ENERGY STORAGE EFFECT IN MSSW METAL-FINGER REFLECTORS

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ABSTRACT

Experimental results are presented on the magnetostatic-surface-wave (MSSW) scattering properties of a grating of metal fingers placed at a variable height above the YIG film and compared with theory. The agreement with theory is excellent if one takes into account energy storage at the metal-finger edges and if the width of the metal fingers is larger than the YIG-film thickness. It is concluded that, for smaller finger widths, the interaction between the edges of a metal finger must *additionally* be incorporated into the theory. The present results are significantly different from those for the scattering of magnetostatic forward volume waves (MSFVW's) by a grating of metal fingers. In the latter case, the scattered modes are *propagating* MSFVW's so that the problem of interaction between the edges of metal fingers is not present, i.e., the theory is valid for all widths of the metal fingers.

INTRODUCTION

The original theoretical modelling of the problem of magnetostatic surface wave (MSSW) scattering by a metal-finger-grating reflector and comparison with experimental results was reported by Collins *et al* [1] and Owens *et al* [2]. These authors employed a phenomenological transmission-line model which takes into account the *nonreciprocal* and *dispersive* properties of MSSW's but only considers *far fields*, i.e., energy storage at the metal-finger edges is ignored. Tuan and Parekh [2] later reported a field-theory of MSSW metal-finger reflectors employing Green's functions but this theory was based on a weak-coupling model, i.e., the metal fingers were assumed to be sufficiently spaced off the YIG surface, and again ignored mode conversion to *evanescent* or *cut-off* modes which manifest themselves through field decay with propagation.

While the evanescent modes are nonphysical in geometries where only a *propagating* MSSW exists, they must be incorporated in discontinuity problems, e.g., scattering at a junction between an unmetallized and a metallized region. In such scattering problems, the evanescent modes represent energy storage at the junction. The contribution of the evanescent modes to the induced current resulting from the interaction of the incident wave with the metal film is significant in the vicinity of the edge of the metal film and is expected to play an important role in the entire scattering process. The need for a complete field solution in arriving at a better understanding of the interaction effect is one of the motivating factors of the present work.

The present theory employs the Weiner-Hopf technique and assumes that the edges of a metal finger do not interact and that the metal fingers are perfectly conductive. The metal-finger grating is assumed to be placed at a variable height above the YIG film. The theory is quite involved even without the inclusion in it of the conductivity of the metal fingers.

Based on computations of the induced current in the metal strip due to the evanescent modes, it is predicted that the two edges of a metal finger start to interact when the finger-width is reduced approximately to the thickness of the YIG film. This prediction is borne out in the experiment.

An important distinction exists between the MSSW and the MSFVW [4] scattering problems in the context of a reflective grating comprised of metal fingers. When the incident wave is an MSFVW, the scattered fields are propagating MSFVW modes and are fully accomodated by a theory of the present type, i.e., the accuracy of the problem is independent of the width of the metal fingers. On the other hand, when the incident wave is an MSSW, the scattered modes are the *evanescent* MSSW modes which *preclude* a closed-form solution in the case of *interacting* edges. It follows that, if a non-interacting edge model is assumed as is the case in the present work, the accuracy of the solution is expected to diminish with a decrease in the width of the metal strip.

EXPERIMENTAL AND THEORETICAL RESULTS

The basic experimental setup consists of an MSSW delay line with a metal-finger reflector grating placed between the input and output microstrip transducers as shown in Fig. 1. The bias field is applied in the plane of the YIG film and normal

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to the propagation direction so that MSSW's are the only magnetostatic-wave (MSW) mode-type supported by the YIG film.

The reflector grating is comprised of 10 fingers with a periodicity of 419 um. Since the *aggregate* length of the grating in the direction of MSSW propagation is less than 1 mm, the dominant loss mechanism is expected to be the mode-conversion process rather than the ohmic loss in the fingers.

