RF Front End Challenges for 3G/4G Wireless Handsets

Semicon China
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Shanghai, China
Outline

• Cellular Handset Markets
• RF Front End Architectures
• Design Challenges
  • Multiple Frequency Bands
  • Interference
  • High Order Modulations
  • Cost and Size
• Future Technology Outlook
An Idea that Changed the Whole World
Mobile Phone Today = Mobile Internet
50 Billion Connections by 2020
Projected Cellular Device Shipments (in billions)
Mobile Device Unit Shipments

3G/4G Smartphone Growth Remains Strong

3G Entry Mass Market Smartphone Growing Rapidly

Cellular Data Devices Growing Rapidly

11% CAGR

<table>
<thead>
<tr>
<th>Year</th>
<th>2G Entry</th>
<th>3G/4G Smartphone</th>
<th>3G Feature, Entry Smartphone</th>
<th>Tablet, M2M</th>
</tr>
</thead>
<tbody>
<tr>
<td>CY10</td>
<td>1,352</td>
<td>135</td>
<td>167</td>
<td>311</td>
</tr>
<tr>
<td>CY11</td>
<td>1,337</td>
<td>190</td>
<td>277</td>
<td>444</td>
</tr>
<tr>
<td>CY12</td>
<td>1,290</td>
<td>480</td>
<td>506</td>
<td>480</td>
</tr>
<tr>
<td>CY13</td>
<td>1,170</td>
<td>557</td>
<td>726</td>
<td>557</td>
</tr>
<tr>
<td>CY14</td>
<td>1,000</td>
<td>654</td>
<td>925</td>
<td>654</td>
</tr>
</tbody>
</table>

3G, 4G Shares
Mobile Wireless Technology Trends

- Higher peak data rates and throughput
  - Higher order modulation
  - Wider bandwidth
  - Multi-carrier
  - MIMO
- Higher spectrum efficiency
- Low cost per bit
- Low delay/Latency
4G Standards

- Peak Data rate
  - 1Gbps
- Peak spectrum efficiency:
  - DL: 15bps/Hz
  - UL: 6.75bps/Hz

- January, 2012, ITU-R approved both LTE-Advanced and WiMAX Release 2.0 (802.16m) as IMT-Advanced standards.
Mobile Data Anyone Anywhere Anytime Anytime
• Governments cannot agree
• 43 Bands; 700MHz to >3500MHz
Mobile Data Forecast & Frequency Band Proliferation

Figure 1. Cisco Forecasts 3.6 Exabytes per Month of Mobile Data Traffic by 2014

TB per Month
3,600,000

108% CAGR 2009-2014

Device Shipments (millions)
700
600
500
400
300
200
100
0

0.09 EB per mo
0.2 EB per mo
0.6 EB per mo
1.2 EB per mo
2.2 EB per mo
3.6 EB per mo

2009
2010
2011
2012
2013
2014

4G Band Combo Forecast

RFMD
What’s Inside Cellular RF Front Ends

- RF Power Amplifiers
- RF Switches
- Receive Filters
- Transmit Filters
- Duplex Filters
2007 iPhone QBE ~200mm²
2010 iPhone QBE, 4 WCDMA ~500mm² (DCDC not pictured)
2011 iPhone QBE, 4 WCDMA ~380mm²
2011 PowerSmart™ QBE, 5 WCDMA <300mm²
Mobile Data Drives RF Content

~$1
2G

$4-6
3G

$6+
4G

$4-$6

Accelerating growth in RF content

~$1 2G
$4-6 3G
$6+ 4G
New Band Challenges on Solution Size

Challenges
- Different standards
- Different band combinations
- Different mobile operators
- More PAs, filters, duplexers and switches

Some Solutions
- Multi-mode, multi-band PA
- Broad band PA
- Supply modulator
  - APT
  - ET
RF Architectures for Multi-Mode, Multi-Band LTE Devices

2010 - 2011

Diversity Switch

Antenna Switch Module

Broad bandwidth Power Core (PA + PA PMIC)

2011 - 2012

Rx Diversity Module

Diversity Switch

Antenna Tuning

Filter Bank

2G/3G/4G MM/MB PA

4G SB / MB PA(s)

PA PMIC

Antenna Switch Module

High Performance LTE-capable Antenna Switch Modules

Antenna tuning
B38 & B40 WiFi/BT Coexistence?
TX Post PA SAW Filters or a Low Pass Filter?
Co-Existence Requirements

2300 MHz

B40: 2300–2400 MHz

2401–2483 MHz

2402–2480 MHz

WiFi

Bluetooth

FDD LTE

B7: UL 2500–2570

DL 2620–2690 MHz

TD-LTE

B7: UL 2500–2570

DL 2620–2690 MHz

B38: 2570–2620 MHz

B41: 2496–2690 MHz

XGP: 2545–2575 MHz (Japan)

Insertion loss at band edge maybe increased to 4 dB
## Switches Requirements

**Impact on Band 7 LTE:**

- **BW**
- **Max Noise Floor @ Cellular Antenna @ BW**
- **Budget for IIP2 products into GPS**

<table>
<thead>
<tr>
<th></th>
<th>Cellular antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WIFI TX</strong></td>
<td>2400-2484 MHz</td>
</tr>
<tr>
<td><strong>Band 7 TX</strong></td>
<td>2500-2570 MHz</td>
</tr>
<tr>
<td><strong>Band 7 RX</strong></td>
<td>2620-2690 MHz</td>
</tr>
<tr>
<td><strong>Required IIP3</strong></td>
<td></td>
</tr>
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- **Super High Linearity**

- **Low Insertion Loss**
Increasing RF Spectral Efficiency


- 4G (LTE/OFDM): About 7:1 (8.5dB), Peak to Average,
  ~30% PA Efficiency
- 3.5G (HSUPA): About 5:1 (6.5dB), Peak to Average,
  ~35% PA Efficiency
- 3G (WCDMA): About 2:1 (3.5 dB), Peak to Average,
  ~45% PA Efficiency
- IS-95B cdmaOne
- IS-95A cdmaOne
- GSM
- GPRS
- EEDGE
- TD-SCDMA
- WCDMA

Spectral Efficiency/Data Rate

Time
Data Requires More Power

* From Nujira white paper
More or Less Power?

Carrier aggregation technique results in higher PAPR

PAPR before aggregation: 5.79 dB
PAPR after aggregation: 6.86 dB
Efficiency Degradation

- Linear PAs are required by EDGE, CDMA, WCDMA and LTE
  - Signals have both amplitude and phase information
- Higher PAPR → More back off → Efficiency Reduced
- Power amplifiers must backed off for linear amplification with an associated reduction in efficiency

LTE ~26% efficiency at 7 dB back-off
2.3 – 2.7GHz LTE Band Requirements
Global QB LTE

- More than 45% of world’s population (i.e. China, India, USA, Russia, Japan, Europe) covered by 2.3-2.7GHz bands.
- More than 1B potential customers served by those bands.
- Other independent research indicates that 25% of operators will use 2.3-2.7GHz spectrum for LTE deployments.

Operator LTE deployment survey (Courtesy of GTI, Informa Telecoms & Media Ref3)
Adaptable Front-Ends: Fact or Fiction?

Architecture Simplification in 3G/4G Front Ends

Current Multi-Mode Tx Architecture

From multiple PA and Switch die in multiple modules

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Signal Routing/Filtering

Single Tx Chip
All band, all modes

Adaptive Tx Architecture

To single tunable PA transmitter

Reducing cost and size while improving performance