THE ULTRASONIC LOSS OF MANGANESE FERRITES (MnxFe3-xO4) WITH A MANGANESE CONTENT BETWEEN 0.7 AND 1.6 AT FREQUENCIES BETWEEN 50 kHz AND 70 MHz AND TEMPERATURES BETWEEN 80 K AND 400 K

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THE ULTRASONIC LOSS OF MANGANESE FERRITES (Mn$_x$Fe$_{3-x}$O$_4$) WITH A MANGANESE CONTENT BETWEEN 0.7 AND 1.6 AT FREQUENCIES BETWEEN 50 kHz AND 70 MHz AND TEMPERATURES BETWEEN 80 K AND 400 K

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Résumé. — Des mesures de pertes ultrasoniques ont été effectuées sur des ferrites de manganèse Mn$_x$Fe$_{3-x}$O$_4$ avec $x$ compris entre 0,7 et 1,6. Un modèle expliquant les résultats obtenus avec les ferrites de concentration comprise entre 0,7 et 1,0 est proposé.

Abstract. — Some ultrasonic loss measurements were performed on manganese ferrites Mn$_x$Fe$_{3-x}$O$_4$ for $x$ between 0.7 and 1.6. A model to explain the results for a manganese content between $x = 0.7$ and $x = 1.0$ is proposed.

In mono-crystalline samples the loss is dependent on the direction of the wave-propagation with respect to the crystal-axis. The loss is nearly temperature independent for longitudinal waves in the $<100>$ direction for manganese ferrites with a manganese content from 0.7 to 1.0. But in the $<111>$ direction the influence of the temperature is very strong (see Fig. 1).

![Fig. 1](image1.png)

**Fig. 1.** — The ultrasonic loss of longitudinal waves as a function of the temperature for Mn$_{0.7}$Fe$_{2.3}$O$_4$.

The temperatures and frequencies at which the maximum loss occurred are given in figure 2 for three compositions both mono- and polycrystalline.

Manganese ferrites with a manganese content from 1.0 to 1.6 have an ultrasonic loss, which is temperature dependent in all directions of the wave propagation when longitudinal waves are used. The temperature dependence was stronger for a wave propagated in the $<100>$ direction than in the $<111>$ direction. The ultrasonic loss for longitudinal waves in the $<100>$ direction was also dependent on the magnetic field (see Fig. 5).

For a similar composition the maximum in the acoustical loss for the wave-vector directions occurs at the same temperature and frequency. The temperature at which the maximum loss occurs is given as a function of the temperature for several compositions in figure 4 [1]. The activation energy of the acoustical loss is given in figure 3 [2].

For the model that is suggested for the explanation of the measurements performed on manganese ferrites

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The temperatures and frequencies at which the maximum loss occurs for manganese contents with a manganese content between 0.7 and 1.0 the following assumptions are made. First there are few manganese ions located on the octahedral sites. Second, the electrical conductivity takes place by the way of the iron ions on the octahedral sites according to

$$\text{Fe}^{2+} + \text{Fe}^{3+} \leftrightarrow \text{Fe}^{3+} + \text{Fe}^{2+}.$$

The ions situated at the octahedral sites are situated in rows with $<110>$ directions. When in figure 6 the unit cell is drawn the rows can have the directions AC and FH. The ions in the rows with the direction AC get more space than those in the rows with the direction FH by a tension in the direction AC. The result is that the electrons which were distributed at random, get a preference for the rows with an AC direction. This is caused by the larger ion radius of the Fe$^{2+}$ ions with respect to that of the Fe$^{3+}$ ions. A compression with an AC direction has the opposite result.
The ultrasonic loss of manganese ferrites $M_{n_z}Fe_{3-z}O_4$.

Activation energy of the magnetic relaxation $k_A$.

Fig. 3. — The acoustical loss in $M_{1.6}Fe_{1.4}O_4$ as a function of the temperature at two values of the magnetic field. The frequency of the longitudinal waves is 30 MHz.

Fig. 4. — The frequency as a function of the temperature at which the maximum loss occurs for manganese contents $1.0 < x < 1.6$.

When a travelling or standing longitudinal wave has a $<110>$ direction, the electrons will hop among the rows with an AC direction and that with an FH direction. The chance that the hopping of an electron really occurs is dependent on the temperature, the frequency, and the height of the potential hills between the octahedral sites.

A tension or a compression in the $<100>$ direction will act upon all octahedral ions equally. So a longitudinal wave with a $<100>$ direction will not cause a stress-induced electron transfer. This can be the reason why there is no relaxation for longitudinal waves with a $<100>$ direction.

The measurements are performed with longitudinal waves with a $<100>$ direction and a $<111>$ direction. It is possible to construct a stress with a $<111>$ direction from three equal stresses with a $<110>$ direction. The effect of this is that the behaviour of a longitudinal wave in the $<111>$ direction is qualitatively equal with that in the $<110>$ direction.

Some other results of the system $x$ between 1.0 and 1.6 are to be published.

References