OPTIMIZING AN ELECTROMAGNETIC FIELD SENSOR FOR MICROWAVE AMPLITUDE AND PHASE DETECTION VIA FIBER OPTIC TRANSMISSION LINK

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Abstract

A study of amplitude and phase detection using an electromagnetic field sensor is presented. A time varying magnetic field probe modulates a high frequency semiconductor GaAlAs laser diode (λ = 840nm). The laser light is then transmitted via a fiber optic transmission line, minimizing the electromagnetic field perturbations,and is detected using an P-I-N photodiode. The frequency band is limited in this study to 2.0 -3.0 GHz.

Introduction

The design and construction of an electromagnetic (EM) field sensor was pursued so that an empirical correlation could be made between infrared (IR) obtained field distributions and a classic detection method such as a time varying magnetic field probe (1,2,3). At the University of Colorado at Colorado Springs, research is progressing toward the development of a microwave field detection technique by observing the radiated IR produced in thin coating materials (4). These coatings can be placed near an object surface for an indication of currents induced by the microwave field or placed away from the target object and combined with a reference beam to investigate amplitude, phase and direction of the scattered EM wave. The extent to which the coating material, which is used as a transducer for the electric and magnetic field components, is perturbing the quantity of interest required another measurement technique (5). A magnetic field probe was therefore investigated to provide this needed data both on the surface and in the scattered field of a complex geometry illuminated by an EM wave.

Current methods in the measurement of microwave radiation primarily utilize conducting cables to transmit information from the probe to recording equipment. These cables can result in perturbing the local field thus preventing reliable measurements. This is especially significant when attempting to determine the phase information of the field. A second problem in using conducting cables is that the cable may itself act as a receiving medium providing unwanted field components. To determine the phase component of the electromagnetic field and to resolve the problems associated with using conducting cables, an electro-optic measurement technique is considered. This report is the result of studies conducted in optimizing an electromagnetic field sensor for microwave amplitude and phase detection via a fiber optic transmission link. In this study the main area considered is the transducing of an electromagnetic signal into an electro-optical form.

Experimental Approach

The final sensor is to be radiated by a microwave source (2.0-3.0GHz) in the free field and with canonical shapes present in the field. The field detection loop senses the time varying magnetic field through a Faraday's Law interaction. This small signal supplies a current to the gate junction of a GaAs FET. The GaAs FET is biased by a power source and its output signal triggers a laser diode. The output of the laser diode is then transmitted via a fiber optic cable to a P-I-N photodiode. The laser diode, GaAs FET, and photodiode are chosen to optimize performance for a given experimental environment. The fiber optic cable considered is the single mode type to optimize signal reconstruction. The computer simulations and experimental results are encouraging but only preliminary at this time.

Sensor Design

The probe and transducer are shown below in Figure 1:

1) EM Field Detection Loop
2) Power Source
3) GaAs FET
4) Laser Diode

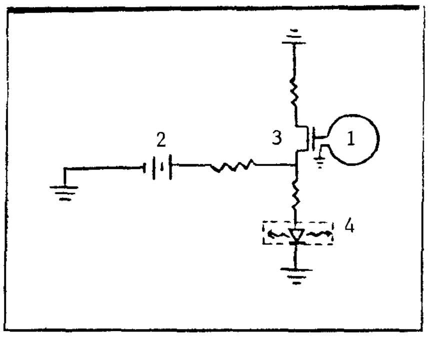

Figure 1 Sensor Design with Battery

The power source is a 3 volt battery which provides a voltage bias for the GaAs FET as was stated earlier. In the second phase of this effort, the battery will be replaced by a multiple turn loop and voltage regulator circuit as seen in figure 2. The electro-optic transducer consists of a GaAs FET and

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an GaAlAs double heterostructure laser diode which has very good modulation frequency efficiency up to 3.0GHz. The GaAs FET was selected to provide a summing of the biasing voltage and the signal from the detection loop to activate the laser diode.

1. Power Loop
2. Voltage Regulator
3. Schottky Barrier Diode

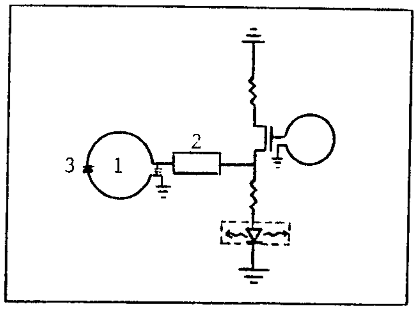

Figure 2 Sensor Design with Power Loop

Experimental Results

In modeling this sensor, the response of the detection loop was first determined. Figure 3 gives the current in the loop versus the magnetic field density.

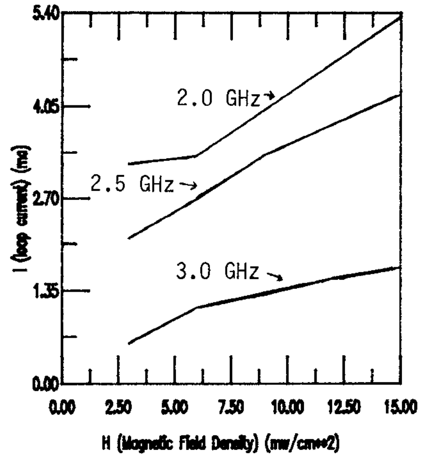

Figure 3 Detection Loop Response

Knowing the magnitude of the current from the loop a microwave circuit model was then developed using a Fujitsu FSC11 GaAs FET with minimum noise figure of less than 1dB from 2-4 GHz and a LED in place of the laser diode for feasibility testing. The Ortel high frequency semiconductor GaAlAs laser diode input parameters were used for circuit design and testing. Over-voltage protection will be installed in the final sensor circuit. The output of this device, through a fiber optic link, will be detected using the Ortel Model PD050-0M GaAlAs/GaAs PIN Photodiode. Several biasing circuits were examined to obtain the desired drain voltage and current with the GaAs FET being self-biased. The objective being to superimpose the input loop signal without excessive distortion and driving a laser diode. In the preliminary findings, as the loop current increased the current to the LED increased after MESFET amplification. A linear correlation was found experimentally between loop current and current through the LED. Further biasing circuit modifications to achieve optimum signal amplification are in progress.

Conclusions

Presently, the sensor design incorporates a battery which is a source of field perturbations in some applications when the battery is not shielded. The second phase of the sensor development should minimize this problem with the incident field supplying the bias voltage through an integrated power loop. The initial objective in the sensor design is for precise phase measurements to support IR research. However, applications of an EM field probe capable of amplitude and phase detection through a fiber optic transmission line would be invaluable in the study of many complex geometries of interest.

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