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Electrooptic Sampling Measurement of Dispersion Characteristics of Slot line and Coplanar Waveguide (Coupled Slot Line) Even and Odd modes

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Abstract

The application of the electrooptic sampling technique for the characterization of propagating modes of uniplanar guiding structures on GaAs is described. The characteristics of slot line and even and odd modes of coplanar waveguide on semi-insulating GaAs substrate are investigated. The potential distribution over the cross section of each was measured. Also the guide wavelength for each guide was directly obtained from standing wave measurements by electrooptic sampling and the dispersion characteristics of CPW modes and slot line were measured from 15 to 40 GHZ.

Introduction

The advancement of GaAs technology has made possible the integration of microwave and millimeter wave passive and active devices on a single substrate. Uniplanar transmission lines are defined as having the ground and signal conductors on the same plane, the topside of the substrate. Coplanar waveguide (CPW) [1,2], slot line [3] and coplanar strips (CPS) [2] are the most well-known uniplanar transmission lines. These guiding structures are compatible with MMIC fabrication techniques [4]. The most commonly used MMIC transmission line presently however, is microstrip, a quasi-TEM transmission line that has been extensively studied. The uniplanar transmission lines have significant advantages over microstrip for MMIC applications [4] at millimeter wave frequencies. These advantages include low sensitivity to substrate thickness, low-inductance access to topside ground plane, realization of both series and shunt transmission line stubs, planar shunt connection of devices and novel structures based on CPW-slot line junctions.

Electrooptic sampling, an optical measurement technique, has been used to investigate the properties of passive and active devices on GaAs [5]. Internal node probing of MMIC's with this technique has been demonstrated [6]. The properties of guiding structures can also be investigated by using this technique [7]. This paper reports electrooptic sampling measurements of transverse potential distribution and the dispersion charactersitics of CPW modes and slot line.

Fabrication

The uniplanar guides were fabricated on a 500 micron thick semi-insulating GaAs substrates. The CPW had slot widths of 50 microns and the center conductor width of 75 microns. The slot line had a slot width of 125 microns. The metallization used was sputtered Ti-Au with one micron Au plating on top to reduce the skin depth losses. The substrate had a polished back side to reduce scattering losses of the electrooptic sampling probe beam at the air-dielectric interface.

Transverse potential distribution measurements

By scanning the electrooptic sampling probe on the conductors transverse to the direction of propagation, the potential distribution over the guide cross section is measured. The transverse potential distributions of the CPW and slot line were measured. Fig. 1 shows the cross section and the potential distribution of the odd mode of the CPW. In the odd mode the signal is applied to the center conductor and the outer conductors are at ground potential as indicated by the data. The cross section and transverse potential of slot line is shown in Fig. 2. In the slot line the difference in the potential amplitude on the two conductors is due to the presence of unbalanced modes. These undesired modes are excited by the imperfect launching of the signal from the Cascade probe. The standing wave measurements of the slot line, described in the next section, verified the presence of these parasitic modes.

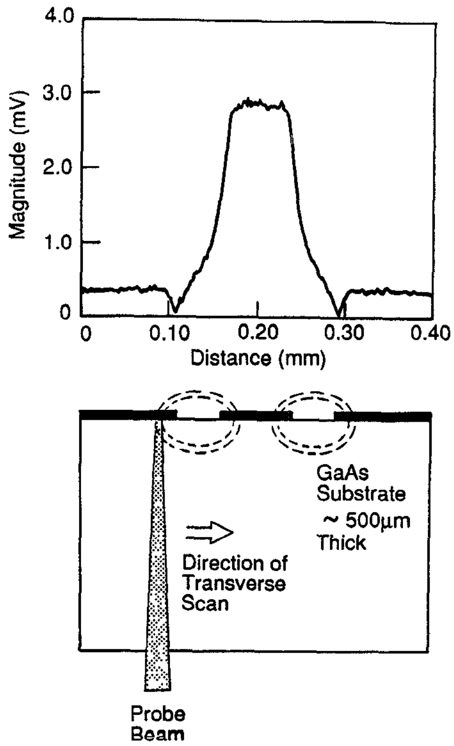

Fig. 1: Transverse potential distribution of CPW odd mode.

