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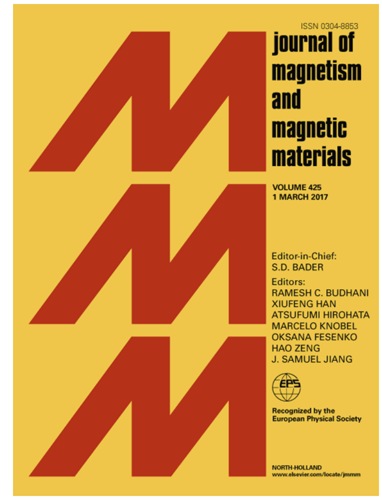

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Antenna Design for Propagating Spin Wave Spectroscopy in Ferromagnetic Thin Films

Yan Zhang*, Ting Yu, Ji-lei Chen, You-guang Zhang, Jian Feng, Sa Tu and Haiming Yu
Fert Beijing Institute, School of Electronic and Information Engineering, BDBC
Beihang University, Xueyuan Road 37, Beijing 100191, China
* yanzhang@buaa.edu.cn

***Abstract* — In this paper, we investigate the characteristics of antenna for propagating-spin-wave-spectroscopy (PSWS) experiment in ferromagnetic thin films. Firstly, we simulate the amplitude and phase distribution of the high-frequency magnetic field around antenna by high frequency structure simulator (HFSS). And then *k* distribution of the antenna is obtained by fast Fourier transformation (FFT). Furthermore, three kinds of antenna designs, i.e. micro-strip line, coplanar waveguide (CPW), loop, are studied and compared. How the dimension parameter of antenna influence the corresponding high-frequency magnetic field amplitude and *k* distribution are investigated in details.**

***Index Terms* —propagating-spin-wave-spectroscopy (PSWS) experiment, antenna, *k* distribution**

1. Introduction

Recently, propagation of spin waves in metallic ferromagnetic films is investigated to the application in next generation of integrated microwave signal-processing devices. The study of logic circuits utilizing spin waves for information transmission and processing is more important [1]-[3]. Propagation of spin waves in nanometers planar waveguides has attracted extensive attention especially [4]. The amplitude of the spin-wave packet depends on the direction of magnetization has been studied in FeNi film and its phase can be controlled by the polarity of pulsed magnetic field for the excitation [5]. Propagation of spin-electromagnetic waves in thin-film multilayered multiferroic structures have been investigated both experimentally and theoretically [6]-[7]. Inverse Spin Hall Effect in nanometer-thick YIG/Pt system is studied in [8]. Yu *et al.* [9] shows how magnons with a wavelength of a few 10nm are exploited by combining the functionality of insulating yttrium iron garnet and nanodisks from different ferromagnets.

Different kinds of antenna probes are used to generate the desired spin wave. A complete description of a propagating spin wave spectroscopy (PSWS) experiment in a permalloy film is provided in [10]. Spang *et al.* [11] presented the probe compensation techniques for near-field measurement. Yu *et al.* [12] used a conventional coplanar waveguide to excite a large series of short-wavelength spin waves. Micrometer sized thin magnetic stripes are presented to developed an all electrical experiment to perform the broadband phase-resolved spectroscopy of propagating spin waves in [13]. And also antenna probe placements are investigated [14]-[15]. The PSWS technique is applied to metallic thin films, allowing to measure magnetostatic wave modes [16]. It is difficult to obtain the near-field performance of complex antenna probe, which has important effect on the excitation of spin wave. And also, the sensitivity and dynamic range of PSWS experiment could be improved by increasing the efficiency of antenna probe.

In this paper, we design three kinds of antenna probes for PSWS experiment in ferromagnetic films. The amplitude and phase distribution of high-frequency magnetic field around antenna probe is simulated by high frequency structure simulator (HFSS). And then *k* distribution of the antenna probe is obtained by FFT. Microstrip-line, coplanar waveguide (CPW), loop antenna probes are designed, respectively. And the effect of dimension parameter of these three antenna probes on high-frequency H-field amplitude distribution and *k* distribution is investigated in detail.

2. Spin wave theory

The expression of dynamic magnetization is shown as

$$\boldsymbol{m} = \hat{\chi} \cdot (\boldsymbol{h}_{\mathrm{s}} + \boldsymbol{h}_{\mathrm{d}}) \qquad (1)$$

where $\boldsymbol{m}$ is the dynamic magnetization in x-y plane. *X* is the microwave susceptibility tensor. $\boldsymbol{h_s}$ is the microwave field, $\boldsymbol{h_d}$ is spin wave dipole field.

$$h_{dx} = \int_{-\infty}^{+\infty} G^{(oo)}(r-r')m_x(r')dr' \qquad (2)$$

The dipole field of spin waves is well described by the Green's function *G*. The function has only two non-vanishing components, both of which are diagonal: the out-of-plane out-of-plane component $G^{(oo)}$ and the in-plane in-plane component $G^{(ii)}$ is the coordinate along the spin wave propagation path. Both components are symmetric: *G(-s)=-G(s)*.

By deriving, the expression of the magnetization of BVMSW mode is obtained as follows: