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THEORETICAL AND EXPERIMENTAL STUDY OF LOW-LOSS, HIGH EFFICIENCY MONOLITHIC ANTENNA STRUCTURES AT 94 GHZ

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PROGRESS REPORT

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7. LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO SPONSORSHIP DURING THIS REPORTING PERIOD, INCLUDING JOURNAL REFERENCES:

(a) Linda P.B. Katehi, "Novel Transmission Lines for the Submillimeter-Wave Region," submitted for publication in the IEEE Proceedings.

(b) A.G. Engel and Linda P.B. Katehi, "On the Analysis of a Transition to a Layered Ridged Dielectric Waveguide," submitted for presentation in the 1992 IEEE MTT-S International Symposium in Albuquerque, New Mexico, June 1992.

(c) T.E. van Deventer and P.B. Katehi, "A Study of Sub-Millimeter Wave Coupled Dielectric Waveguides Using the GIE Method," submitted for presentation in the 1992 IEEE MTT-S International Symposium in Albuquerque, New Mexico, June 1992.

(d) Kazem Sabetfakhri and Linda P.B. Katehi, "A Study of Open Dielectric Waveguides Using the Generalized Integral Equation Method," submitted for presentation in the 1992 International Radio Science Meeting in Chicago, Illinois, July 1992.

(e) Curtis C. Ling and Gabriel M. Rebeiz, "94 GHz Integrated Horn Monopulse Antennas," submitted for presentation in the IEEE Trans. on Antennas and Propagation.

(f) Curtis C. Ling and Gabriel M. Rebeiz, "Advances in 94 GHz Integrated Horn Monopulse Antennas," submitted for presentation in the 1992 IEEE AP-S International Symposium in Chicago, Illinois, July 1992.

(g) Daniel F. Filipovic and Gabriel M. Rebeiz, "An Azimuthal Omni-Directional Array for Multi-Target Acquisition and Tracking," submitted for presentation in the 1992 IEEE AP-S International Symposium in Chicago, Illinois, July 1992.

8. SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD:

Graduate Students	Faculty
Kazem Sabetfakhri	Linda P.B. Katehi
Curtis C. Ling	Gabriel M. Rebeiz

9. BRIEF OUTLINE OF RESEARCH FINDINGS

During the reporting period our effort concentrated in two specific applications: (a) The development of a 94 GHz Monolithic Array with a very low-loss dielectric feeding network and (b) the development of a 94 GHz Monolithic Monopulse Antenna. The progress of our study in each one of these projects is discussed briefly below:

(a) 94 GHz Low-loss Monolithic Array. The goals of this study is to develop a monolithic array operating at 94 GHz which is fed by a dielectric network exhibiting low-losses. The most critical part of this effort is the successful development of the feeding network. Towards achieving this goal we have accomplished the following:

(i) We have accurately characterized the propagation characteristics of two-dimensional dielectric waveguides using a variety of dielectric films and semiconducting materials. The theoretical analysis predicted very low-loss propagation and wide single-mode frequency range.

(ii) The theoretical analysis has been extended to characterizing appropriate transitions from conventional monolithic lines to the dielectric lines under development.
Specifically, we have concentrated on the design of a microstrip to a dielectric-ridge waveguide transition as we believe that this is a very critical element for the fabrication of the above low-loss Monolithic Array.

(iii) In parallel with the theoretical study discussed above we have been able to fabricate low-loss dielectric-ridge waveguides and measure their attenuation and phase constant at lower frequencies using scaled models.
Furthermore, we have fabricated and measured a transition from a ridge microstrip to a dielectric waveguide. Even if, the de-embedding and calibration have not been completed yet, the preliminary experiments have given very encouraging results.
We expect our first repeatable measurements to be completed and results to be reported towards the end of the next reporting period.

