ST H9SOI_FEM:
0.13um RF SOI Technology for Front End Module Monolithic Integration

Pietro Maestri, RF Product Line Director
SOI Consortium Forum, Tokyo, January 21st, 2016
Mobile RF Evolution driven by LTE

**RF band proliferation**
- The exponential growth of mobile data has driven up wireless spectrum need
- 3GPP Release 12 standardized in Q1’15: > 40 RF bands
- 3GPP Release 13: RF spectrums from 600 MHz to ~6 GHz (LTE)

**Carrier Aggregation (CA) combinations are proliferating**
- Carriers in within the same RF band or across multiple RF bands
- Current LTE CA FEM degrading RF performances Vs classical LTE FEM
- CA band combinations: 28 for 3GPP Release 11
  115 for 3GPP Release 12

**Antenna proliferation / challenge**
- Primary & secondary antennas to support 3G Rx Diversity & 4G MIMO
- Extended RF bands support forcing to LB / MB / HB / multi-feed antennas
- Transmit antenna swap to optimize uplink performance at cell edges, avoiding dropped calls

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RF SOI adoption in FEM

- RF SOI market growth (> 25% AGR) still driven by the RF Switch!
  - RF SOI is the most viable technology
  - RF SOI widely used for Antenna Switches, Diversity path, PAD, Antenna tuner

- RF SOI quickly gaining ground against GaAs in PA market

- RF SOI is driving the FEM integration thanks to:
  - Fully Integrated solution
  - Smart and reconfigurable Front End
  - Better Insertion loss and linearity for RF Switch
  - Better matching capability
  - Cheap process using large volume CMOS fabs
RF SOI FEM Integration: The Next Step

Front-End integration is the path for small, high performing and cost effective solutions to address 3G LTE/4G CA and Wi-Fi 802.11ac

Benefits of Monolithic Integration

- Reduced size and cost
- Improved performance
  - Reducing inter-die signal routing and constrains of MCM
  - Taking advantage of shorter and faster on die interconnection
  - Avoiding non predictable behavior in interfacing devices independently designed
- Simplified supply-chain
- Reduced and simplified product development cycle time

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ST Value Proposition

ST is **fully committed** to RF SOI technology with its **H9SOI_FEM** providing to the market a **long term technology roadmap** and **high capacity** foundry services.

### Technology Partner
- Technology Roadmap
  - Substrate, IP, Process
- Design Expertise
- Design Services
  - Modeling, Packaging, Testing

### Performance & Integration
- Switch \( R_{on,Coff} \), Linearity
- Power Amplifier Efficiency
- LNA low noise figure
- On-board Filtering

### Top Class Manufacturing
- High quality fabs
- Scalable Capacity
- Best in Class TTM & customer service

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**H9SOI_FEM**

High performance Technology developed for FEM integration

ST H9SOI_FEM maintains best RF Switches performances when integrating PA and LNA devices

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### H9SOIFEM Roadmap

<table>
<thead>
<tr>
<th><strong>Switch Device</strong></th>
<th><strong>2015</strong></th>
<th><strong>2016</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ron*Coff</td>
<td>185fs</td>
<td>170fs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Switch Perf</strong></th>
<th><strong>2015</strong></th>
<th><strong>2016</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular SP9T</td>
<td>0.4dB @1GHz</td>
<td>0.3dB @1GHz</td>
</tr>
<tr>
<td>Cellular LTE 3G/4G</td>
<td>0.25dB @1GHz</td>
<td></td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th><strong>Cellular Power PA</strong></th>
<th><strong>2015</strong></th>
<th><strong>2016</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>maxPAE Gain 3G PA FoM</td>
<td>73% 14dB</td>
<td>77% 14dB</td>
</tr>
<tr>
<td>Interleaved Cascode Gen 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>LNA</strong></th>
<th><strong>2015</strong></th>
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<tbody>
<tr>
<td>GO1 MOS 0.13um/1.2V</td>
<td></td>
</tr>
<tr>
<td><strong>NFmin</strong></td>
<td><strong>2015</strong></td>
</tr>
<tr>
<td>0.4dB @2GHz, fully compatible with all Switch options</td>
<td></td>
</tr>
</tbody>
</table>

