COMPACT GRATING STRUCTURE FOR APPLICATION TO FILTERS AND RESONATORS FOR MONOLITHIC MICROWAVE INTEGRATED CIRCUITS

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Abstract

Possible high-Q circuits based on a new crosstie overlay slow-wave structure are proposed for monolithic microwave integrated circuits. Configurations and results of slow-wave factors are presented. This structure is used for construction of a frequency-selective reflector with a compact size. The effect of loss is considered

I. Introduction

One of the problem of microwave and millimeter-wave integrated circuits is lack of high-Q resonators except for a dielectric resonator. In the monolithic integrated circuit, dielectric resonators are not compatible with the concept of monolithic integration. Microstrip patches provide a relatively low Q. In this study, we investigate a possibility to realize resonator and oscillator, with a physically resonable size, by the use of grating structures formed by a new low-loss slow-wave structure.

It is known that a grating structure exhibits the stop-band phenomenon which can be used as a band-reject filter [1] and as a band pass filter if combined with a coupler [2]. Band reject filter has been used for a Distributed Bragg Reflector Gunn oscillator [3]. The problem of the grating, however, is that its physical length is very long. In this paper, we propose the use of a slow-wave structure to form a printed-line grating so that its physical dimension is more reasonable.

Conventional MIS or Schottky slow-wave structures are fundamentally lossy. Recently, Hasegawa proposed a new crosstie CPW slow-wave structure in which the wave attenuation is due only to the conductor loss [4]. We propose here a crosstie overlay slow-wave structure (Fig. 1) which is a modification of Hasegawa's structure, but is more adaptable for monolithic circuit integration. Fabrication is easier because we deposit a dielectric overlay and crosstie strips after the CPW or microstrip is fabricated on a GaAs substrate. Also, it is possible to combine this new structure with a Schottky slow-wave mechanism by providing a doped layer before the CPW or microstrip is fabricated.

This structure is essentially a grating. However, we do not use this structure as a grating. By choosing the period l_A+l_B sufficiently smaller than the operating wavelength, this structure models a uniform transmission line. From this "uniform" line, we create a grating with its period comparable to the guide wavelength. Hence, the proposed device is a doubly-periodic structure.

The basic operating principle of how the crosstie structure works as a slow-wave line is a spatial separation of electric and magnetic energy. In the section with a crosstie strip, the line capacitance is significantly increased whereas the section with only the dielectric overlay is inductive.

II. Predicted Results of the Slow-Wave Structure

Fig. 2 shows the normalized propagation constants of the constituent sections in the crosstie overlay structure. Curve A corresponds to the Section A (with a crosstie strip) and Curve B is for the Section B. Fig. 3 shows the characteristic impedances of Sections A and B. There exists a significant difference in the characteristic impedance for the two sections, one of which is much more capacitive and the other is more inductive. The data for Fig. 2 and 3 have been calculated by a standard spectral domain method [5].

Fig. 4 shows the dispersion characteristics of the infinitely long crosstie overlay CPW. The information for each constituent section has been used in Floquet's theorem. We then obtain curves in Fig. 4. It is noticed that as the frequency is increased, the curve approaches a very dispersive region which is caused by the stopband phenomenon. The frequency at which such a region appears increases as the period of the grating is reduced. Therefore, if the period is chosen much smaller than the operating wavelength, the corresponding stopband frequency becomes very high. The desired operating frequency should be chosen at a linear portion of the curve much below the stopband so that the structure can be viewed as a uniform transmission line. At the frequency of 20GHZ on the Curve C in Fig. 4, the slow-wave factor (β/β_0) is 11.6.

III. Results of Grating made of New Slow-Wave Structures

As shown in Fig. 5, one period of the grating consists of two crosstie overlay slow-wave CPW's. One of the CPW's consists of Sections A and B of 5 μm long while another is made of 10 μm long sections. After cascading 20 periods of 5 μm structures and 10 periods of 10 μm strctures, we obtain the band-reject grating with its period of 400 μm.

Fig. 6 are the reflection coefficient of the wave incidence into a band-reject grating with 10 periods. The physical length of this grating is 4mm. The center frequency of the stop band is about 28.7 GHZ. In the calculation for Fig. 6, the conductor loss has been neglected.