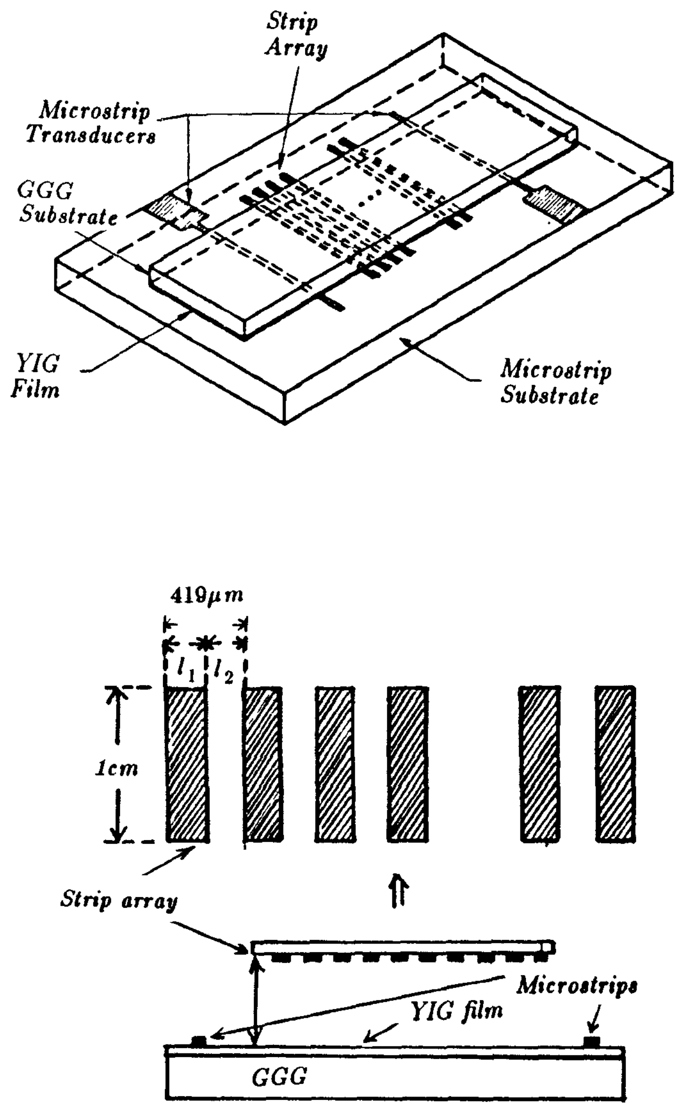

Fig. 1. Geometry of an MSSW delay line with a metal-finger reflector grating placed between input and output transducers. The bias field lies in the plane of the YIG film and is oriented normal to the propagation direction.

