NONLINEAR BEHAVIOR OF ELECTROMAGNETIC WAVES IN THE YIG FILM MICROSTRIP LINE

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Abstract

The limiter and microwave soliton behavior were experimentally demonstrated in the microstrip line using the 20μm thick yttrium iron garnet film substrate at S band. These nonlinear phenomena were explained by the strong coupling between quasi-TEM and magnetostatic forward volume wave modes at magnetic resonance frequency of $\gamma\mu_0 H_0/2\pi$ from an implicit dispersion relation of the stripline.

I. Introduction

Recently, authors have experimentally demonstrated magnetostatic wave (MSW) delay line using microstrip line with yttrium iron garnet(YIG) film-gadolinium gallium garnet(GGG) substrate, and MSW in the linear state was found to be efficiently excited through quasi-TEM mode which is dominant mode propagated along the stripline[1].

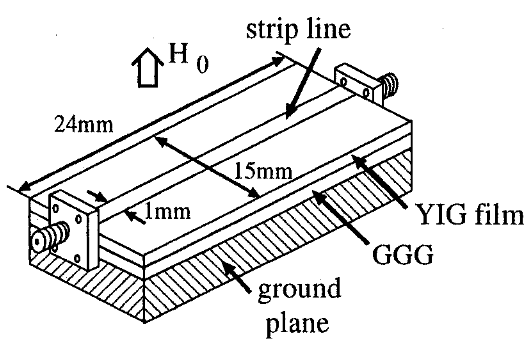

Fig.1 Microstrip line with YIG film substrate.

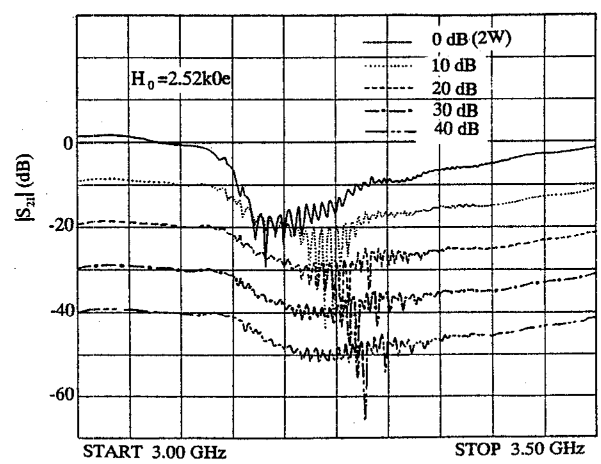

Fig.2 RF power-dependence on transmitted power S_{21}.

This paper experimentally investigates the nonlinear characteristics of the stripline with YIG film-GGG substrate. The limiter and MSW soliton behavior were shown and discussed with the dispersion curve.

II. Nonlinear characteristics of stripline

i) Limiter properties

Figure 1 shows the geometry of the microstrip line used in the experiment. It consists of a 1mm-wide stripline put on the surface of a YIG film with thickness 20μm, which is magnetized normal

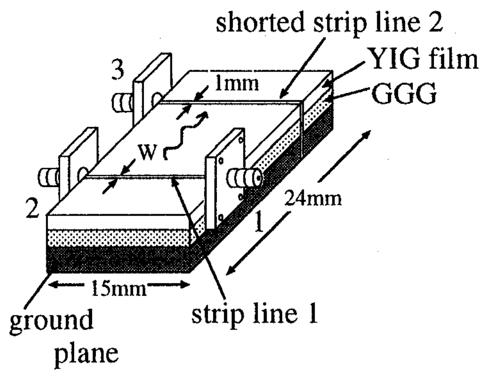

Fig.3 Measurement setup on radiation of MSFVW.