To study how this wave attenuation affects the grating performance, we evaluated the reflection characteristics of the 4mm grating structure in the presence of conductor loss. Based on the perturbation approach, the attenuation constants have been calculated for every constituent section of the grating. The results have then been used in the calculation of the input impedance of this grating. Fig. 7 are the reflection coefficient of the 4mm grating. Due to the conduction loss, the center frequency of the stop band has shifted from 28.7 GHZ to 28.1 GHZ and the rejection band has been broadened. The peak of the reflection coefficient has been reduced from 0.996 to 0.810. It is well-known that the "sidelobes" can be eliminated if we use a weight taper in the grating.

IV. Conclusions

A new slow-wave grating structure is proposed which has a possibility to be used as band-reject and band-pass filters and resonators. Respectable slow-wave factors and promising bandstop phenomena are obtained. The effect of the conductor loss has been taken into account. This structure can also be used in a frequency-selective Distributed Bragg Reflection (DBR) Gunn Oscillator in a planar circuit form.

Acknowledgment

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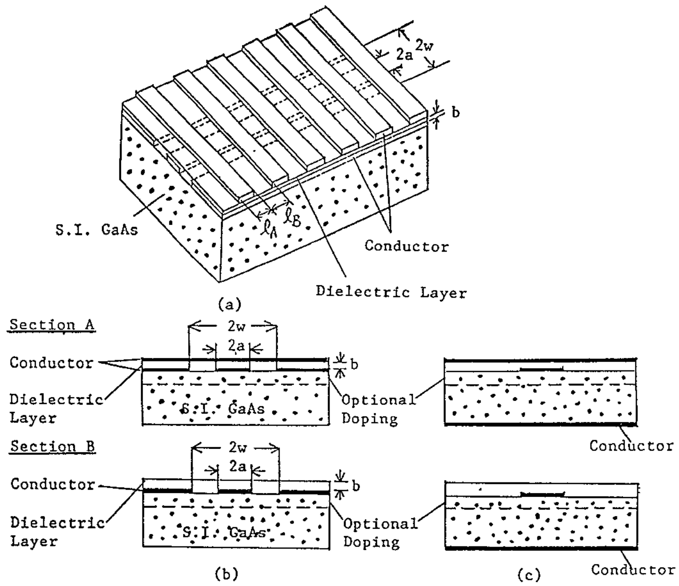

Figure 1. Overlay crosstie CPW and microstrip slow-wave structures. (a) CPW (b) Cross sections of CPW (c) Cross sections of microstrip

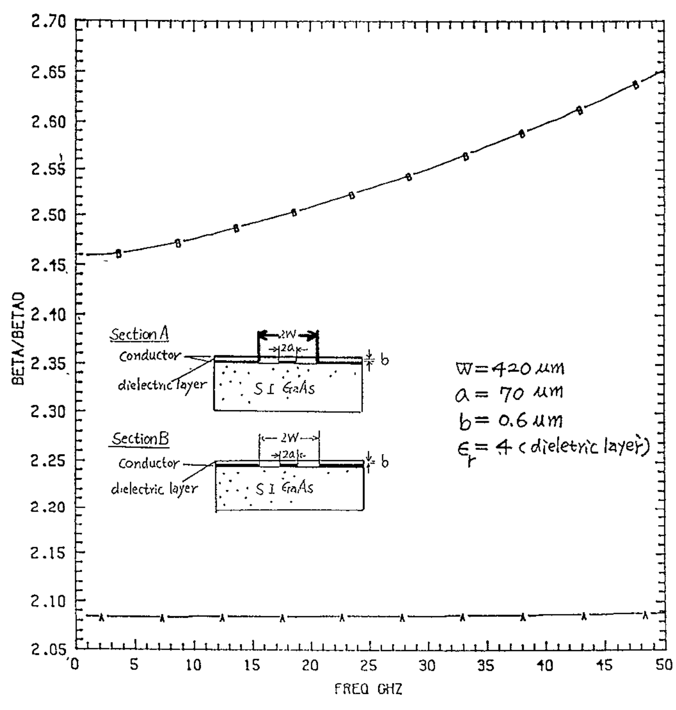

Figure 2. Normalized propagation constant of slow-wave CPW.

