An Investigation of the Channel Crosstalk in Optical Heterodyne Controlled Phased Array Radars

The principal objective of this project is to investigate problems associated with achieving the drive/read-out system complexity necessary to control a phased array antenna with optical heterodyne techniques. In particular, this work has concentrated on multi-channel microwave optical conversion. The approach has been to study the problems associated with device arrays of single sideband modulators that would be necessary to control the amplitudes and phases of all signals delivered to a phased array front end. The incorporation of our available in-house developed tools into that of already existing tools (such as MDS-Microwave Design Software) has been undertaken to design a single sideband modulator (SSBM). It was found that MESFET oscillators and the associated control lasers can be modeled by simply changing a constant in the model to give their characteristics with and without optical injection. This is useful for injection locking of active antennas for accurate and efficient phased array antenna design.
FINAL PROGRESS REPORT
for Office of Naval Research
for the period August 1992 through January 1995

1. **Contract Title:**  
An Investigation of the Channel Crosstalk in Optical Heterodyne Controlled Phased Array Radars

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2. **Technical Objectives:**  
The principal objective of this project is to investigate problems associated with achieving the drive/read-out system complexity necessary to control a phased array antenna with optical heterodyne techniques. In particular, this work concentrated on multi-channel microwave optical conversion.

3. **Approach:**  
The approach has been to study the problems associated with device arrays of single sideband modulators that would be necessary to control the amplitudes and phases of all signals delivered to a phased array front end. Our approach has also focused on increasing the complexity of control by modulating only a small number of optical channels which can then be locked to a previously locked active antenna array. This approach has enabled a better understanding of the accuracy and validity of our computer aided analysis and also has allowed a greater range of device complexity to be analyzed.

4. **Accomplishments:**  
The development of "ZOOM," a computer-aided electromagnetic analysis technique, was extended to allow analysis of more complicated electrode geometries. A greens function for electrodes on multiple dielectric layers was derived and incorporated into the program. This allows accurate modeling of realistic optical devices. Additionally, the incorporation of our available in-house developed tools into that of already existing tools (such as MDS-Microwave Design Software) has been undertaken to design a single side-band modulator (SSBM).

Potential distributions of an active antenna array (composed of a 5X5 array of oscillating field effect transistors) given by optical sampling measurements agree with theoretical calculations. These results show that the stability of the active device is determined by the near field radiation and electrode geometry within a period of an elementary cell. Additionally, it was found that the bias lines of the active array provide both the dc bias to the active device and provides a coplanar structure that supports a radiation mode.

The optical to microwave modulation transfer function has been derived for an optically injected FET (field effect transistor). The transfer function can then give the characteristics of the optically injected microwave MESFET oscillator circuit. The model can vary the injected
power level and the amount of phase detuning between the injected signal and the free running oscillation making it possible to accurately model microwave control by optical means.

5. **Significance:**
The significance of these accomplishments are threefold. First, the CAD tools for microwave devices has been a hierarchical one, much as hierarchical tools are the ones in use in the digital and microwave circuit design areas. Here, we have used MDS CAD for the design of the higher level simulations in the design of a SSBN. Secondly, the geometry of an active antenna plays an important role in its feasibility as an effective control for complicated drive/read-out phased array system. This will enable an efficient antenna array to be constructed. Electromagnetic analyses of a realistic stacked multilayer dielectric and its associated electrode structure makes it possible to design and model the required complexity needed for multi-channel microwave optical conversion. Finally, it was found that MESFET oscillators and the associated control lasers can be modeled by simply changing a constant in the model to give their characteristics with and without optical injection.

6. **Future Efforts:**
Future work involves trying to physically understand locked array results while simultaneously trying to modify exisiting software to accurately analyze optically addressed antenna elements.

7. **Publications and Presentations Partially Supported Under This Grant June 1, 1994 through February 28, 1995**

S. L. Kwiatkowski and A. R. Mickelson, "Perturbations on Effective Index of Refraction from Prism Coupling," submitted to *Appl Optics*.


A. R. Mickelson, "Rare Earth Doped Polymers," International Union of Radio Science, Boulder (CO), (Jan. 3-6, 1995).


**Theses During Project:**

L. Rohlev, Ph.D., "Characterization of Optical Polymers for Multilayered Electrooptic Devices."

S. Genco, Ph.D., "Characterization of Microwave MESFET Circuits under Laser Illumination: Applications to Phased Array Radar, Microwave Communications, and Digital Clock Control."

K. Chen, Ph.D., "Active Antennas with Periodic Structures."

8. **Participants:**
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