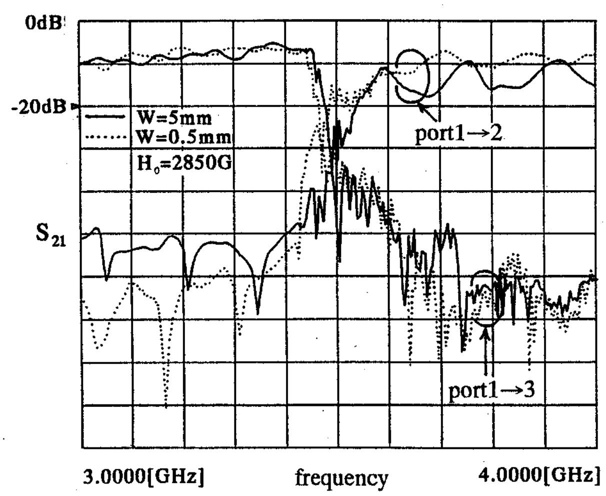

Fig.4 Radiation properties of MSFVW.

to the surface. Figure 2 shows the measured input power dependence of the transmission characteristics S_{21} from 10mW to 2W. The limiter operation of 10dB can be seen around 3.2 GHz. The cut-off behavior with the limiter operation may be caused by the excitation of magnetostatic forward volume wave (MSFVW) mode. To confirm the excitation of the MSFVW mode through quasi-TEM mode, the radiation properties of MSFVW mode in the transverse direction to the stripline was examined by using the traditional transducer design of MSW waveguide, as shown in Fig. 3[2]. Figure 4 shows the S_{21} properties from port 1 to 2 and S_{21} from

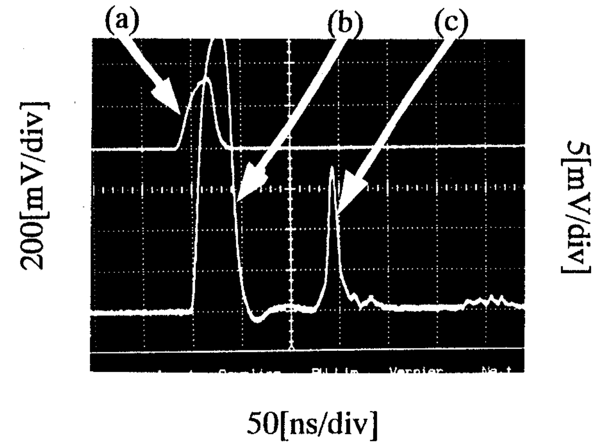

Fig.5 Photograph of input and output waveform.

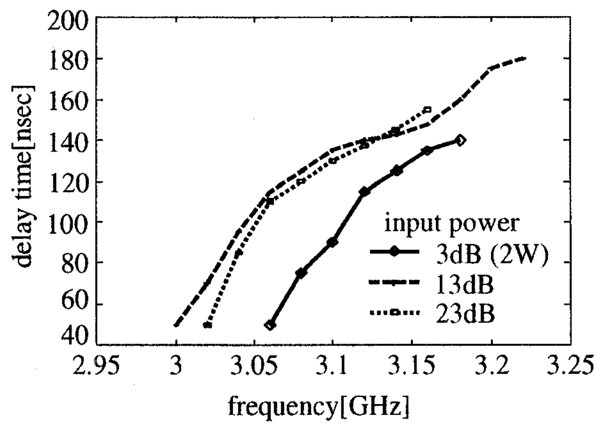

Fig.6 Power-dependence of group delay time.

port 1 to 3 under the linear regime. It can be seen from figure that the radiation is significant for the narrow stripline of $W = 0.5mm$, but the power is transmitted to the port 2 although a power radiates in the transverse direction to the stripline, port 3.

ii) Group delay time

The nonlinear characteristics of the group delay line was measured using microstrip line structure of Fig. 1 and using short microwave pulse. Figure 5 shows a typical photograph of input signal (a), quasi-TEM signal with zero delay time at 3.2 GHz (b), and delayed output signals (c), where input power of 1W was applied. Frequency dependence of the group delay time was reduced

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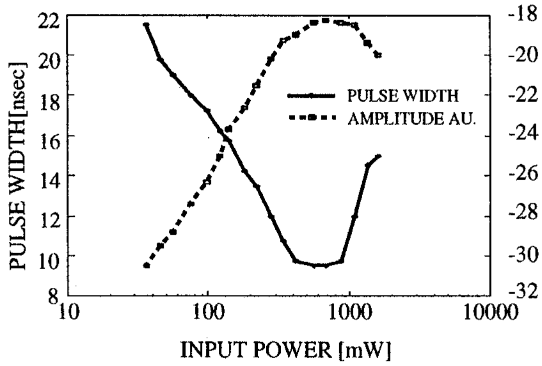

Fig.7 RF power-dependence on soliton pulse width and amplitude.