(b) 94 GHz Monolithic Monopulse Antenna. First, we have developed a monolithic monopulse antenna at 94 GHz for tracking applications. The antenna consist of two sets of dipoles, the sum channel and the difference channel, in an etched pyramidal cavity in silicon. The isolation between the two channels was measured at microwave frequencies and was better than -25dB over a 10% bandwidth. The monopulse antenna was subsequently integrated with bolometer detectors and the measured patterns at 90-94 GHz show a -30dB at broadside for the difference antenna.

In order to improve the gain, a machined horn extension has been added to the integrated structure. This extension increases the effective aperture of the sum and difference antennas and thereby increases the gain. Furthermore, a novel design was used with the difference antenna that allowed us to hybridly bond a planar beam-lead diode without affecting the symmetry of the structure. Again, the measured results at 88-94 GHz are excellent with a -25dB difference null and a 20dB and 18.5dB gain for the sum and difference antennas, respectively. Currently, we are working on building a 22.5 GHz local oscillator network for subharmonic mixing applications.

In another project, we have investigated a novel technique for multi-target acquisition and tracking.The design can operate over a wide frequency range and can resolve a large number of targets.The technique only requires the amplitude and not the phase of the signals. A computer program was written to simulate the operation of the array, and the results indicate that the array can resolve multiple targets even under a low S/N ratio (10dB).

Novel Transmission Lines for the Submillimeter-Wave Region

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Abstract

Technology based on the sub-millimeter wave range offers narrow-beam, high-resolution antennas which are essential for intelligent computer control guidance, command systems for space applications, and sensors operating in an optically opaque environment. There are two typical approaches for the design of low-loss transmission lines. The first approach attempts an extension of the millimeter-wave monolithic technology to higher frequencies. In this manner, planar conductors are used extensively for the guidance of the waves but with important structural modifications in their supporting dielectric material in order to avoid excessive loss of power in the form of radiation. This approach has resulted in the successful development of low-loss planar and non-planar lines but is limited to the lower end of the sub-mm-wave spectrum (up tp 500 GHz) due to ohmic losses and fabrication tolerances. The second approach extends optical techniques to lower frequencies and has resulted in low-loss, quasi-planar lines made exclusively of intrinsic semiconducting materials combined in an appropriate way. Due to the present status of the fabrication processes, this second approach is limited to the higher end of the sub-mm-wave spectrum.

Since the sub-mm-wave region is rather unexploited, the development of the above referenced lines is still in its infancy. However, a detailed presentation of the available information on their electrical properties is given. Furthermore, these lines are compared to more conventional monolithic lines, such as microstrip, in terms of performance, fabrication feasibility and availability. There are three types of novel monolithic waveguides which have shown promise for use in the submillimeter frequency range: monolithic dielectric guides, microshield lines, and lens-supported coplanar waveguides. The advantages as well as disadvantages associated with the use of these guides are discussed extensively.

Submitted to the IEEE Proceedings

On the Analysis of a Transition to a Layered Ridged Dielectric Waveguide

Submitted to the
1992 IEEE MTT-S International Microwave Symposium

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Abstract — In sub-mm and THz monolithic circuits, transitions between layered ridged dielectric waveguides and power sources may include short lengths of conductor. An integral equation-mode matching technique is expanded so that such a transition may be analyzed, and results for one-port discontinuities in microstrip on a dielectric ridge and preliminary characterization of an actual transition are presented.

A STUDY OF SUB-MILLIMETER WAVE COUPLED DIELECTRIC WAVEGUIDES USING THE GIE METHOD

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Abstract-

In this paper the coupling properties of coupled dielectric waveguides are e· uated using a novel and powerful method which relies on the concept of equival planar polarization dipole moments to simulate the guides. Generalized impedance boundary conditions are enforced to provide a simple planar integral equation (Generalized Integral Equation). This method can account for multiple dielectric strips on different levels. Phase constants of the different modes and coupling characteristics are calculated for several structures, such as rib waveguides and insulated image guides.

