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Monthly Progress Report 5

INVESTIGATION OF SOLID STATE TRAVELING-WAVE AMPLIFIER TECHNIQUES FOR FUTURE SATELLITE APPLICATIONS

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I. OBJECTIVE

The objective of this program is to carry out investigations of solid state traveling-wave amplifier techniques, with emphasis on those problem areas critical to the future use of these techniques in satellite applications. Particular tasks include development of improved transducers, elimination of spurious oscillations, evaluations and selection of optimum semiconductor materials, and investigation and evaluation of properties of the solid state traveling-wave amplifier process. An ultimate objective is a conclusive over-all evaluation of the solid state traveling-wave amplifier as a device to perform as a conventional traveling-wave amplifier with the unique advantages of the solid state. These key potential advantages important to satellite applications include inherent simplicity, ultra lightweight, unusually small size, broad bandwidth characteristics, long life, radiation resistance, and high reliability under the arduous space environment from launch through orbit.

II. PROGRAM PLAN

The objectives of this program are to be achieved by performing the following coordinated set of tasks:

TASK 1: Developing Improved Transducers

This phase involves study, fabrication and evaluation of materials and processes for improved microwave-frequency acoustic-wave transducers. Major emphasis will be placed on developing ferromagnetic and piezoelectric thin-film transducers and associated thin-film impedance matching layers. This topic will be investigated in considerable depth since the development of improved transducers is critical to subsequent phases of the investigation.

TASK 2: Eliminating Oscillations

This phase involves testing and proving the effectiveness of proposed techniques for suppressing spontaneous oscillations in the amplification process. These techniques include suppression of oscillations due to reflected waves and elimination of oscillations due to external feedback.

TASK 3: Investigating Optimum Materials

Using the improved transducers and tested techniques for eliminating oscillations of the first and second tasks, the most promising acoustic amplification materials will be evaluated. Particular emphasis will be placed on choosing the material offering the highest possible operating efficiency as a microwave amplifier.

TASK 4: Evaluating the Solid State Amplifier

Results of the previous tasks will be combined in the design, development and fabrication of a model solid-state traveling-wave amplifier, suitable for determining many of the performance characteristics of the amplification technique. This investigation will provide initial data on size, weight, gain, efficiency, bandwidth, frequency range, noise performance, life and reliability.

III. PROGRESS DURING THIS PERIOD

Efforts during this reporting period were directed toward design and fabrication of a new bonding jig, a continuation of the theory for selection of optimum materials, preparation of the quarterly report covering the previous period and a continuation of the initial fabrication and design of shear-wave transducers.

The apparatus required for making good acoustic bonds operable in the kilomegacycle frequency range, and bonding buffer crystals to the amplifier crystal has been designed and fabricated. This equipment was designed to be operated in a simple manner and give the operator accurate temperature and pressure control at all times. The evaporating station is being modified to accept this equipment; therefore initial bonding, fabrication and testing will begin during the next monthly period. The necessary CdS crystals were lapped and polished and the Z-cut quartz bars to be used as buffer crystals were set aside so that tests may begin when the vacuum station is prepared.

The theoretical study to pick the optimum amplifier crystal material under requirements of oscillation-free amplification and maximum efficiency conditions were continued during the first few weeks of this period. As a result three optimum materials were selected which have very good characteristics: (CdSe, CdS and ZnO.) Of these, CdS and CdSe are commercially available in resistivity ranges that are near those of interest to this project. However, ZnO is not available in the desirable resistivity range. CdS has previously been used to some extent on this project and crystal suppliers are presently checking to see if they can supply the necessary quality of CdSe crystals. The detailed considerations leading to the choice of these preferred materials were included in the recent quarterly report.

Fabrication of shear-wave transducers, begun during the previous month was continued during this period and two successful tests were made. The data has not been reduced; however, work will continue and the results will be given as soon as sufficiently complete.

Because of the necessity of using test and buffer materials of proper acoustic impedance, acoustic attenuation, and size, a study has been made of available materials. Those of interest are listed, with some of their properties, in Table I.

IV. PROGRAM FOR NEXT INTERVAL

Techniques for making good acoustic bonds will be tested as soon as the equipment is mounted in the vacuum station. When the necessary information is received from the crystal manufacturer, CdSe crystals will be

Table I

Material and Cut	Acoustic Mode	Velocity cm/sec	Impedance kg/m^2 sec	Attenuation at 1.5 Gc
X Quartz	longitudinal	5.6×10^5	14.7×10^6	10 db/cm
Z Quartz	longitudinal	6.3×10^5	16.7×10^6	5.8 db/cm
AC Quartz	shear	3.32×10^5	8.8×10^6	12 db/cm
BC Quartz	shear	5.04×10^5	13.4×10^6	3.3 db/cm
Sapphire	longitudinal	11.2×10^5	43.6×10^6	1.6 db/cm
Sapphire	shear	6.1×10^5	23.8×10^6	3.2 db/cm
Rutile	longitudinal	10.3×10^5	43.9×10^6	
Rutile	shear	5.4×10^5	23.0×10^6	1.7 db/cm
YIG	longitudinal	7.2×10^5	37.2×10^6	
YIG	shear	3.87×10^5	20×10^5	0.43 db/cm
YGaG	longitudinal	7.08×10^5	41.0×10^6	
YGaG	shear	4.06×10^5	23.5×10^6	1.4 db/cm
YAIG	longitudinal	8.56×10^5	38.9×10^6	
YAIG	shear	5.03×10^5	22.9×10^6	2.1 db/cm
CdS	longitudinal	4.3×10^5	20.75×10^6	
CdS	shear	1.75×10^5	8.44×10^6	

ordered for testing. Design and fabrication of an amplifier model which does not use buffer crystals is planned so that the importance of reducing electromagnetic feedthrough may be determined. When a sufficiently good bond-making procedure is available amplifier models incorporating buffer crystals will be fabricated.