Longitudinal Ferrimagnetic Resonance

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Susceptibility components are calculated for a triangular ferrimagnetic system when the oscillating field is parallel to both the constant field and the net magnetization. Two new effects are found which are analogous to that discussed previously. The consist in the production of oscillating magnetization components of the same frequency as the external field and which are parallel and perpendicular to the net magnetization.

IN a previous paper,[1] the magnetic resonance properties of three-sublattice ferrimagnetic systems were briefly discussed and it was shown that a new effect should exist for systems with triangular configurations and in which the sublattice gyromagnetic ratios were all different. For the conventional arrangement of external magnetic fields in which the constant field is parallel to the net magnetization and a small oscillating field is perpendicular to this direction, this effect consists in the production of an oscillating magnetization component which is parallel to the net magnetization (and hence perpendicular to the oscillating field). This magnetization component has the same frequency as the applied field and does not arise from the nonlinear terms in the equations of motion.

A qualitative explanation for the occurrence of this effect was given in reference 1 with the aid of Fig. 2 of that paper. If one now looks afresh at Fig. 2, one sees that the situation depicted there suggests the possibility of two more new effects associated with triangular configurations if the oscillating field is now applied parallel to the common direction of the constant field and the net magnetization rather than perpendicular to it. The first of these effects is, in a sense, the reciprocal of that discussed in reference 1 and consists in the production of an oscillating magnetization component in the transverse x-y plane by the external field in the z direction of the net magnetization. The second effect involves the simultaneous occurrence of an oscillating magnetization component parallel to the z direction. Ordinarily in ferrimagnetic resonance, the z component of the induced magnetization is assumed to be zero because it arises only from second order terms in the equations of motion and these are usually neglected. In the triangular case, however, the existence of possibly large transverse static sublattice magnetization components suggests that this z component can have a nonzero value even when only linear terms are kept. The purpose of this paper is to show that these effects do exist in principle and to give the results of a calculation of the relevant components of the susceptibility.

We use exactly the notation and basic sublattice equations of motion of reference 1. If we now assume in addition a small external field component $h_z \propto e^{i\omega t}$ and proceed as before, we find that the only changes in the final Eqs. (21) are the addition of the following terms to the right-hand sides:

$$\mathcal{V}_1=\bar{M}_xB(A_2^{-1}-A_3^{-1})h_z, \tag{1}$$

$$\mathcal{V}_2=\{-\bar{M}_x[(H_2/A_2)+(E/A_3)]+\bar{M}_y\}h_z, \tag{2}$$

$$\mathcal{V}_3=\{\bar{M}_x[(G/A_2)+(H_3/A_3)]-\bar{M}_y\}h_z, \tag{3}$$

$$\mathcal{V}_4=-\bar{M}_xL_1(A_2^{-1}-A_3^{-1})h_z. \tag{4}$$

We note that these terms all vanish when $=\bar{M}_x\bar{M}_y=0$, i.e., no triangles, so that the existence of the triangular configuration is essential in order that h_z enter into the linearized equations.

We define additional susceptibility components by

$$m_x=\chi_{xz}h_z, \tag{5}$$

$$m_z=\chi_{zz}h_z. \tag{6}$$

Using the general solutions of Eqs. (21) given by (23)–(29), we find that, to the highest order of the molecular field coefficients,

$$\chi_{zz}=-1/\lambda_0=-1/\lambda_{23}, \tag{7}$$

$$\begin{aligned}\lambda\beta^2(\gamma_2-\gamma_3)(\bar{M}_x^2+\bar{M}_y^2)[(\omega^2/\gamma_t^2)-H^2]\chi_{xz}\\ =\omega^2\bar{M}_x\{(M_1/\gamma_1)+(M_2/\gamma_2)+(M_3/\gamma_3)\\ +(1-\beta)[(M_2/\gamma_3)+(M_3/\gamma_2)]\}\\ -i\omega\bar{M}_y\{MH-(\omega^2/\gamma_1\gamma_2\gamma_3\beta H)\\ \times[\gamma_1M_1+\beta^2(\gamma_2M_2+\gamma_3M_3)]\},\end{aligned} \tag{8}$$

where γ_t is the effective gyromagnetic ratio for the triangular case given by (42).

These results show, therefore, that the new effects discussed qualitatively in the preceding paragraphs should exist for triangular ferrimagnetics. The value of the longitudinal susceptibility χ_{zz} is particularly simple (to this order, at least) and this should enable the molecular field coefficient λ_{23} to be measured directly in this way, rather than by having to try to deduce its value more indirectly from static susceptibility and magnetization measurements.

With this background, one can now see qualitatively more possibilities of interesting effects which can occur, depending on the relative orientations of external fields and magnetizations. For example, one could let the constant field be perpendicular to the net magnetization (in the x direction, say), and then apply the oscillating field in the x-y plane or in the z direction. One would expect these field configurations to induce oscillating magnetizations both along the z direction and in the x-y plane. Further quantitative calculations would be needed to see if results as simple as (7) can be obtained for these cases also.

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[1] R. K. Wangsness, Phys. Rev. 119, 1496 (1960).