathenau for suggesting the experiment and Mr. A. van der Grijp and Mr. H. van der Heide for assistance during the measurements.

[6] J. J. Went and E. W. Gorter, Philips Tech. Rev. **13**, 181 (1951).

[7] R. Becker and M. Kersten, Z. Physik **64**, 644 (1930).

DISCUSSION

G. T. Rado, *Naval Research Laboratory, Washington, D. C.:* It was suggested in my paper that the addition of Zn-ferrite to a magnetic ferrite (e.g., Li-ferrite) tends to coalesce the two natural resonances, and it was shown that our experimental results support this suggestion. The fact that Wijn, Gevers, and van der Burgt (WGv) found only one resonance in some Ni—Zn ferrites is, therefore, consistent with the views presented in my paper. It is noteworthy, moreover, that in pure Ni-ferrite our group observed an indication of a second resonance (see Fig. 7 of my paper) at a microwave frequency which is just above the highest frequency shown in the results of WGv.

Concerning the mechanisms of magnetization, it may well be that at certain relatively low frequencies the initial permeability due to rotations predominate over that due to wall displacements in the special case of some Ni—Zn ferrites. However, the method used by WGv to establish this point may be questioned because the presence of an external stress obviously modifies the magnetization processes and hence changes the physical conditions of the problem.