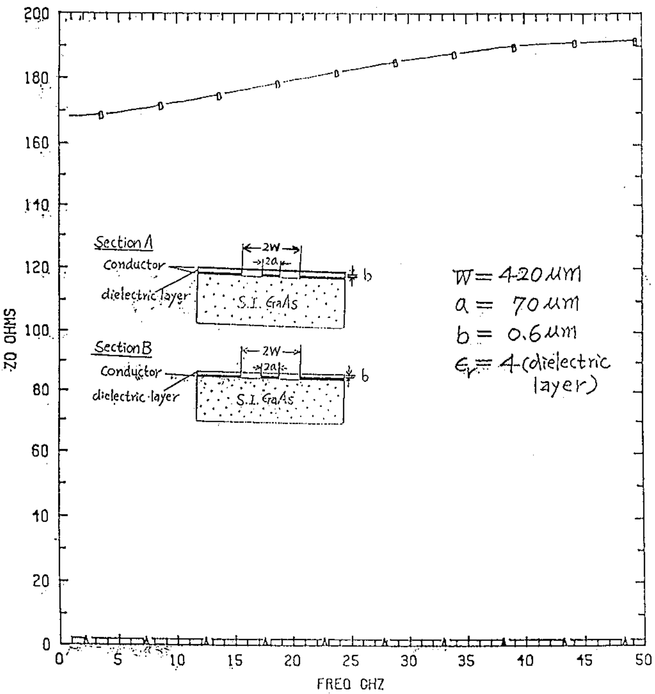

Figure 3. Characteristic impedance of slow-wave CPW.

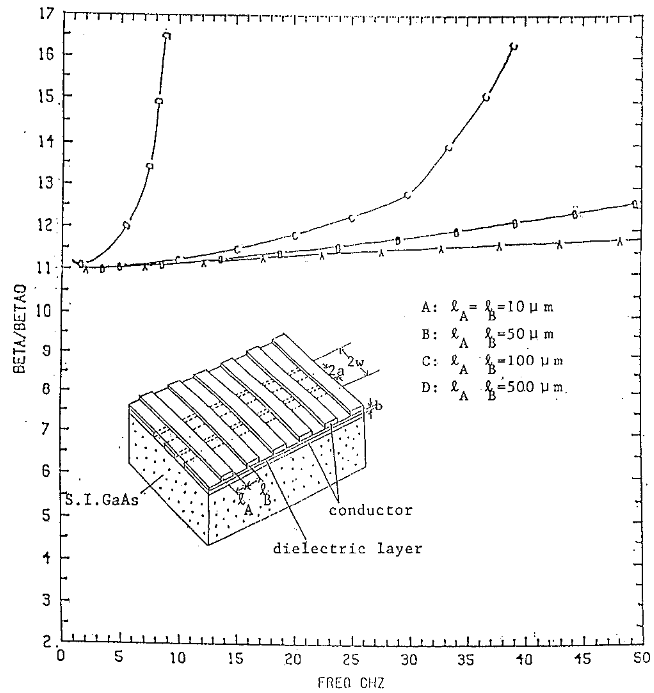

Figure 4. Normalized propagation constant of a periodical slow-wave CPW with different periodicity. a=70 μm w=420 μm, b=0.6 μm, ϵ_r=4 (overlay)