(*) Pin: 26dBm

**Beyond Device FoM, ST roadmap is driven by standards evolution and performances in application**

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H9SOI_FEM BEOL Stacks

M3ALU

2.5 µm
12 mΩ/☐

54 mΩ/☐
M2

155 mΩ/☐
M1

R☐=9.23 mΩ/☐

M4ALU

2.5 µm
12 mΩ/☐

54 mΩ/☐
M3

54 mΩ/☐
M2

155 mΩ/☐
M1

R☐=7.88 mΩ/☐

M4TC

1.2 µm
25 mΩ/☐

4 µm Cu

5 mΩ/☐

R☐=3.67 mΩ/☐

M3TCTA

4 µm
7.5 mΩ/☐

4 µm Cu

5 mΩ/☐

R☐=2.65 mΩ/☐

Aluminium BEOL

Thick Copper Options

4 different BE stacks → 4 different DK in a single Design Flow

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H9SOI_FEM RF Switch performances

Available in DK
Qualified for production

Ron Level (Ohm.mm)

Lower Ron = Better Harmonics

Best \( R_{on} \) of the market, H9SOI_FEM RF Switches
Low Ron has strong factor of merit on top of Low Ron*Coff

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State of the art RF Switch performances for both Cellular and Wi-Fi

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GO1 0.13 µm MOS optimized for LNA

- 1.2V / GO1 gate oxide
- Very low noise figure measurements:
  - 0.4 dB @ 2 GHz
  - 0.6 dB @ 6 GHz
- >0.4 dB better than 0.18µm lithography

0.13µm 1.2V MOS allows best in class Cellular LNA performances
(Wide band LTE requirements and WiFi high frequencies)
CMOS SOI PA Challenges and Success

A Power Amplifier is a solution based on technologies, transistors, passives, biasing, control circuits, and innovation to provide an amplified signal to an output load.

<table>
<thead>
<tr>
<th>Cellular 3G/4G PA</th>
<th>Meas</th>
</tr>
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<tbody>
<tr>
<td>Power Gain (28dBm)</td>
<td>27.5 dB</td>
</tr>
<tr>
<td>Pmax</td>
<td>31.2dBm</td>
</tr>
<tr>
<td>P1dB (average)</td>
<td>30.5dBm</td>
</tr>
<tr>
<td>PAE@28dBm 2 stages</td>
<td>39%</td>
</tr>
<tr>
<td>PAE max</td>
<td>50%</td>
</tr>
<tr>
<td>ACLR 5MHz@28dBm</td>
<td>-41dBc</td>
</tr>
<tr>
<td>ACLR 10M@28dBm</td>
<td>-54dBc</td>
</tr>
<tr>
<td>Factor Of Merit (FOM) ACLR + PAE @ 28 dBm</td>
<td>80</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Wi-Fi PA</th>
<th>Meas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain at 21dBm @ 5.9 GHz</td>
<td>12.6 dB</td>
</tr>
<tr>
<td>ICC at 21dBm</td>
<td>165 mA</td>
</tr>
<tr>
<td>Pmax @ 5.9 GHz</td>
<td>28 dBm</td>
</tr>
</tbody>
</table>

Best in Class Cellular RF SOI 3G/4G PA performances (FoM=80) Wi-Fi PA key parameters demonstrated @ 5.9 GHz

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H9SOIFEM Design Ecosystem

- Active devices: MOS transistors Pcells for RF SWITCH, LNA and PA
- High Quality Factor Passive devices Pcells: inductances, capacitances
- 4 metal stacks to address all applications specificities

Close collaboration with major EDA companies to provide state-of-the-art tools

- ESD KIT Library
- Pads Library (WB, FC, WLCSP)
- 2.5V Standard cells and IOs library compatible with MIPI (MIPI IP available)
- Digital Cadence Flow

- Substrate Modeling Task Force to develop CAD tools addressing Hx < -95dBm
- Fully integrated Thermal Simulation CAD Flow under development

NEW January 26, 2016
More than a pure foundry, a long term partner with a global manufacturing structure

Dedicated R&D activity (process, design, tools) to develop specific devices in partnership

RF SOI Power devices

Experienced Supply Chain handling Billion Units/year

Customer-Oriented Service & Support Failure Analysis

Assembly & Packaging Facilities

Industrialization Expertise

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Summary : ST Added Value

- Excellent RF Switch Linearity
- Outstanding RF SOI PA Factor of Merit : 80
- Complete integration (LNA, Switch, PA, filtering) with no performance compromise
- Very Predictive silicon behavior from accurate modeling
- Reliable process with very short Cycle time (prototyping / production)

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