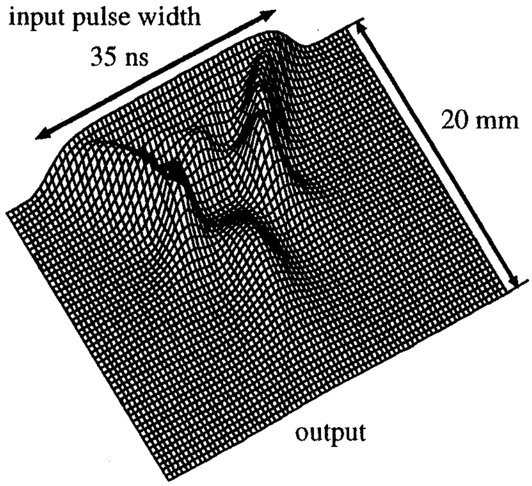

Fig.8 Simulation of MSFVW soliton form.

by increasing microwave power up to 1W as shown in Fig. 6. It means that nonlinear coefficient of the dispersion of MSFVW is positive, which has been proven by many workers[3].

iii) Soliton behavior

In the photographs of Fig. 5, output group delay signal is compressed with compression ratio of 4 for the input pulse width 40 nsec of quasi-TEM mode. It means that MSFVW soliton can be formed due to the nonlinear characteristics of the stlipline through MSFVW mode. The power dependence of the pulse width and the amplitude were measured and shown in Fig. 7, which shows the similar limiter characteristics observed as the CW signal of Fig. 2. To confirm the soliton be-

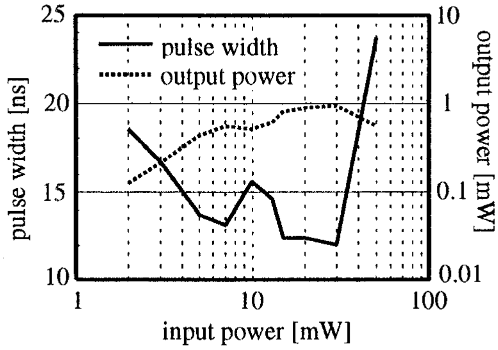

Fig.9 Simulation results on pulse width and amplitude.

havior of Fig. 7, the simulation of MSFVW form was undertaken under numerical calculations of nonlinear Schrödinger equation[3]. The numerical parameters used in the simulation were similar to that of traditional MSFVW delay line. A typical simulation results is shown in Fig. 8. Power-dependence of pulse width and amplitude can be read from Fig. 8, and it is depicted as shown in Fig. 9. It can be seen from the figure that the soliton characteristics have the similar tendency to the experimental results of Fig. 7, but the calculated input power does not match with the experiment.

III. Dispersion relation

Nonlinear phenomena discussed is mainly concerned with MSFVW mode in the stripline. Therefore, the quasi-TEM mode may be coupled to the MSFVW mode. To simplify the analysis of the microstrip line with YIG film substrate, two dimensional theoretical model of the stripline was assumed in infinite extent of the substrate to the transverse direction, i.e., a parallel plates model of YIG film waveguide. The dispersion relation could be derived from Maxwell's equation with boundary conditions in implicit form and with hybrid status of TE-TM modes. Fig. 10 shows a typical dispersion curve for applied dc field H_0 of 570G and for 20μm YIG film and 400μm thick

