Low Profile Tunable Dipole Antennas Using BST Varactors for Biomedical Applications

David Cure and Thomas Weller
University of South Florida

Tony Price - INTEL Corporation

Félix A. Miranda - NASA Glenn Research Center
Outline

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- Background
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- 1-D Varactor based Tunable Antenna
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MOTIVATION
Motivation

- Design a low profile, conformal, tunable antenna for biomedical applications
- Portable radiometer applications:
  - Health monitoring sensor – astronauts, sports medicine, etc.
  - Remote Underground Thermal Detection
Motivation (Cont.)

- Antenna Requirements for wearable radiometer:
  - Minimize back-side radiation
  - Large bandwidth (~100 MHz)
  - Low profile and conformal (flexible)
  - Low weight, low cost & low complexity

  27 mm height
  ~λ/8 at 1.4 GHz


Cons: Bulky, heavy.
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PREVIOUS WORKS
Antenna Structure

**Top View**
- Dipole
- High Impedance Surface
- Live vias

**Bottom View**
- Balun

**Side View**
- Dipole - Layer 1
- HIS - Layer 2
- Balun - Layer 3
- End-Loaded Planar Open-Sleeve (ELPOSD)
- Broadband or dual response
- Tunable: Several parameters
- \( L_p \) affects the upper resonance frequency
- \( L \) affects the Lower resonance frequency
1-D Varactor based Tunable Antenna

- Height $\sim \lambda/45$ at 2.4 GHz
- Bias and fabrication simplicity
- Minimize the use of vias (potentially conformal nature)
- High front-to-back radiation pattern ratio
- Ability to dynamically adjust the center frequency

DC Bias

1 KΩ resistors and ground

FSS

ELPSOD

Dipole Layer

FSS Layer

Ground plane

133 mm

120 mm

$V_1$, $V_2$, $V_3$, $V_4$, $V_5$, $V_6$, $V_7$, $V_8$
Common bias applied

Non-uniform bias voltages

Config $V_1, V_2$ $V_3$ $V_4, V_5$ $V_6$ $V_7, V_8$

A 30 V 30 V 30 V 30 V 30 V

B 70 V 70 V 30 V 70 V 70 V
Operation using non-uniform bias voltages with Human Core Model (HCM)

<table>
<thead>
<tr>
<th>Config.</th>
<th>$V_1$, $V_2$</th>
<th>$V_3$</th>
<th>$V_4$, $V_5$</th>
<th>$V_6$</th>
<th>$V_7$, $V_8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (No HCM)</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
</tr>
<tr>
<td>E (w/ HCM)</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
</tr>
<tr>
<td>F (w/ HCM)</td>
<td>10 V</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
<td>20 V</td>
</tr>
<tr>
<td>G (w/ HCM)</td>
<td>50 V</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
<td>50 V</td>
</tr>
<tr>
<td>H (w/ HCM)</td>
<td>100 V</td>
<td>100 V</td>
<td>100 V</td>
<td>100 V</td>
<td>100 V</td>
</tr>
</tbody>
</table>
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1-D BST VARACTOR BASED ANTENNA
BST Varactor Based antenna

- Height $\sim \lambda/45$ at 2.4 GHz
- Bias and fabrication simplicity
- Take advantage of the C-V symmetry curve
- Avoid the use of vias (potentially conformal nature)
- High front-to-back radiation pattern ratio
- Ability to dynamically adjust the center frequency
FSS Layer Using Barium Strontium Titanate (BST) Varactors

84 mm

86 mm

V=0 V
V=35 V
V=70 V

-40
-30
-20
-10
0

Frequency (GHz)

-30 dB
-20 dB
-10 dB
0 dB

V=0 V
V=35 V
V=70 V

2.25 GHz
2.3 GHz
2.4 GHz
2.45 GHz

225 MHz
230 MHz
240 MHz
245 MHz
Operation using non-uniform bias voltages with Human Core Model (HCM)

Impedance match adjustment in:
- Close proximity to a HMC
- At contact with HMC
## GaAs vs. BST antenna

