HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

CONTRACTING AGENCY: NASA LEWIS RESEARCH CENTER

CONTRACTOR: MICROWAVE MONOLITHICS INCORPORATED

CO-PRINCIPLE INVESTIGATORS: WENDELL C. PETERSEN, DANIEL P. SIU

SBIR PHASE II: 1987 Phase II
Proposal No.: 403-6642
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N94-10852

Unclas

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G3/03 0183138
PROGRAM OBJECTIVES

* DEVELOP A HIGHLY EFFICIENT, LOW COST RF MODULE FOR SARSAT BEACONS

* ACHIEVE SIGNIFICANTLY LOWER BATTERY CURRENT DRAIN, AMOUNT OF HEAT GENERATED, & SIZE OF BATTERY REQUIRED

* UTILIZE MMIC TECHNOLOGY TO IMPROVE EFFICIENCY, RELIABILITY, PACKAGING, & COST

* PROVIDE A TECHNOLOGY DATABASE FOR GaAs BASED UHF RF CIRCUIT ARCHITECTURES
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

ABBREVIATED PHASE II STATEMENT OF WORK

TASK 1) COMPLETE MODULE DESIGN STARTED IN PHASE I

TASK 2) FABRICATE INITIAL MODULES

TASK 3) CHARACTERIZE INITIAL MODULES

TASK 4) ITERATE INITIAL DESIGN INTO FINAL DESIGN

TASK 5) FABRICATE FINAL MODULES

TASK 6) CHARACTERIZE FINAL MODULES

TASK 7) REVIEW FINAL DESIGN

TASK 8) ASSESS PRODUCTION DESIGN

TASK 9) PREPARE FINAL REPORT

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PHASE II PROGRAM ACCOMPLISHMENTS

* HIGH EFFICIENCY GaAs MMIC POWER AMPLIFIER DESIGNED, FABRICATED, & CHARACTERIZED

* PERFORMANCE ACHIEVED:
  - OUTPUT POWER > 5 WATTS
  - ASSOCIATED GAIN > 25 dB
  - POWER-ADDED EFFICIENCY ~ 60 %

* MONOLITHIC GaAs PHASE MODULATOR DESIGNED, FABRICATED, & CHARACTERIZED

* AVERAGE MEASURED PHASE ERROR < 0.03 RADIANS

* ALL PROGRAM TASKS COMPLETED

* ALL PROGRAM GOALS MET AND/OR EXCEEDED

* TWO SETS OF GaAs MONOLITHIC POWER AMPLIFIERS AND PHASE MODULATORS DELIVERED TO NASA

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HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

GaAs MMIC RF MODULE

CONTROLLER → DATA → BI-PHASE MODULATOR → POWER AMPLIFIER

406.025MHz OSCILLATOR

FUNCTIONAL BLOCK DIAGRAM OF SARSAT DISTRESS BEACON USING GaAs MMIC RF MODULE CHIP SET

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HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

PERFORMANCE GOALS FOR THE MONOLITHIC GaAs SARSAT BEACON PHASE MODULATOR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>406.025 MHz</td>
</tr>
<tr>
<td>Input Impedance</td>
<td>50 ohms</td>
</tr>
<tr>
<td>Output Impedance</td>
<td>50 ohms</td>
</tr>
<tr>
<td>Phase States</td>
<td>0.0 degrees</td>
</tr>
<tr>
<td></td>
<td>+1.1 radians (± 0.1 radians)</td>
</tr>
<tr>
<td></td>
<td>-1.1 radians (± 0.1 radians)</td>
</tr>
<tr>
<td>Insertion Loss</td>
<td>&lt; 3 dB for all phase states</td>
</tr>
<tr>
<td>DC Supply Voltage</td>
<td>9 to 15 Volts</td>
</tr>
<tr>
<td>DC Supply Current</td>
<td>&lt; 10 mA</td>
</tr>
</tbody>
</table>