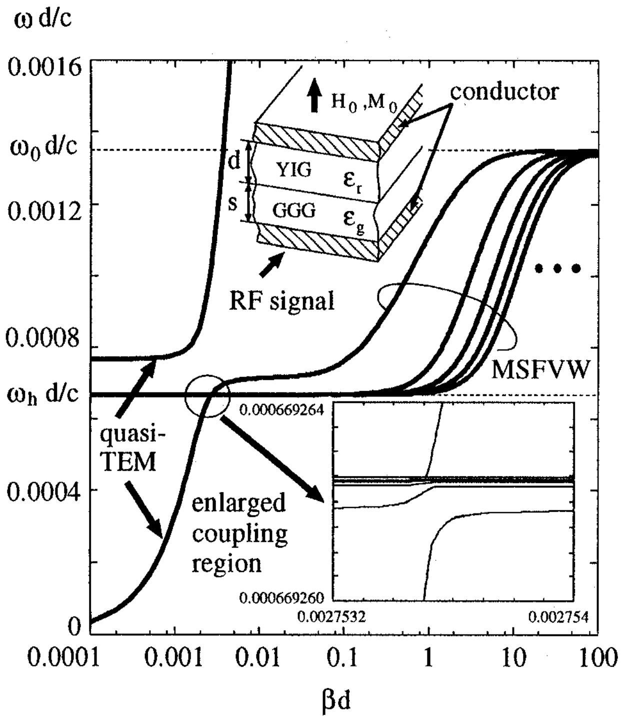

Fig.10 Dispersion curve ($\mu_0 M_0 = 0.175$[T], $\mu_0 H_0 = 0.057$[T], $\varepsilon_r = 15.3$, $\varepsilon_g = 7.7$, $d = 20\mu$m, $s = 400\mu$m).

GGG. The dispersion curve shows under mixed state of quasi-TEM mode with cut off bahavior due to magnetic resonance and MSFVW mode. It is noted that quasi-TEM mode is coupled to the MSFVW mode at gyromagnetic frequency of $f_h = \gamma H_0/2\pi$ [1], i.e., cut off frequency of MSSW. Effect of strip width is also examined, which gives the change of cut off behavior at the dispersion curve[4].

IV. Conclusions

Nonlinear characteristics of the stripline with YIG-GGG layered substrate were demonstrated experimentally with limiter and soliton operations. The dispersion relation of the stripline was derived from direct calculation of Maxwell's equations and boundary condition, which was shown with mixed state of quasi-TEM and MSFVW mode, and coupled each other at gyromagnetic frequency. These nonlinear phenomena have potentials of applications to limiter[5], S/N enhancer[6] and pulse compression devices[7].