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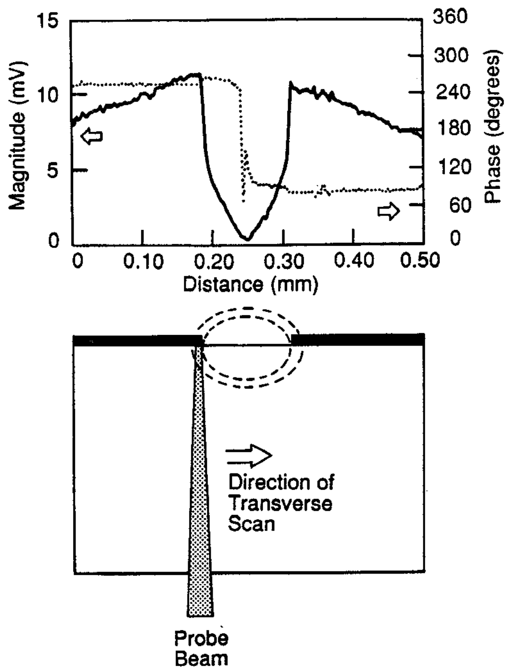

Fig. 2: Transverse potential distribution of slot line.

Standing wave measurements

Measurement of standing waves on uniplanar guides were obtained by scanning the probe along the direction of propagation. In this paper the terms CPW and coupled slot line are used interchangeably, referring to the same physical structure. The CPW mode, which is the same as the odd mode of the coupled slot line, has the electric fields of opposing polarity in the two slots. The even mode of the coupled slot line, has the electric fields of the same polarity in the two slots. When the CPW mode is used, the even mode is suppressed by shorting the two outer conductors with an air bridge.

The uniplanar guides were tested using a Cascade probe station modified for electrooptic sampling. Fig. 3 shows the magnitude and phase of the odd mode voltage standing wave on the center conductor at 18.464 GHZ. The odd mode guide wavelength measured is 6.1 ± .03 mm corresponding to a value of 2.62 ± .01 for the ratio of the free space to guide wavelength. A quasi-TEM approximate analysis [1] of the odd mode gives a zero order value of 2.598 for this ratio. The calculated ratio of the same quantity from Gupta's expression [8] is 2.592. The worst case difference between the measurement and the theoretical value for the odd mode guide wavelength is therefore less than 1 %.

Even mode measurement results at 18.464 GHZ are shown in Fig. 4. The measured even mode guide wavelength is 7.0 ± .03 corresponding to a free space to guide wavelength ratio of 2.32 ± .01. The wave propagation in this mode is not significantly affected by the presence of the center conductor between the two coupled slots when the center conductor width S is small compared to the substrate thickness. Coupled slots can therefore be approximated by a single slot line of width (2W+S), where W is the width of a single slot [8]. According to Gupta [8] the free space to guide wavelength ratio for a 175 microns wide slot line is 2.324, within 1 % of the measured value. The slot line standing wave at 40 GHZ is shown in Fig. 5. The measured guide wavelength was 2.90 ± .03 mm. The theoretical value from Mariani [8] is 2.87 mm. The difference between the theoretical and measured results was less than 3%.

In the standing waves measured on the slot line, the amplitudes of the minima are not equal to zero and there are also variations in the amplitudes of the maxima and minima. The cause of these is the presence of the undesired propagating unbalanced modes in addition to the fundamental balanced mode of each of the guides under investigation, as described in the preceding section. The guide wavelengths for these modes are different from the guide wavelength of the fundamental mode. Therefore the interference of these parasitic modes and the balanced mode results in the change in the amplitudes of the maxima and minima of the standing waves as a function of distance along the direction of propagation.