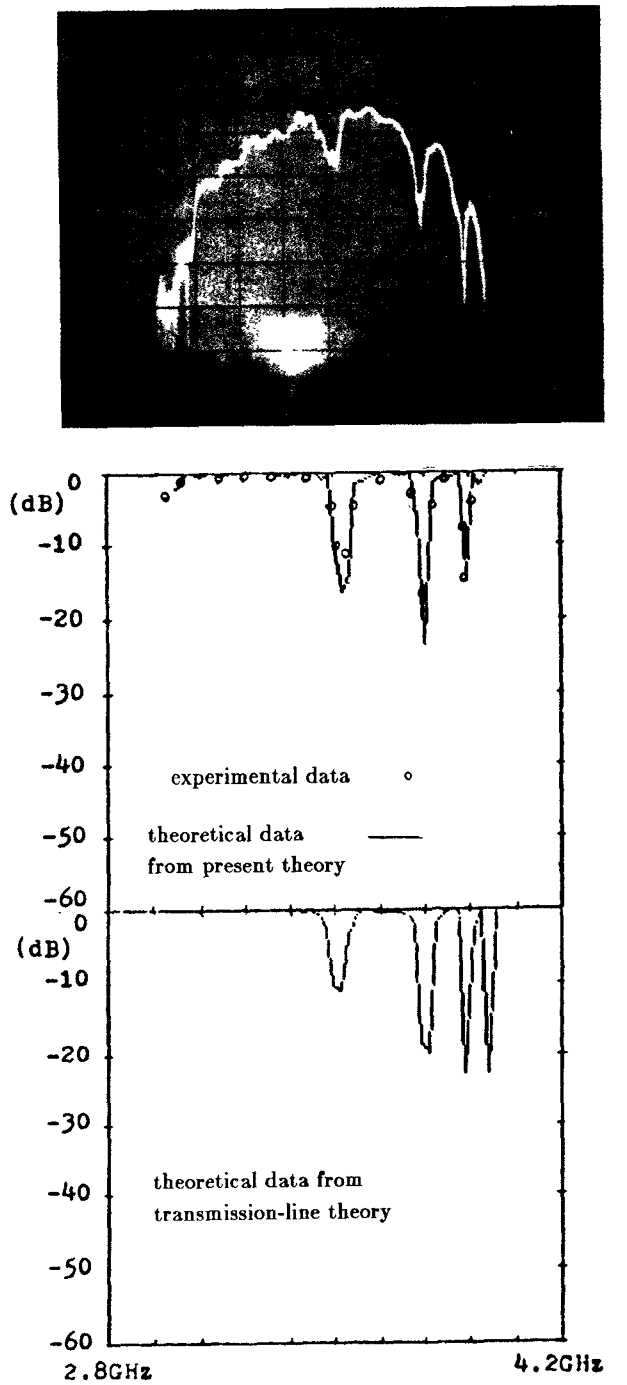

Fig. 2. Insertion loss vs. frequency for reflector grating #2 placed directly on the YIG film: (a) Insertion loss of delay line; (b) experimental insertion loss of the grating alone compared with present theory; (c) theoretical results of the transmission-line theory

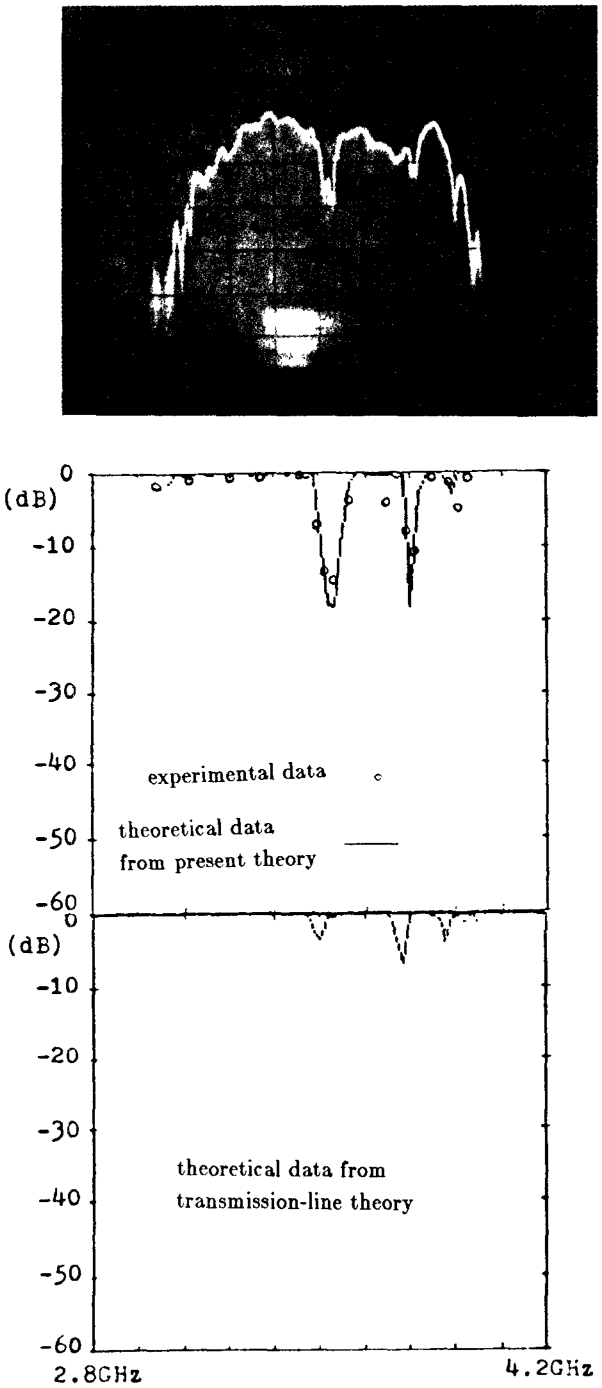

Fig. 3. Same as Fig. 2, i.e., for grating #2, except for placement of grating at a height of 30 um above the YIG film. The three sub-figures have the same meaning as in Fig.2.