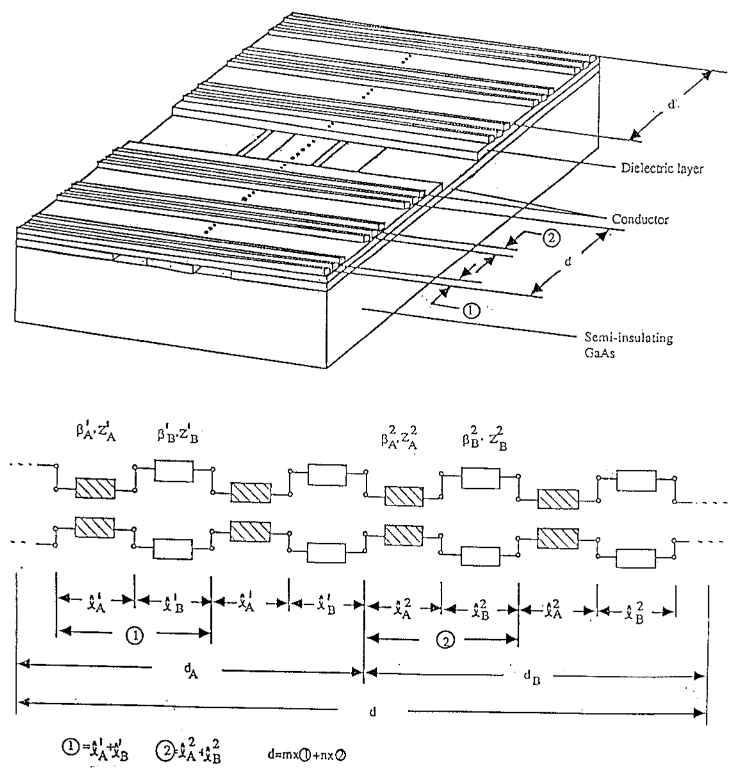

Figure 5. Doubly-periodic grating made of overlay crosstie slow-wave structure.

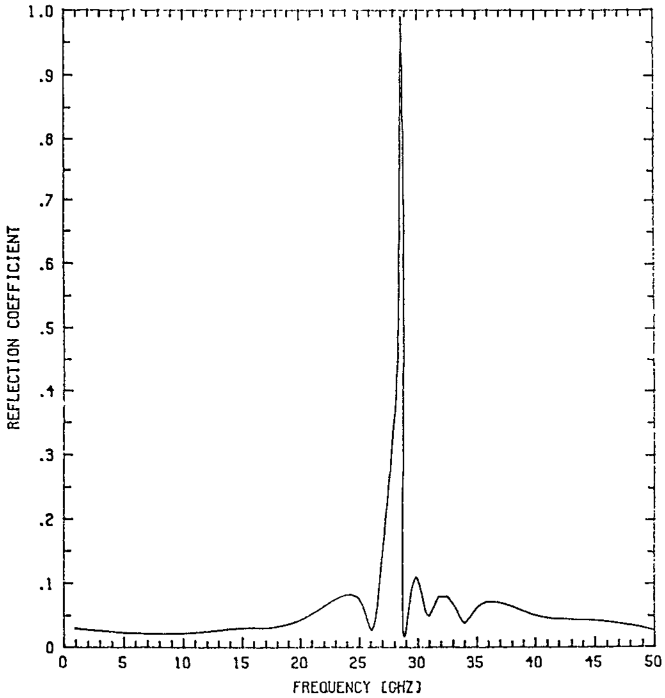

Figure 6. Reflection coefficient of the overlay crosstie slow-wave structure with lossless conductor.

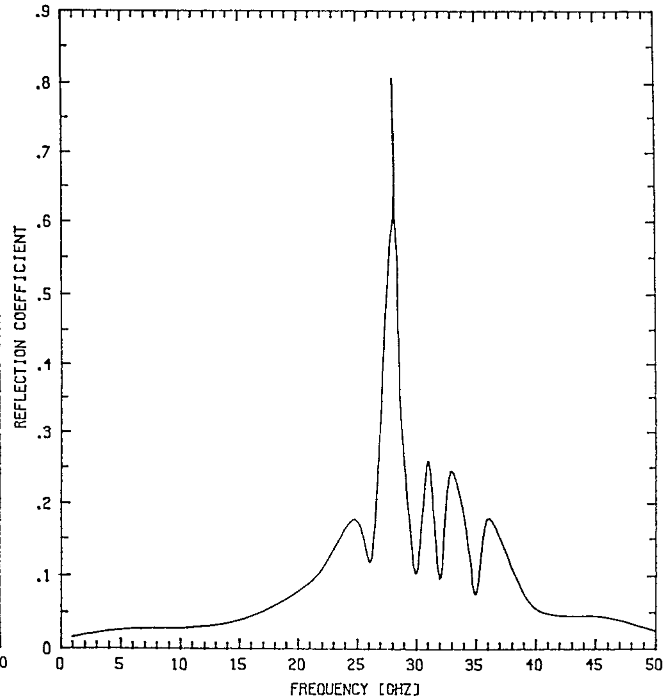

Figure 7. Reflection coefficient of the overlay crosstie slow-wave structure with lossy conductor.