Surface Micromachining

- Low loss and low power consumption
- Eliminate dielectric loss
  - Loss is high in V-band
- Previously developed modules
  - Vertical monopole
  - Vertical Yagi-Uda
  - Elevated patch antenna
  - Elevated coupler
Enabling Technology - Polymer core conductor

High-Q elevated Cavity resonator
(2-pole surface micromachined waveguide filter)

Air-lifted pillars
Air
Ground
CPW feeding
Port 1
Coupling stub
Substrate
Port 2
Metal Cap
Top plate not shown for clarity

<table>
<thead>
<tr>
<th></th>
<th>$f_{res}$</th>
<th>S12 (dB)</th>
<th>Unloaded Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sim</td>
<td>29.23 GHz</td>
<td>-12.6</td>
<td>280</td>
</tr>
<tr>
<td>Meas</td>
<td>29.65 GHz</td>
<td>-20.27</td>
<td>&gt; 219</td>
</tr>
</tbody>
</table>

a planar CPW or microstrip resonator on the same substrate

23.2
V-Band Prototype I
(2-pole surface micromachined waveguide filter)

Top plate not shown for clarity

<table>
<thead>
<tr>
<th></th>
<th>$f_{\text{center}}$</th>
<th>Insertion loss (dB)</th>
<th>3-dB BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sim</td>
<td>60.20 GHz</td>
<td>2.4 dB</td>
<td>1.6 GHz (2.65%)</td>
</tr>
<tr>
<td>Meas</td>
<td>60.25 GHz</td>
<td>2.9 dB</td>
<td>1.6 GHz (2.65%)</td>
</tr>
</tbody>
</table>
V-Band Prototype II
(2-pole surface micromachined cavity filter)

No waveguide transition
micromachined probe directly fed into cavities

Top plate not shown for clarity

Less than 1.5 dB insertion loss for 60 GHz

(Patent pending)
V-Band Prototype III
(Prototype and Measurements)

SEM picture of the cross-coupling structure

Measured filter response vs. simulated one
2.45 dB insertion loss observed
UWB antennas on flexible organic substrates

The objective of this research is the design and development of novel compact UWB antennas with omni-directional radiation patterns and good matching along the whole UWB range (3.1-10.6 GHz) that can be used for hand-held devices for personal communications. Polygon monopoles, elliptical monopoles and elliptical slot antennas are used to meet various required specifications.

All the presented antennas are fabricated on Liquid Crystal Polymer (LCP) (\(\varepsilon_r=3\), \(\tan\delta=0.002\)) and were tested in non-planar shapes to investigate their potential use in different applications like wearable electronics.

**Polygon-shaped**

\[ \varepsilon_r = 3.0 \quad \tan\delta = 0.002 \]

Impedance matching technique

4 mil LCP Substrate

CPW feeding

Antenna mounted on Cylinder
Polygon Antenna

Return Loss

\[ \varepsilon_r = 3.0 \quad \tan \delta = 0.002 \]

Impedance matching technique

4 mil LCP Substrate

CPW feeding

Antenna mounted on Cylinder

UWB (3.1-10.6 GHz)

\[ \varepsilon_r = 3.0 \quad \tan \delta = 0.002 \]

Simulation (HFSS) vs Measurement

E Plane

H Plane
Elliptical-shaped

CPW feeding

Impedance matching technique

U-fed elliptical slot

40 mm

38 mm

CPW feeding

Impedance matching technique

Radiation Patterns

E Plane H Plane E Plane H Plane

Measurement Simulation Measurement Simulation Measurement Simulation

5 GHz 9 GHz

Antenna mounted on Cylinder

3-D Radiation Patterns

E plane @ 8 GHz H plane @ 8 GHz

Folded Planar
U-fed Elliptical Slot

Impedance matching technique

CPW feeding

Antenna mounted on Cylinder

3-D Radiation Patterns

Return loss

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>S11 (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-15.5</td>
</tr>
<tr>
<td>4</td>
<td>-12.8</td>
</tr>
<tr>
<td>6</td>
<td>-10.1</td>
</tr>
<tr>
<td>8</td>
<td>-7.4</td>
</tr>
<tr>
<td>10</td>
<td>-5.7</td>
</tr>
<tr>
<td>12</td>
<td>-4.0</td>
</tr>
</tbody>
</table>

E plane @ 8 GHz

H plane @ 8 GHz
3D Integrated Modules for RF and mm-wave applications

Considering the importance of broadband and high-data rate (> 2 Gb/s) wireless services such as a high-speed internet, real-time video streaming, high-definition television (HDTV), wireless Gigabit Ethernet and automotive sensor, wireless communication systems call upon miniaturization, portability, cost-saving and performance improvement to satisfy the specifications of the next generation multi-gigabit per second wireless transmission. The 3-D integration approach using multilayer technologies, such as LTCC and LCP, has emerged as an attractive solution for these systems due to its high level of compactness and mature multilayer fabrication capability. In this research, we design, analyze and optimize 3D millimeter-wave (mm-W) modules in multilayer substrates. It includes the design of integrated interconnects, distributed passives and antennas for applications up to 100 GHz. The optimal integration of mm-W passives into a 3-D front-end module is researched to improve package efficiency and electrical high-frequency performance and to eliminate a separate package for passives, yielding the lower cost, reduced profile and weight.
3-Pole Cavity Band Pass Filters using LTCC

- **Type I**
  - Diagram showing the layout of the cavity band pass filter with labeled components:
    - 1st cavity
    - 2nd cavity
    - 3rd cavity
    - Metal layers
    - Substrate layers
    - Via walls
    - Microstrip feedlines
    - External slots

- **Type II**
  - Diagram showing the layout of the cavity band pass filter with labeled components:
    - Metal layers
    - Substrate layers
    - Via walls
    - Microstrip feedlines
    - External slots

Diagram includes external slot, via walls, metal, substrate, microstrip feedlines, and internal slots.
Simulation & Measurement Results

- **Type I**

- **Type II**

![Graphs showing S21 (measured) and S21 (simulated) for Type I and Type II, with Frequency (GHz) on the x-axis and dB on the y-axis.](image-url)
Integration (Filter + Antenna)

- V-band transceiver block diagram
- Side view of the Integration
- Fabricated Integration
- 3-D overview of the Integration
Simulation & Measurement Results

1st Channel (Rx band)

2nd Channel (Tx band)

<table>
<thead>
<tr>
<th>Design Parameters</th>
<th>1st Channel</th>
<th></th>
<th>2nd Channel</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10-dB Bandwidth (%)</td>
<td>3.65</td>
<td>4.18</td>
<td>3.51</td>
<td>3.84</td>
</tr>
<tr>
<td>Center Frequency (GHz)</td>
<td>57.5</td>
<td>57.45</td>
<td>59.9</td>
<td>59.85</td>
</tr>
<tr>
<td>Isolation (dB)</td>
<td>&gt;49.1 (56.2-58.6GHz)</td>
<td>&gt;51.9 (58.4-60.7GHz)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>