200 and 400 GHz Schottky diode Multipliers Fabricated with Integrated Air-Dielectric (Substrateless) Circuitry


**SWAT Team**

*Submillimeter Wave Advanced Technology*

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Missions Needing Submillimeter LO Systems

- High-resolution spectroscopy for Earth, planetary and astrophysical observation
- Typical missions are FIRST, Cloud Ice, AMLS, ...

First Band 5 Receiver
14 % Bandwidth

Oscillator  Power Amp  Multiplier Chain

100 GHz  200 GHz  400 GHz
250 mW    40 mW    10 mW

RF In  Mixer  IF Out  LO Feed

1200 GHz  0.5 mW
Multiplier Requirements for FIRST

- Efficient, accurate assembly of multiplier circuits in blocks — need over 100 for FIRST!
- Ruggedness, resistance to shock and vibration for space qualification
- Wide bandwidth (10 to 14 %)
- High power capability (200 - 250 mW)
- High efficiency for multiple cascaded stages
- Cryogenic (100 K) operation
Planar Balanced Doubler Technologies
Based on Neal Erickson Split-Block Concept

- Chip soldered to block
- Bondwire connects chip to DC Bias Cap
- Chip soldered to block or Quartz
- Bondwires connect quartz to Bias Cap and to block (for chip on quartz version)
- All chip connections to block made with beam leads
- Diodes integrated into circuit
- GaAs under metal removed for low loss
Substrateless Circuit Mounted in Block

Output Guide

Output Matching Circuit

Frame

Diodes

Length: 1.5 mm

DC Bias Filter

Bias Capacitor

Bond to Connector
Doubler Design Strategy

Linear Circuit

- Linear sim TLines
- HFSS Model of Diodes in Waveguide + embedding impedances from non-linear diode optimization
- HFSS Step
- HFSS Filter Model
- HFSS Backshort

Non-Linear Circuit

- Full Structure Analyzed at Input Frequency with HFSS
- Full Structure Analyzed at Output Frequency with HFSS
- Waveguide Input Port
- Waveguide Output Port

Diode Models
Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

400 GHz Doubler Test Set

Backward Wave Oscillator
Attenuator
100 GHz TRW based Power Amp
Low-loss Millitech Isolator
200 GHz Doubler
400 GHz Doubler Under Test
Wideband U. Mass Calorimeter

| X 2 | X 1 |

HIFI_PR_JPL_4_25_00.ppt Imran Mehdii/JPL
Substrateless Technology for 200 GHz MMCs

- Full view of structure mounted in a waveguide block
- Close-up of the anodes
  - Gives 8% efficiency, despite design flaw

3 mm

440 um
Substrateless Technology for 400 GHz MMCs

Doubler mounted in block

Closeup of diode on frame

1.5 mm

30 um
Measured Performance of 400 GHz Doubler

Input Power (mW), Efficiency (%) vs. Output Frequency (GHz)

Output Power (mW) vs. Output Frequency (GHz)
First-order random vibration test on the Substrateless MMCs

- 200 and 400 GHz blocks, length of the block parallel to x-axis

<table>
<thead>
<tr>
<th>Test I specifications</th>
<th>Test II specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Hz--0.001 g²/Hz</td>
<td>20 Hz--0.001 g²/Hz</td>
</tr>
<tr>
<td>20-100 Hz--+6dB/oct</td>
<td>20-100 Hz--+6dB/oct</td>
</tr>
<tr>
<td>100-500 Hz--0.1, 0.2,0.4,0.6,0.8,1.0,1.2 g²/Hz</td>
<td>100-1000 Hz--0.8 g²/Hz</td>
</tr>
<tr>
<td>500-2000 Hz-- -6dB/oct</td>
<td>1000-2000 Hz-- -6dB/oct</td>
</tr>
<tr>
<td>Overall: 7.9,10.9,15,18,21,23,28 Grms</td>
<td>Overall: 28.7 Grms</td>
</tr>
<tr>
<td>Duration: 60 seconds</td>
<td>Duration: 440 seconds</td>
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</tbody>
</table>

- no change in I(V)
- no change in RF
  (only 200 GHz measured)
Summary of Problems Being Addressed

- **Blocks had machining errors** — Process corrected, new blocks are much improved and within specifications.

- **Input design error on 200 GHz Doubler** — Experience with design procedure improves detection of errors.

- **Matching network in channel is sensitive to machining variations, especially low impedance lines** — New design techniques put most matching in waveguide, vastly improving performance and robustness.
Conclusions

- Novel substrateless multiplier technology has been developed which fulfills the goals of efficient assembly and high performance.
- First substrateless iteration has yielded state-of-the-art power, bandwidth and efficiency at 400 GHz.
- 200 GHz doubler being redesigned and fabricated to eliminate errors and improve performance.
Lessons Learned from First Iteration

- Assembly takes only 1/2 hour per block.
- Alignment of circuit with block is very repeatable between blocks.
- Circuits are robust and reliable.
- No soldering or other high temperature assembly procedure needed.
- Thermal questions to be addressed with short beam leads and analysis.