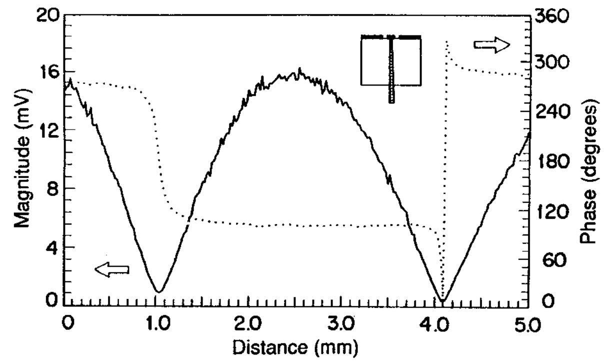

Fig. 3: Magnitude and phase of the CPW odd mode 18.464 GHZ standing wave.

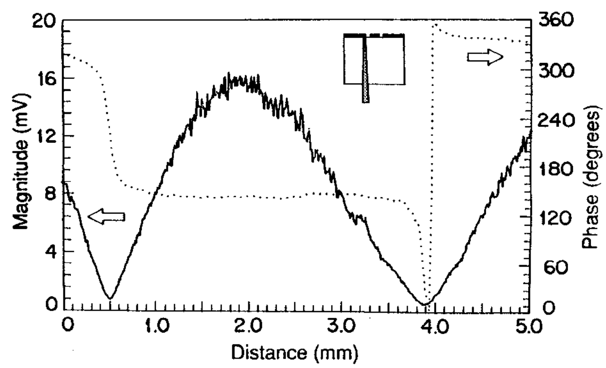

Fig. 4: Magnitude and phase of the CPW even mode 18.464 GHZ standing wave.

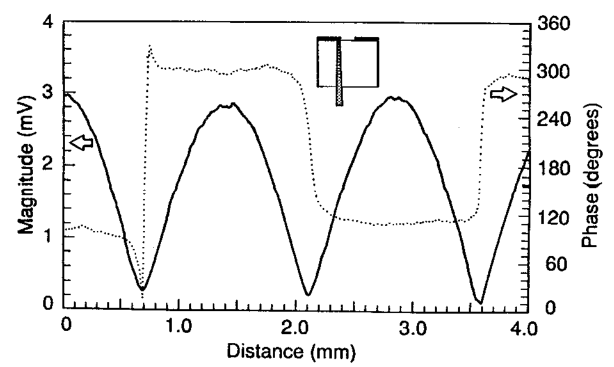

Fig. 5: Magnitude and phase of the slot line 40 GHZstanding wave.

Dispersion characteristics measurements

The guide wavelength of a 50 ohm CPW was measured from 15 to 40 GHz in a single mode operation of the CPW, under odd and even mode excitations. The odd mode was excited by applying the signal to the center conductor and grounding the outer conductors. Figure 6 shows the odd mode measurement results. The same CPW was then excited in the even mode by applying two signals of equal amplitude and opposite phase to the outer conductors and grounding the center conductor. Even mode results are shown in Fig. 7. Fig. 8 shows the ratio of the free space wavelength to guide wavelength versus frequency for the even and odd modes of CPW. The dispersion of the odd mode is significantly less than the even mode as indicated by the results. The standing wave measurements were repeated on the slot line. The dispersion characteristics are shown in Fig. 9. Since the cutoff frequency of the lowest order quasi-slab mode is 45 GHz, coupling to parasitic slab modes can be ignored in all three cases.

Conclusion

The electrooptic sampling technique was used to measure the propagation characteristics of uniplanar guides on GaAs. The transverse potential distribution and standing waves of CPW modes and slot line were measured. The dispersion characteristics of CPW odd and even modes and slot line from 15 to 40 GHZ were also measured. These characteristics are important in designing uniplanar MMIC circuits. Electrooptic sampling may also be used to investigate other characteristics, such as characteristic impedances, of the uniplanar guides on semi-insulating GaAs substrate.

Acknowledgements

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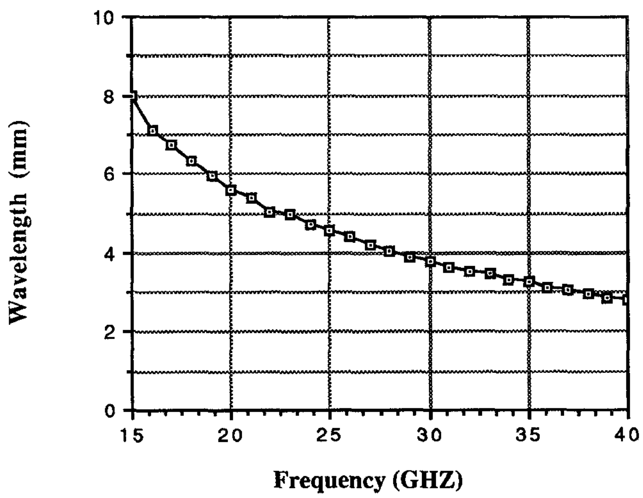

Fig. 6: CPW odd mode 15-40 GHZ dispersion characteristics.