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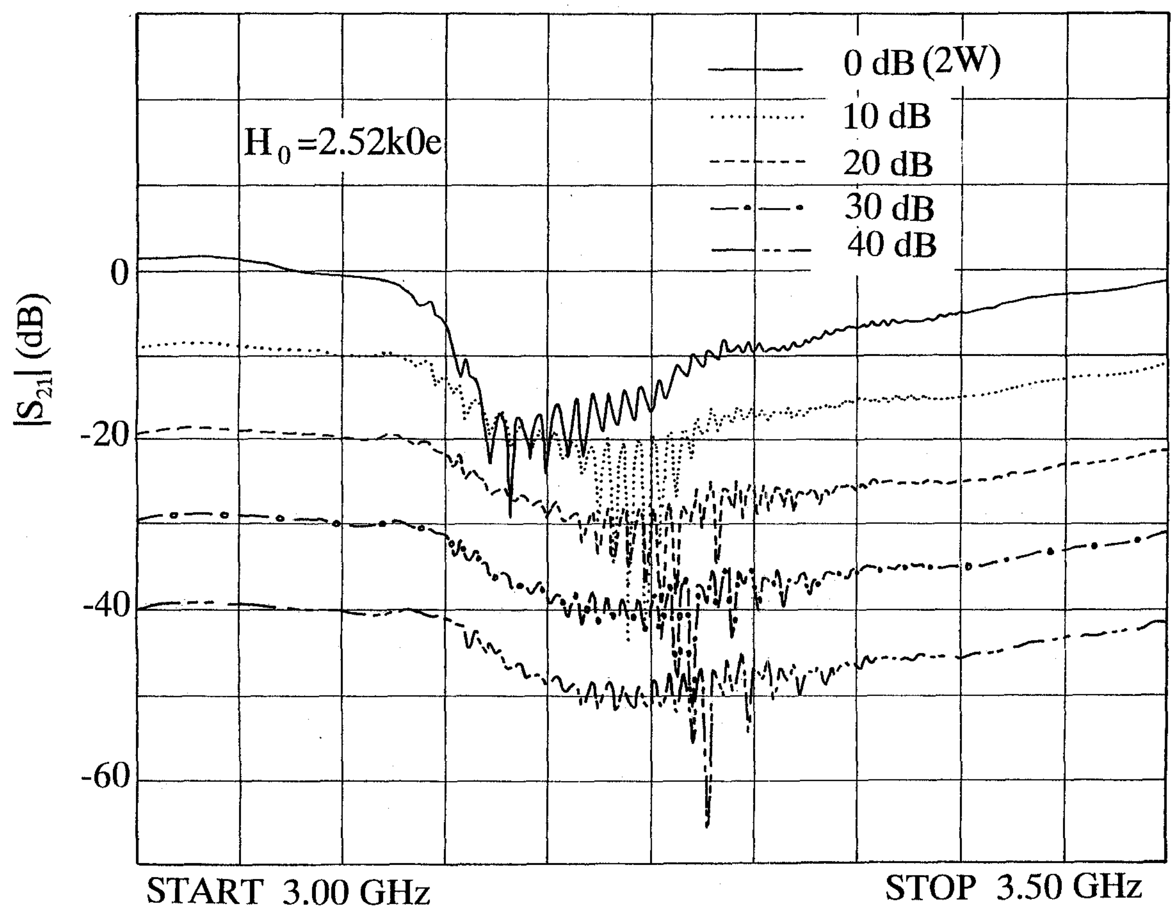

Fig.2 RF power-dependence on transmitted power S_{21}.
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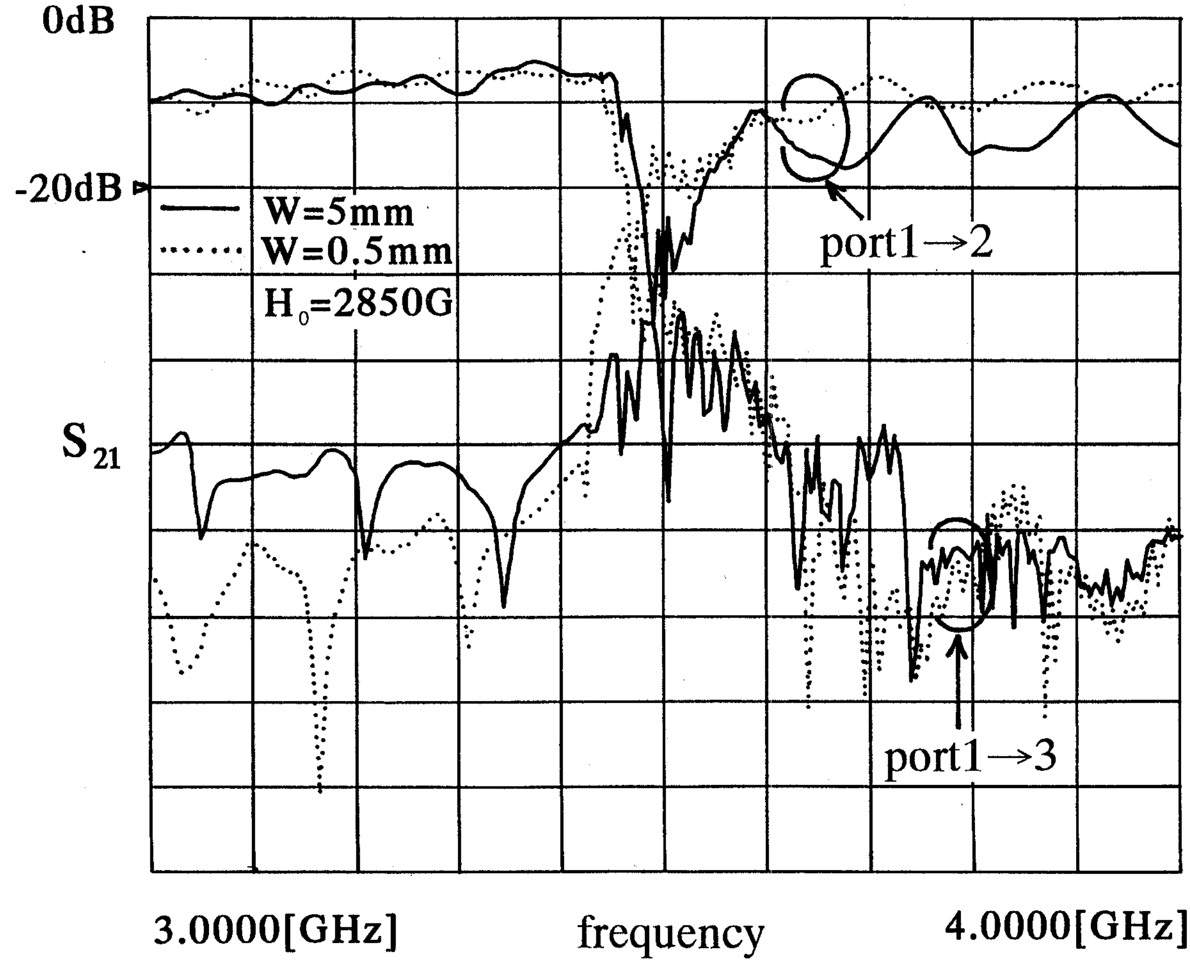

