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.: 1403-6642

Release Date: 11-11-93

"NOTICE - SBIR DATA - PHASE II"

This SBIR data is furnished with SBIR rights under NASA Contract No. NAS3-25712. For a period of 2 years after acceptance of all items to be delivered under this contract the Government agrees to use this data for Government purposes only, and it shall not be disclosed outside the Government (including disclosure for procurement purposes) during such period without permission of the Contractor, except that, subject to the foregoing use and disclosure prohibitions, such data may be disclosed for use by support contractors. After the aforesaid 2-year period the Government has a royalty-free license to use, and to authorize others to use on its behalf, this data for Government purposes, but is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of this data by third parties. This notice shall be affixed to any reproductions of this data, in whole or in part.

N94-10852

10/29/92

Microwave Monolithics Incorporated (N/A)
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

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

10/29/92

Microwave Monolithics Incorporated
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

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

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

10/29/92

Microwave Monolithics Incorporated
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

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

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

BLOCK DIAGRAM OF THE SARSAT BEACON RF MODULE

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
## PERFORMANCE GOALS FOR THE MONOLITHIC GaAs SARSAT BEACON PHASE MODULATOR

<table>
<thead>
<tr>
<th>Specification</th>
<th>Specification Details</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>

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

PERFORMANCE GOALS FOR THE MONOLITHIC GAAS SARSAT BEACON POWER AMPLIFIER

- Operating Frequency: 406.025 MHz
- Input Impedance: 50 ohms
- Output Impedance: 50 ohms
- Output Power: 5 Watts
- Power Gain: 10 dB
- Power-Added Efficiency: > 50%
- DC Supply Voltage: 9 to 15 Volts
- Idle DC Supply Current: < 5 mA

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

BLOCK DIAGRAM OF THE SARSAT BEACON RF MODULE COMPONENTS

10/29/92
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

SCHEMATIC DIAGRAM OF GaAs MONOLITHIC BI-PHASE MODULATOR

10/29/92
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

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

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

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

10/29/92

Microwave Monolithics Incorporated
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

SCHEMATIC DIAGRAM OF GaAs MONOLITHIC BUFFER AMPLIFIER

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

PREDICTED PERFORMANCE OF GaAs MONOLITHIC BUFFER AMPLIFIER @ 406.025 MHz

| SMALL SIGNAL GAIN | = 12.5 dB |
| OUTPUT @ 1 dB COMP. | = 19.3 dBm (85 mW) |
| STAND-BY DRAIN CURRENT | = 5 mA |

10/29/92

Microwave Monolithics Incorporated
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

SCHEMATIC DIAGRAM OF GaAs MONOLITHIC POWER AMPLIFIER OUTPUT STAGE

10/29/92

Microwave Monolithics Incorporated
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>ALL ELEMENTS</th>
<th>GAIN</th>
<th>OUTPUT POWER</th>
<th>POWER-ADDED EFFICIENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;ON-CHIP&quot;</td>
<td>11.2dB</td>
<td>37.3dBm (5.4W)</td>
<td>62 %</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>12.5dB</td>
<td>38.6dBm (7.2W)</td>
<td>83 %</td>
</tr>
</tbody>
</table>

10/29/92

Microwave Monolithics Incorporated
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

SCHEMATIC DIAGRAM OF GaAs MONOLITHIC POWER AMPLIFIER DRIVER STAGE

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
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>

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

PEN PLOT OF SECOND ITERATION GaAs MONOLITHIC RF MODULE CHIP SET

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
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>Module</th>
<th>First Iteration</th>
<th>Second Iteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODULATOR</td>
<td>4.0 MM X 1.7 MM</td>
<td>4.1 MM X 2.5 MM</td>
</tr>
<tr>
<td>BUFFER + DRIVER</td>
<td>3.3 MM X 2.6 MM</td>
<td>4.1 MM X 2.5 MM</td>
</tr>
<tr>
<td>OUTPUT STAGE</td>
<td>4.0 MM X 2.9 MM</td>
<td></td>
</tr>
<tr>
<td>TOTAL AREA:</td>
<td>27.0 MM²</td>
<td>20.5 MM²</td>
</tr>
</tbody>
</table>

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

MEASURED PHASE STATES OF A GaAs MONOLITHIC PHASE MODULATOR

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
HIGH EFFICIENCY LOW COST MONOLITHIC MODULE FOR SARSAT DISTRESS BEACONS

MEASURED INSERTION LOSS OF A GaAs MONOLITHIC PHASE MODULATOR

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
## 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**

\(+14 \text{ dBm}\)

10/29/92

**Microwave Monolithics Incorporated**
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

10/29/92

MICROWAVE MONOLITHICS INCORPORATED
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

10/29/92

MICROWAVE MONOLITHICS INCORPORATED