Smart Measurement Setup for Spin-Wave Linewidth ΔH_k

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***Abstract*—A new setup for measuring spinwave linewidth ΔH_k is described. By use of a dielectric resonator instead of a standard waveguide resonator it is possible to realize much higher microwave magnetic fields at the sample position. Due to the smaller size of the resonator and a more efficient field distribution, the necessary microwave power can be reduced by nearly a factor of 300. Therefore, it is possible to measure spinwave linewidth ΔH_k up to 20 Oe (1.6 kA/m) with only 20-W microwave power.**

***Index Terms*—High-power microwave measurements, magnetic materials, microwave devices, microwave measurements, radar applications.**

I. Introduction

THE POWER capability of ferrite-based high-power applications, like circulators and phase shifters for radar systems, is limited by the onset of Suhl instabilities, which sensitively depends on dissipation. Therefore, spin-wave linewidth measurements are very important. Moreover, the microstructure of polycrystalline ferrite material leads to a frequency-dependent spin-wave linewidth [1], [2]. High-power microwave sources and the related waveguide equipment are expensive, so a low power, low cost and wide frequency measurement setup would be helpful. Such a setup will be presented in the following.

Instead of a standard waveguide cavity [3], a dielectric puck resonator [4] driven in the $TE_{01\delta}$-mode is used. This type of resonator is widely used for oscillator and filter applications and is commercially available with Q factors between 10 000 and 30 000 at microwave frequencies [5], [6].

In the center of such a resonator, very high H field amplitudes can be realized for two reasons: First, the volume of the resonator is reduced by factor ε_r and, therefore, the energy density is increased. Second, for the $TE_{01\delta}$-Mode the H field distribution is close to a dipole field and maximized at the center of the resonator.

II. Theory

The microwave field inside a dielectric puck resonator driven in the $TE_{01\delta}$ mode is approximately given with the nonvanishing field components of the TE_{01} mode of a shielded resonator [4]

$$H_z = H_0 \cdot J_0(k_r \cdot r) \quad H_r = -i \cdot \frac{\beta}{k_r} \cdot H_0 \cdot J_1(k_r \cdot r)$$

$$E_\phi = -i \cdot \frac{\omega \cdot \mu_0}{k_r} \cdot H_0 \cdot J_1(k_r \cdot r)$$

with $k_r \cdot r = 2.405$ (first zero of the Bessel function).

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J_m denotes Bessel functions of the mth order, k_r the radial wave number, r the distance from symmetry axis z, β the radial propagation constant, H_0 the amplitude of the microwave magnetic field, and ω the frequency.

Therefore, the energy inside the resonator can be calculated from

$$W = \tfrac{1}{2} \cdot \varepsilon_0 \varepsilon_r \cdot \int E_\phi^2 \cdot dV.$$

From the relation

$$\int_0^{2.405} J_1(x)^2 \cdot x \cdot dx = 0.779$$

the energy is evaluated to be

$$W = 5.83 \cdot 10^{-3} \cdot \varepsilon_0 \varepsilon_r (\omega \mu_0 D)^2 \cdot H_0^2 \cdot V_{\mathrm{DRO}}.$$

With the definition of the quality factor $Q \cdot P = \omega \cdot W$ and considering, that the power P inside the resonator is related to the incident power P_{in} by $P = (1 - r^2) \cdot P_{\mathrm{in}}$, where r is the reflection coefficient at the resonator input, we obtain an expression for the maximum magnetic microwave field amplitude

$$H_0 = 13.1 \cdot \sqrt{\frac{Q_l \cdot P_{\mathrm{in}} \cdot (1 - r^2)}{\omega \cdot \varepsilon_0 \varepsilon_r \cdot (\omega \mu_0 D)^2 \cdot V_{\mathrm{DRO}}}}.$$

Q_l is the relevant loaded Q factor and V_{DRO} the volume of the dielectric resonator (DR).

The resonance frequency f_R of the DR can be estimated using the formula given in [4]

$$f_R = \frac{34 \cdot \mathrm{mm}}{0.5 \cdot D \cdot \sqrt{\varepsilon_r}} \left(\frac{0.5 \cdot D}{L} + 3.45 \right) \cdot \ \mathrm{GHz}.$$

The expression for H_0 is an approximate solution. First, the field dependence in z direction for the $TE_{01\delta}$-mode is neglected, and it is assumed that the field is totally inside the resonator. This can be done for symmetry reasons, if one only discusses the magnetic field in the center of the resonator. Second, the hole for mounting and sample insertion inside the resonator can be neglected, because for the $TE_{01\delta}$-mode (and TE_{01}-mode) the electrical field is vanishing in the center of the resonator. However the solutions should be checked with an appropriate microwave field simulation software. Examples for useful resonators are listed in Table I. For these examples, the difference between the approximate analytical solution for H_0 given above and the corresponding numerical simulations $H_0/H_{0-\mathrm{SIM}}$ were 1.16 for 2.44 GHz, 0.96 for 4.04 GHz, and 0.99 for 9.04 GHz.