Fig.4 Radiation properties of MSFVW.
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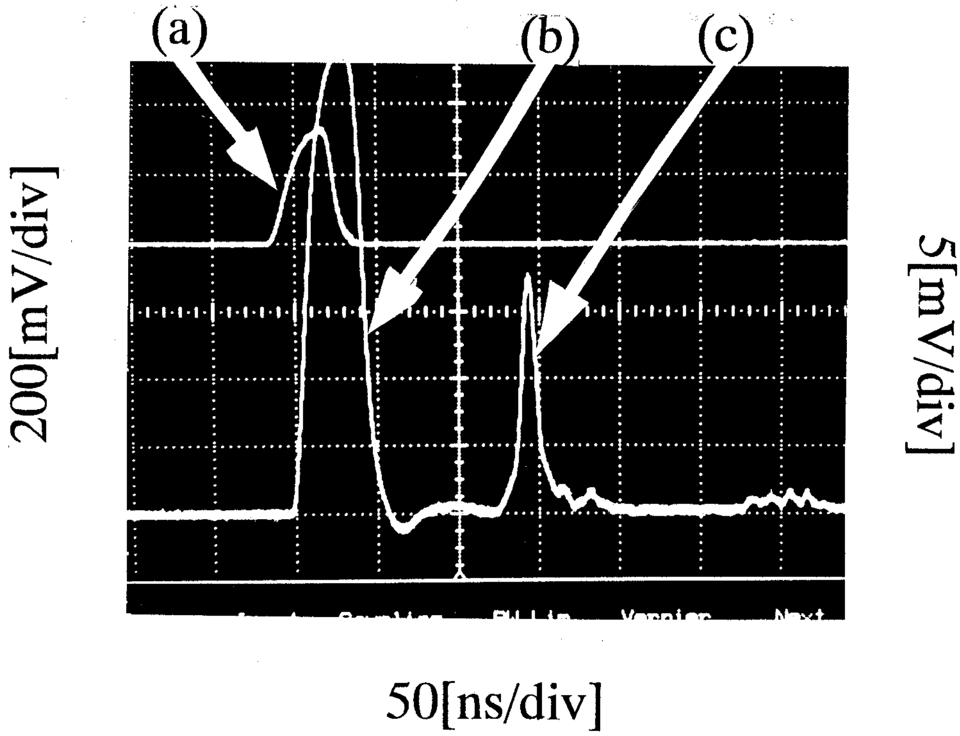

Fig.5 Photograph of input and output waveform.
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