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# High Efficiency Low Cost Monolithic Module for SARSAT Distress Beacons

## Performance Goals for the Monolithic GaAs SARSAT Beacon Power Amplifier

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>406.025 MHz</td>
</tr>
<tr>
<td>Input Impedance</td>
<td>50 ohms</td>
</tr>
<tr>
<td>Output Impedance</td>
<td>50 ohms</td>
</tr>
<tr>
<td>Output Power</td>
<td>5 Watts</td>
</tr>
<tr>
<td>Power Gain</td>
<td>10 dB</td>
</tr>
<tr>
<td>Power-Added Efficiency</td>
<td>&gt; 50%</td>
</tr>
<tr>
<td>DC Supply Voltage</td>
<td>9 to 15 Volts</td>
</tr>
<tr>
<td>Idle DC Supply Current</td>
<td>&lt; 5 mA</td>
</tr>
</tbody>
</table>

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HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

BLOCK DIAGRAM OF THE SARSAT BEACON RF MODULE COMPONENTS

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SCHEMATIC DIAGRAM OF GaAs MONOLITHIC BI-PHASE MODULATOR

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HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

PREDICTED PHASE STATES VERSUS FREQUENCY OF GaAs MONOLITHIC BI-PHASE MODULATOR

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PREDICTED INSERTION LOSS VERSUS FREQUENCY OF GaAs MONOLITHIC BI-PHASE MODULATOR

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SCHEMATIC DIAGRAM OF GaAs MONOLITHIC BUFFER AMPLIFIER

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PREDICTED PERFORMANCE OF GaAs MONOLITHIC BUFFER AMPLIFIER @ 406.025 MHz

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMALL SIGNAL GAIN</td>
<td>12.5 dB</td>
</tr>
<tr>
<td>OUTPUT @ 1 dB COMP.</td>
<td>19.3 dBm (85 mW)</td>
</tr>
<tr>
<td>STAND-BY DRAIN CURRENT</td>
<td>5 mA</td>
</tr>
</tbody>
</table>

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SCHEMATIC DIAGRAM OF GaAs MONOLITHIC POWER AMPLIFIER OUTPUT STAGE

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HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

PREDICTED PERFORMANCE OF GaAs MMIC POWER AMPLIFIER OUTPUT STAGE @ 406.025 MHz

<table>
<thead>
<tr>
<th></th>
<th>GAIN</th>
<th>OUTPUT POWER</th>
<th>POWER-ADDED EFFICIENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL ELEMENTS</td>
<td>11.2dB</td>
<td>37.3dBm (5.4W)</td>
<td>62 %</td>
</tr>
<tr>
<td>&quot;ON-CHIP&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POWER COMBINER</td>
<td>11.8dB</td>
<td>37.9dBm (6.2W)</td>
<td>72 %</td>
</tr>
<tr>
<td>&quot;OFF-CHIP&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POWER COMBINER &amp;</td>
<td>12.5dB</td>
<td>38.6dBm (7.2W)</td>
<td>83 %</td>
</tr>
<tr>
<td>DRAIN RESONATOR /</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIAS &quot;OFF-CHIP&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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SCHEMATIC DIAGRAM OF GaAs MONOLITHIC POWER AMPLIFIER DRIVER STAGE

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HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

PREDICTED PERFORMANCE OF GaAs MMIC POWER AMPLIFIER DRIVER STAGE @ 406.025 MHz

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAIN</td>
<td>11.5 dB</td>
</tr>
<tr>
<td>OUTPUT POWER</td>
<td>27.8 dBm (610 mW)</td>
</tr>
<tr>
<td>POWER-ADDED EFFICIENCY</td>
<td>61 %</td>
</tr>
</tbody>
</table>
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

PEN PLOT OF SECOND ITERATION GaAs MONOLITHIC RF MODULE CHIP SET

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HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

