SOI for RF Applications and Beyond

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Outline

• SITRI Introduction
• RF SOI technology
• RF SOI switches for tunable antenna
• SOI for applications beyond RF
  • RF energy harvester
  • Wireless charging
• Summary
SITRI- an IoT Catalyst

- We commercialize technologies and invest in interesting companies in the IoT and Wearable space
- We provide design, financial, and supply chain support to make these new ventures successful
- We provide access to China markets and manufacturing infrastructure to companies in the IoT and Wearable space seeking rapid growth
- Backed by the Shanghai government and Shanghai Institute of Microsystem and Information Technology (SIMIT), we leverage deep technical, industrial and commercial connections to create a vibrant IoT industry.
SITRI Functions: Address All Key Ecosystem Needs to Build a Vibrant Industry

- Design Services
- Analysis and Research
- IoT Fund for Startup Investment
- CAS
- LETI
- Startup Incubation
- BSAC
- Shanghai Industrial Parks
- Jiading Science Park

Investment and Engineering Services

Commercializing New Technologies

Microfabrication and Prototyping
Introduction of RF SOI Technology

- Minimizes the parasitic capacitance from source/drain to the substrate and reduce substrate coupling
- Increases the device isolation to allow practical device stacking for power handling and linearity
- Uses high resistivity silicon substrate
Today, RF FEM has to face the challenge of supporting multiple frequency bands and multiple communication modes to meet the requirement of 4G.
Tunable Antenna

There are two kinds of tunable antenna:

1. Aperture tuning
2. Mismatched impedance tuning

SOI switches are used to generate a switch multiplexer for the tunable modules.
Aperture Tuning Antenna to address the Multi-band Challenge of 4G

Most of today’s 3G antennas operates on 824-960 MHz and 1710-2170 MHz frequency bands.

4G would need to push the low band down to 700MHz and high band up to 2700MHz.
Antenna Aperture Tuning Examples

High Performance Switches needed:
- Low insertion loss
- High linearity (low distortion)
- Need to stand high RF voltage swing (40+ V)

Huawei, Lenovo, ZTE are currently using active antenna designs

Courtesy of Infineon
High Performance SOI Switches Developed by SITRI

<table>
<thead>
<tr>
<th>Test Item</th>
<th>STS21401</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>787 MHz H2/H3 (dBc)</td>
<td>-110/-113</td>
<td>25 dBm input</td>
</tr>
<tr>
<td>900 MHz H2/H3 (dBc)</td>
<td>-99/-91</td>
<td>35 dBm input</td>
</tr>
<tr>
<td>1800 MHz H2/H3 (dBc)</td>
<td>-87/-85</td>
<td>33 dBm input</td>
</tr>
<tr>
<td>IMD @ 2140 MHz (dBm)</td>
<td>-111</td>
<td>20 dBm @ 1950 MHz and -15 dBm @ 1760 MHz</td>
</tr>
<tr>
<td>IMD @ 881.5 MHz (dBm)</td>
<td>-107</td>
<td>20 dBm @ 836.5 MHz and -15 dBm @ 791.5 MHz</td>
</tr>
<tr>
<td>VDD Range (V)</td>
<td>2.1 – 5.5</td>
<td></td>
</tr>
<tr>
<td>IDD (uA)</td>
<td>60</td>
<td></td>
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<tr>
<td>Package</td>
<td>2.5 x 2.5 x 0.8 16-Pin QFN</td>
<td></td>
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</tbody>
</table>
Co-development work of SITRI with *Radiate* on tunable antenna
Proposal of using SPDT or SP4T to deliver the performance
A New Trend of Consumer Electronics - Smart Wearable Devices

Contact lens (Google)

www.google.com

Watch

www.centralstandardtiming.com

Sports wristbands

www.fixbit.com

Smart fabrics

Holst Centre
More than 70 million devices is predicted to be sold in 2016.
About 17 billion CNY (2.7 billion USD) of market scale is predicted in 2016.
Technical Challenges in Wearable Devices