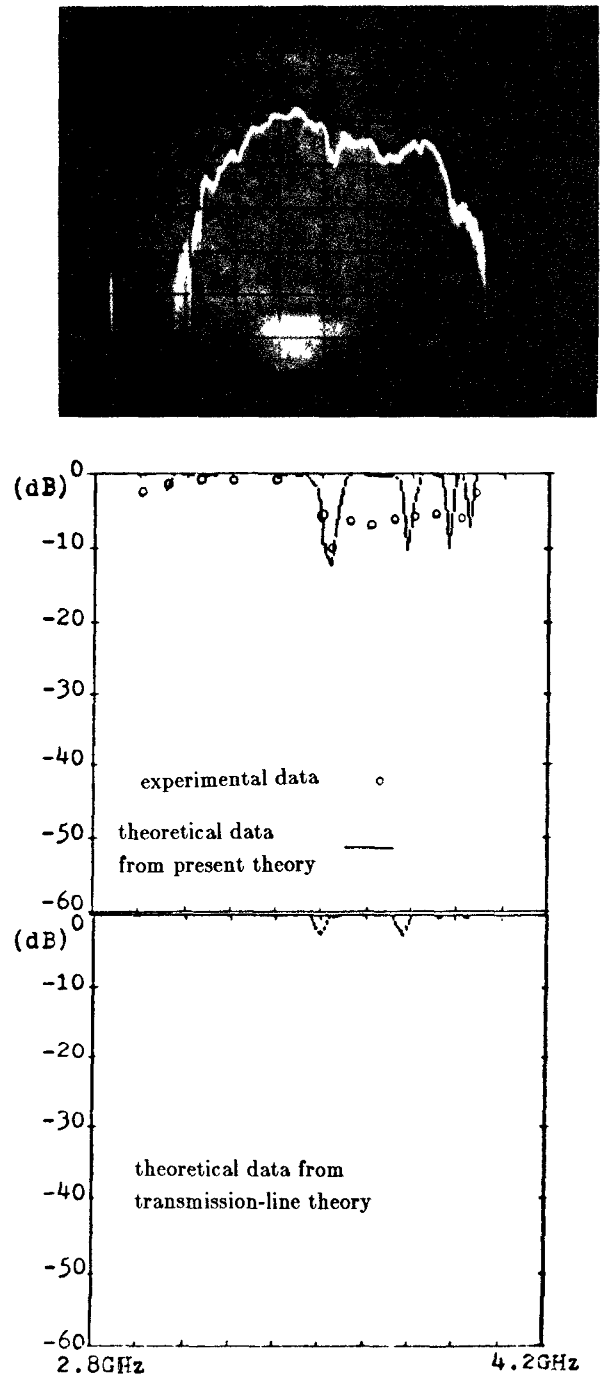

Fig. 4. Insertion loss vs. frequency for reflector grating #1 placed at a height of 30 um above the YIG film. The three sub-figures have the same meaning as in Fig. 2.

Two reflector gratings have been employed in the experiment. Both gratings consist of 10 fingers with a periodicity of 419 um. However, the finger widths are different in the two gratings, being 42 um (the same as the thickness of the YIG film) in one grating (grating #1) and 84 um (twice the thickness of the YIG film) in the other grating (grating #2).

Sample experimental and theoretical data are shown in Figs. 2 through 4. The oscillograms in these figures represent the insertion loss of an MSSW delay line with a metal-finger grating placed between the input and output transducers. The experimental data shown at the middle of these figures represents the insertion loss of the reflector grating *alone* and is obtained by subtracting out the observed insertion loss of the delay line with the reflector grating *removed* from that obtained with the reflector grating *present*. Superimposed on the experimental data are the present theoretical data on the insertion loss of the grating. For comparison, theoretical computations of the insertion loss of the grating employing the simple transmission-line model without storage elements at the junctions are shown at the bottom of the figures.

The results in Figs. 2 and 3 are for grating #2 while the results in Fig. 4 are for grating #1. The results in Fig. 2 correspond to a reflector grating placed directly on the YIG film while the results in Figs. 3 and 4 correspond to a reflector grating placed at a height of 30 um above the YIG film. The mechanical housing assembley employed a window machined at the center to allow for lifting the reflector grating above the YIG film through the use of Mylar strips sandwiched between the YIG film and the grating.

The agreement between experiment and the *present* theory is excellent in Figs. 2 and 3 but relatively poor in Fig. 4. An important observation is that there is a better fit of experimental data with the prediction of the present theory than with that of the transmission line theory. The theory based on transmission line essentially matches with experiment in Fig. 2 but is very much at variance with the experiment in Figs. 3 and 4.

CONCLUSION

The present paper has reported experimental and theoretical results on the scattering of an incident MSSW by a grating of metal fingers of variable finger width and variable grating placement above the YIG film. The theoretical results are in excellent agreement with experiment if one takes into account energy storage at the metal-finger edges and if the width of the metal fingers is larger than the YIG-film thickness. For smaller finger widths, the agreement is relatively poor. Improvement in agreement would require that the theoretical model be improved by incorporating the interaction between the metal-finger edges.

REFERENCES

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