<table>
<thead>
<tr>
<th>Antenna</th>
<th>Mass (gms)</th>
<th>Total devices</th>
<th>Cost per device</th>
<th>Cost</th>
<th>Area (mm²)</th>
<th>Eff. (%)</th>
<th>Tunable BW (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GaAs</td>
<td>188</td>
<td>56</td>
<td>50 US$</td>
<td>High</td>
<td>15600</td>
<td>50-80</td>
<td>520</td>
</tr>
<tr>
<td>BST</td>
<td>87</td>
<td>56</td>
<td>0.1 US$</td>
<td>Low</td>
<td>7900</td>
<td>30-60</td>
<td>425</td>
</tr>
</tbody>
</table>

- **GaAs vs BST varactor based antenna**
  - Both - low profile
  - Both - Easily tunable
  - BST - Reduced planar size and mass compared to GaAs
  - BST- Cost effective
  - BST - Compact and robust
Summary

- A low profile, tunable dipole antenna using BST varactors has been demonstrated.
- The total antenna thickness is $\sim \lambda /45$ when using 1-D varactor-loading.
- A tunable frequency response from 2.2 to 2.55 GHz.
- Cost effective, compact, robust, easily tunable and low profile antenna.
- BST varactor antenna enables:
  - Small bias Network voltages.
  - Potential use of flexible substrates.
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References


References


Add. 1 BST Varactor Characterization

Schematic for diode simulation.

- **3rd layer**: Gold layer, \( h_1 = 800 \text{ nm} \)
- **2nd layer**: BST layer, \( \varepsilon_r = 200 \text{ to } 350 \), \( h_2 = 350 \text{ nm} \)
- **1st layer**: Alumina layer, \( \varepsilon_r = 9.8 \), \( h_3 = 500 \mu\text{m} \)

![Diode simulation schematic](image)

![Measured and modeled capacitance vs. frequency](graph)
Add. 2

\[ C_{\text{end}} = 4ns(2 + \pi)e_{\text{end}}e_0 \frac{K(\kappa_{0\text{end}})}{K(\kappa'_{0\text{end}})} \]

54% error

\[ C_{\text{end}} = 2ns \left( 2 + \frac{\pi}{2} \right) e_{\text{end}}e_0 \frac{K(\kappa_{0\text{end}})}{K(\kappa'_{0\text{end}})} \]

6% error

<table>
<thead>
<tr>
<th>Number of Fingers</th>
<th>Measured Effective Capacitance at 0 volts</th>
<th>Measured Effective Capacitance at 90 volts</th>
<th>Permittivity extracted at 0V and 90 V (HFSS)</th>
<th>Permittivity extracted at 0V and 90 V (Eq. 4.09)</th>
<th>Permittivity extracted at 0V and 90 V (Eq. 4.10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.17 pF</td>
<td>0.88 pF</td>
<td>800-500</td>
<td>400-250</td>
<td>750-510</td>
</tr>
<tr>
<td>5</td>
<td>2.1 pF</td>
<td>1.5 pF</td>
<td>750-500</td>
<td>450-270</td>
<td>770-500</td>
</tr>
<tr>
<td>7</td>
<td>3.2 pF</td>
<td>2.2 pF</td>
<td>750-500</td>
<td>470-270</td>
<td>800-500</td>
</tr>
</tbody>
</table>

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</thead>
<tbody>
<tr>
<td>3</td>
<td>0.75 pF</td>
<td>.5 pF</td>
<td>350-230</td>
<td>160-70</td>
<td>350-200</td>
</tr>
<tr>
<td>5</td>
<td>1.4 pF</td>
<td>0.98 pF</td>
<td>350-230</td>
<td>180-90</td>
<td>360-210</td>
</tr>
<tr>
<td>7</td>
<td>2.1 pF</td>
<td>1.45 pF</td>
<td>350-230</td>
<td>200-100</td>
<td>370-220</td>
</tr>
</tbody>
</table>