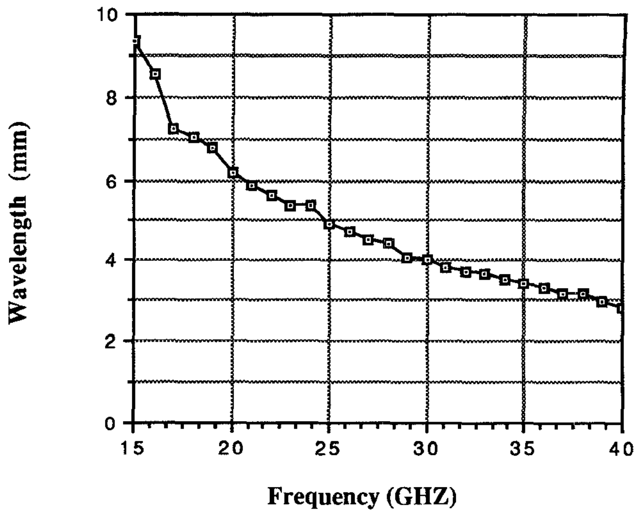

Fig. 7: CPW even mode 15-40 GHZ dispersion characteristics.

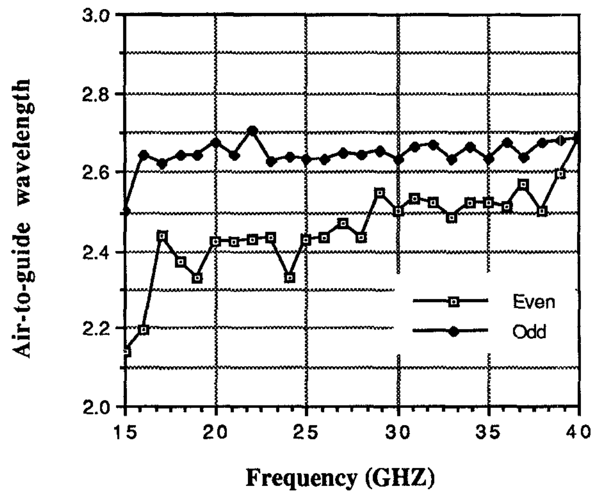

Fig. 8: Comparison of CPW odd and even modes dispersion characteristics.

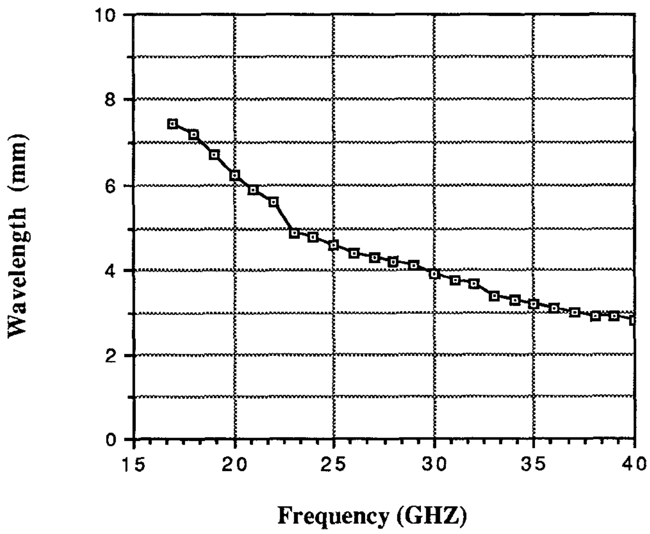

Fig. 9: Slot line 15-40 GHZ dispersion characteristics.

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