SIZE COMPARISON OF FIRST AND SECOND ITERATION RF MODULE CHIP SETS

FIRST ITERATION:

<table>
<thead>
<tr>
<th>MODULATOR</th>
<th>BUFFER + DRIVER</th>
<th>OUTPUT STAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 MM X 1.7 MM</td>
<td>3.3 MM X 2.6 MM</td>
<td>4.0 MM X 2.9 MM</td>
</tr>
</tbody>
</table>

TOTAL AREA: 27.0 MM$^2$

SECOND ITERATION:

<table>
<thead>
<tr>
<th>MODULATOR WITH BUFFER</th>
<th>2-STAGE AMPLIFIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 MM X 2.5 MM</td>
<td>4.1 MM X 2.5 MM</td>
</tr>
</tbody>
</table>

TOTAL AREA: 20.5 MM$^2$

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MEASURED PHASE STATES OF A GaAs MONOLITHIC PHASE MODULATOR

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MEASURED INSERTION LOSS OF A GaAs MONOLITHIC PHASE MODULATOR

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MEASURED INPUT RETURN LOSS OF A GaAs MONOLITHIC PHASE MODULATOR

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### Measured Performance of a GaAs Monolithic Phase Modulator

<table>
<thead>
<tr>
<th>State</th>
<th>Gain</th>
<th>Phase Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ($V_{c1}=0$, $V_{c2}=0$)</td>
<td>-20.2 dB</td>
<td>-0.15 Rad.</td>
</tr>
<tr>
<td>2 ($V_{c1}=-5$, $V_{c2}=0$)</td>
<td>-2.2 dB</td>
<td>-1.10 Rad.</td>
</tr>
<tr>
<td>3 ($V_{c1}=0$, $V_{c2}=-5$)</td>
<td>-3.8 dB</td>
<td>+1.16 Rad.</td>
</tr>
<tr>
<td>4 ($V_{c1}=-5$, $V_{c2}=-5$)</td>
<td>-4.2 dB</td>
<td>Reference</td>
</tr>
</tbody>
</table>

**Output VSWR**

< 1.2:1

**Output Level @ 1 dB "Gain" Compression**

+14 dBm
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

MEASURED PERFORMANCE OF TWO-STAGE GaAs MONOLITHIC POWER AMPLIFIERS

<table>
<thead>
<tr>
<th></th>
<th>CHIP &quot;A&quot;</th>
<th>CHIP &quot;B&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Output</td>
<td>5.6 Watts</td>
<td>7.0 Watts</td>
</tr>
<tr>
<td>Gain</td>
<td>25.3 dB</td>
<td>28.3 dB</td>
</tr>
<tr>
<td>Power-Added Efficiency</td>
<td>59 %</td>
<td>56 %</td>
</tr>
</tbody>
</table>

SUPPLY VOLTAGE = 9 VOLTS

OFF-CHIP OUTPUT TUNING

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HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

CONCLUSIONS & RECOMMENDATIONS

* HIGH EFFICIENCY GaAs MMIC POWER AMPLIFIER DEMONSTRATED:
  
  OUTPUT POWER > 5 WATTS
  ASSOCIATED GAIN > 25 dB
  POWER-ADDED EFFICIENCY ~ 60 %

* MONOLITHIC GaAs PHASE MODULATOR WITH VERY ACCURATE PHASE SHIFTS DEMONSTRATED

* ALL PROGRAM TASKS COMPLETED & ALL PROGRAM GOALS MET AND/OR EXCEEDED

* TWO SETS OF GaAs MONOLITHIC POWER AMPLIFIERS AND PHASE MODULATORS DELIVERED TO NASA

* PROOF OF CONCEPT FOR LOW COST HIGH PERFORMANCE SARSAT DISTRESS BEACONS DEMONSTRATED

* LOW RISK PHASE III PROGRAM FOR FINAL MMIC ITERATION AND BEACON INTEGRATION RECOMMENDED

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