- Energy harvesting, wireless charging, energy storage
- Voice, motion, text
- 2/3/4G, Wi-Fi, BLE, NFC
- AP/MCU
- Memory
- Display
- Sensor
- Wireless Connectivity
- Energy
- Ultra low power consumption SoC and SiP integration
- OLED, E-ink, projector
- Temperature, pressure, light, motion, gyro, bio-signal, and etc.
Energy Harvesting Market Prediction

Energy harvesting module market forecast by application (in M$)
(Source: Emerging energy harvesting devices report, Yole Développement, November 2012)
A comparison of the 4 main ambient energy sources (before conversion) shows each has a different power density. (Source: CEA-Leti)
Available Ambient RF Energy Sources

RF energy is small but
- 24-hour 7-day Available
- Not dependent on weather, location and day/night shift
1. DTV
2. Radio
3. Cellular base stations
4. Wi-Fi
5. Bluetooth

Frequency: 0.1 – 3 GHz and 5 – 6 GHz
Key technical challenges and contribution:
1. Broadband or multi-band antenna with miniaturized size.
2. Rectifiers for both broadband and high efficiency operation.
3. Smart DC/DC for both DC load tuning and various storage units.
4. Integrated on SOI CMOS.
Loosely Coupled Wireless Charging (A4WP)

• Midrange charging distance with constant system efficiency.
• Loosely resonance coupling enables multi-device charging.
• Receivers can be freely positioned in height, lateral distance and orientation angle.
A4WP Wireless Charging Architecture

**Driving Technologies**
- Class-E power amplifiers
- Synchronous rectifiers
- High efficiency DC/DC
- Impedance matching
- Dynamic charging state monitoring
- Simultaneous multiple receivers to-be-charged

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<table>
<thead>
<tr>
<th>Class</th>
<th>$P_{RX,IN,MAX}$</th>
<th>Minimum PRU Support Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>TBD</td>
<td>1 x Category 1</td>
</tr>
<tr>
<td>Class 2</td>
<td>10 W</td>
<td>1 x Category 1, 2, or 3</td>
</tr>
<tr>
<td>Class 3</td>
<td>16 W</td>
<td>2 x Category 1, 2, or 3, or 1 x Category 4</td>
</tr>
<tr>
<td>Class 4</td>
<td>22 W</td>
<td>3 x Category 1, 2, or 3, or 1 x Category 4</td>
</tr>
<tr>
<td>Class 5</td>
<td>TBD</td>
<td>TBD</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>PRU</th>
<th>$P_{RX,OUT,MAX}$</th>
<th>Example Applications</th>
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</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>TBD</td>
<td>BT headset</td>
</tr>
<tr>
<td>Category 2</td>
<td>3.5 W</td>
<td>Feature Phone</td>
</tr>
<tr>
<td>Category 3</td>
<td>6.5 W</td>
<td>Smart Phone</td>
</tr>
<tr>
<td>Category 4</td>
<td>TBD</td>
<td>Tablet</td>
</tr>
<tr>
<td>Category 5</td>
<td>TBD</td>
<td>Laptop</td>
</tr>
</tbody>
</table>
Dynamic Load Tracking Experimental Results

Load variation

Coils’ position variation

Tracking trajectory
Multiple Receiver System Optimization

\[ Z_{Li} = R_{Li} + jX_{Li} \]

\[ X_{Li,OPT} = - \sum_{k=1,k\neq i}^{n} \frac{\omega M_{ik} M_{lk} (R_i + R_{Li})}{M_{li} (R_k + R_{Lk})} \]

\[ \eta = \frac{\sum_{i=1}^{n} P_i}{P_{IN}} = \frac{\sum_{i=1}^{n} I_i^2 R_{Li}}{V_{IN} I_t} \]

Efficiencies comparison
SOI for RF Energy Harvesting and Wireless Charging

- Higher $g_m$
- Enhanced Latchup immunity
- Faster working speed
- Low leakage current
- Functional at higher temperatures
- Integration of various function blocks: rectifiers, PA, DC/DC, analog and digital.
Summary

- 4G wireless communication brings new challenges to the RF front-end modules/components.
- RF SOI is the mainstream technology for antenna switches presently.
- Wearable devices is a new trend in consumer electronics with a fast grow rate.
- As promising energy solutions to wearable devices, RF energy harvester and wireless charging can be benefited from SOI technology as well.
THANK YOU.