RF SOI for Front-End Tunability Components

New challenges and opportunities in 4G LTE phones

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Outline

- SITRI Introduction
- Brief review on RF SOI technology
- RF SOI for cellular phone FEM and the challenges of 4G LTE
- RF tunability components
  - Antenna Tuner
  - Tunable PA
  - Tunable Filter/Duplexer
- 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
- CAS
- LETI
- BSAC

Investment and Engineering Services

- Commercializing New Technologies
- Microfabrication and Prototyping

IoT Fund for Startup Investment
Startup Incubation
Shanghai Industrial Parks
Jiading Science Park
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
- Use high resistivity silicon substrate
SOI Substrate for RF Applications: HR vs TR

IBM’s TQ Process

SOITEC’s Trap-rich solution

Parasitic surface conduction (PSC) due to the oxide charge.

Inversion layer

Courtesy of IBM

Courtesy of SOITEC
The Primary Market that RF SOI Targets is the Cellular Phones

More than 1B smart phones will be sold in 2014 worldwide.
China is the largest market for smart phones. Estimated 400M smart phones sold in 2014 in China.
RF Front End Modules for Cellular Phones

- The most dominant components in a FEM: Switch, PA and filter

- More Envelop Tracking and Antenna Tuning in 4G LTE FEM has been seen.

- SOI switch is becoming the mainstream. RF switch & antenna tuner market is growing at 29%, with the SOI portion growing much faster at 46%

Source: Yole
RF Front End Markets Breakdown

<table>
<thead>
<tr>
<th>Mobile Phones FEM</th>
<th>2011 Market</th>
<th>2016 Market</th>
<th>2011-2016 CAGR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M unit</td>
<td>M $</td>
<td>volume</td>
</tr>
<tr>
<td>PA</td>
<td>4,316</td>
<td>1,943</td>
<td>4,796</td>
</tr>
<tr>
<td>RF Filter/Duplexer</td>
<td>5,897</td>
<td>1,199</td>
<td>10,140</td>
</tr>
<tr>
<td>Antenna Switch</td>
<td>1,511</td>
<td>407</td>
<td>2,346</td>
</tr>
<tr>
<td>Tunability Components</td>
<td><strong>6.7</strong></td>
<td><strong>8.8</strong></td>
<td><strong>1,031</strong></td>
</tr>
</tbody>
</table>

Source: Yole

- The tunability component market corresponds to the components that
  - get optimized performance across all frequency bands used
  - get optimized performance under various environments/conditions
  - apply at antenna tuning, PA tuning and Filter/duplexer tuning
Today, RF FEM has to face the challenge of supporting multiple frequency bands and multiple communication modes to meet the requirement of 4G.
Front-End FEM Evolution: From MBMM to Reconfigurable

- Duplications FEM components (including SMDs) demands more PCB space.
- More pressure on the antenna switch due to the increase of the throw counts

Reconfigurable front-end module

Source: Yole
The concept of tunability has been raised more than 10 years ago. However, it did not get widely adopted in the 3G phones.

We believe 4G and the needs for higher bandwidth and smaller board/antenna space will drive the tunability market.

Market leaders as well as start-ups are pushing the R&D effort in this area now.

Others will follow as the demands pick up.
Tunable Modules in the Radio Handset

SOI Switches are used to generate a switch multiplexer for the tunable modules.
Tunable Antenna

There are two kinds of tunable antenna:

- Aperture Tuning
- Mismatched Impedance tuning
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

Using switches to optimize antenna radiation efficiency and pattern

Courtesy of Infineon
Mismatched Impedance Tuner for Antenna

Loss in RF performance due to mismatch between antenna and FEM

Freespace → Approx. -1 dB

Human body phantoms (head and hand) → Up to -3 dB

Real-life (many user conditions) → Up to -7 dB

Terminal Cost
Network Cost

1dB loss in RF performance = 14% more sites for same coverage

Source: Vodafone; IWPC workshop 2011
Mismatched Impedance Tuner for Antenna

Command for Open Loop

Closed loop

Source: Yole

Epcos D7005 Closed Loop Tuner with GaAs Switches

Courtesy of Epcos

Epcos D7005
Epcos D7005 Tuner Test Results

**Without tuner**

Output power varies between 25 and 31.5 dBm

**With EPCOS D7005 closed-loop tuner**

Output power varies between 29 and 31 dBm

Commercial phone at 850 MHz; colors represent low, mid and high channels

Courtesy of Epcos
Tunable PA

Shanghai, China
Motivations for Tunable PA

- Lower Power Consumption
- Increase PA efficiency
- Provide by-pass function
- Support global frequency bands and multiple/varied RF standards for seamless roaming.
- Cost and size.
- Easy to use to catch up the fast market opportunity

Courtesy of SmarterMicro
Reconfigurable PA Technology Platform by SmarterMicro

With AgiPAM, a high performance SOI technology platform, SmarterMicro is capable of:

- Making all basic elements of RF power amplifier reconfigurable
- Providing digital calibration and compensation function to further optimize the performance.

Courtesy of SmarterMicro
SmarterMicro Reconfigurable PA

- Reconfigurable Structure
- Tunable narrowband approach

- Smallest Size
- Best Performance
- One Chip solution

Optimized PA performance for each mode/band

SmarterMicro Solution (Narrow Band tuning)

Discrete solution

Broadband solution (Others)

Courtesy of SmarterMicro
Tunable Filter/Duplexer
Tunable Duplexer is Still a Challenge

- SAW/BAW filter can achieve Q of several thousands. This is still challenging for other technologies to achieve.
- Tunable notch filter is under developments currently.
The Foundation Behind NewLANS’s Approach

- Very high Q components
  - Q > 300
  - Digitally controlled
  - Small size & High linearity

Key Components with Qs of 300 to 2000

Super Q Inductor
- Low cost & miniature size

Highly Linear Variable Capacitor
- 8 or 10-bit control word for precise filter settings

Both Components Verified
Courtesy of NewLANS
NewLANS Tunable Filter Approaches

The connectivity support isn’t shown to simplify the drawing

Optional

Tunable filter for TDD bands 38, 39, 40, & 41

Courtesy of NewLANS
The connectivity support isn’t shown to simplify the drawing.

Tunable notch filter to address the harmonic issues for the various CA and coexistence scenarios.

Courtesy of NewLANS.
NewLANS Tunable Filter Approaches

The connectivity support isn’t shown to simplify the drawing.

Optional

Please note the lower throw counts.

Courtesy of NewLANS
NewLANS Tunable Filter Approaches

The connectivity support isn’t shown to simplify the drawing.

Optional

Digitally programmable RX filters & matching networks

Courtesy of NewLANS
Product Roadmap for Tunable Components

Source: Yole
Summary

- 4G wireless communication brings new challenges to the RF front-end modules/components.
- RF SOI is the mainstream technology for antenna switches presently.
- RF SOI technology also offers the possibility to develop tunable/reconfiguration RF FEMs for 4G devices. This includes tunable antenna, tunable PA and tunable filters.

“4G is a journey, let’s make it TUNABLE”