A Study of Open Dielectric Waveguide Problems Using The Generalized Integral Equation Method

by

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Abstract

Theoretical studies on geometrically simple optical and microwave dielectric waveguides have been presented in the past decade using approximate or numerical methods. The approximate methods are represented by an analytical approximation introduced by marcatili and by the effective index method. The numerical methods are divided into variational methods, mode matching methods, finite element methods and integral equation methods using volume polarization currents. These methods have been exclusively applied to two-dimensional problems with most of the existing techniques performing a fine discretization of the cross section. Such discretization introduces many unknowns and strong numerical instabilities. Consequently, an extension of these methods to three-dimensional problems faces many practical limitations and requires special care.

This paper presents a novel formulation which can be applied to two- and three-dimensional open dielectric waveguide problems. This powerful method transforms complex problems to simplified equivalent planar ones which are then solved using known planar integral equation techniques. At first, the electric field in the dielectric waveguide is expressed in terms of a volume polarization dipole moment from which a planar polarization dipole moment is defined. Further, generalized boundary conditions on the surface of the dielectric waveguide are enforced to make the introduced planar dipole moment equivalent to the original volume polarization dipole moment. In this manner, a simplified planar integral equation is derived which is then solved in the spectral domain to provide very satisfactory results. In this presentation, for the sake of simplicity, the above formulation will be applied to a variety of infinite as well as finite dielectric slab waveguides and the merits and numerical attributes of the technique will be extensively discussed.

Acknowledgements

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AN AZIMUTHAL OMNI-DIRECTIONAL ARRAY FOR MULTI-TARGET ACQUISITION AND TRACKING

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ABSTRACT

This paper presents a novel technique for multi-target acquisition and tracking. The target localization technique requires only the amplitude signal of each antenna, and not the phase. The proposed design can operate over a wide frequency range (20-100GHz). The array can resolve a large number of targets accurately, is lightweight, and relatively small (2 feet in diameter or less). The array has no moving parts, and no expensive RF electronics such as phase shifters and power combiners are needed. The design can be extended to hemispherical arrays for omni-directional half-plane coverage.

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Advances in 94GHz Integrated Horn Monopulse Antennas

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I. INTRODUCTION

Recent progress in integrated 94GHz monopulse antennas presented in the APS-91 Conference is discussed [1]. The structure consists of a single dipole suspended in one plane of an integrated horn cavity to obtain the sum pattern, and an anti-parallel pair of dipoles suspended in a different plane of the same horn cavity to achieve the difference pattern (Fig. 1). The sum and difference antennas are located 0.39λ and 0.79λ from the apex, and couple to the TE_{10} and TE_{20} modes of the horn cavity, respectively [2]. Detectors are integrated or hybrid mounted at the apex of the sum antenna, and for the difference antenna, in the center of the transmission line structure between the dual dipoles. Advances made beyond previous work include attaching a machined extension with a step discontinuity to the mouth of the integrated portion of the horn. This extension increases the gain from 12dB to 20dB by introducing a discontinuity in the flare angle of the horn. The theoretical analysis is presented in [3]. In addition, the difference antenna has been modified to accommodate the hybrid mounting of a beam-lead Schottky diode. Pattern measurements at millimeter-wave frequencies show good agreement with theory and exhibit a sharp null below -26dB at broadside for the difference antenna. The construction of the integrated portion of the monopulse system is achieved using photolithographic techniques identical to those used in the production of conventional integrated circuits [4].

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94GHz Integrated Horn Monopulse Antennas

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ABSTRACT

A monolithic azimuthal monopulse antenna for 94GHz applications has been developed. The structure consists of a single dipole suspended in one plane of an integrated horn cavity to obtain the sum pattern, and an anti-parallel pair of dipoles suspended in a different plane of the same horn cavity to achieve the difference pattern. Pattern measurements of microwave models and on the millimeter-wave antennas show good agreement with theory and exhibit symmetry with a sharp -30dB null at broadside for the difference antenna. Microwave model measurements show input impedances close to 50Ω, with greater than -25dB isolation between sum and difference antennas across a 10% bandwidth.