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Power Amplifier and Front-End Module Technology for 3.9G LTE/EUTRAN applications

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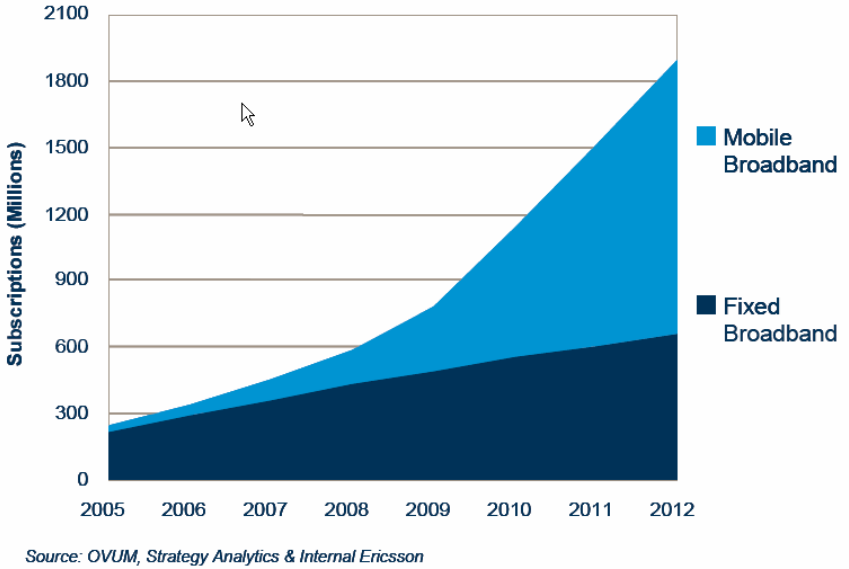
Outline

- Introduction – LTE
- RF Hardware requirements
- Device and Technology Solutions
- Summary

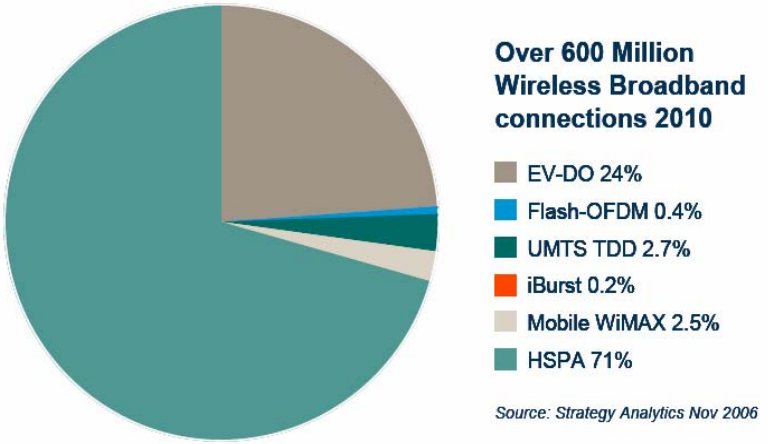
LTE/EUTRAN Basics

- LTE = Long Term Evolution (of the WCDMA/HSPA 3GPP standards)
- EUTRAN = Evolved Universal Terrestrial Radio Access Network



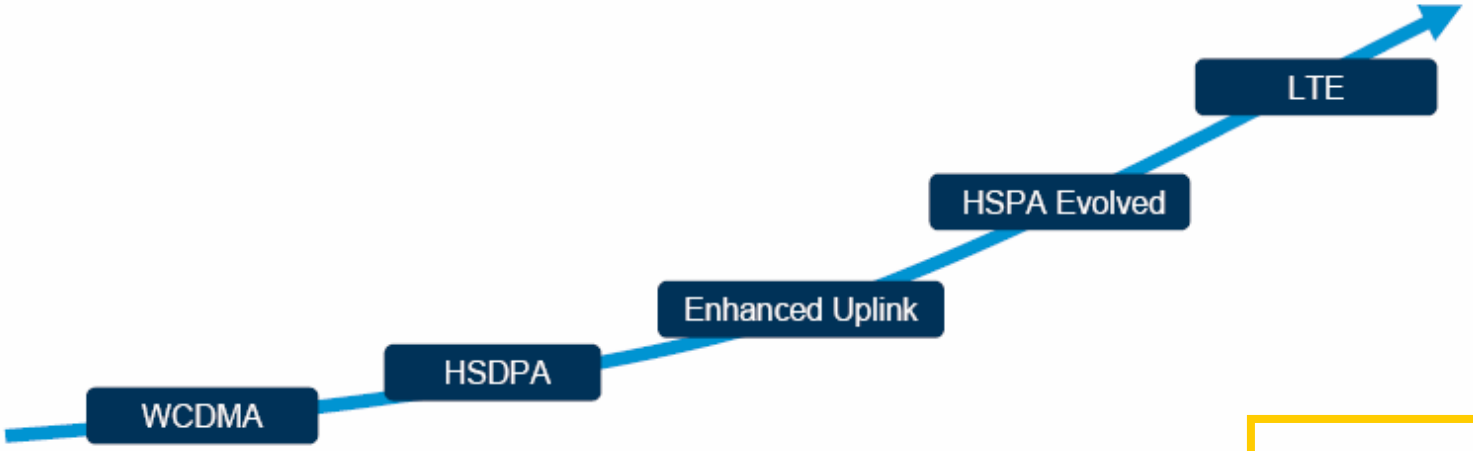
Source: OVUM, Strategy Analytics & Internal Ericsson

- Mobile broadband technology
- Higher data rates (and capacity)
- Improved quality of service and latency
- Greater coverage



Source: Strategy Analytics Nov 2006

Evolution of 3GPP Family Standards

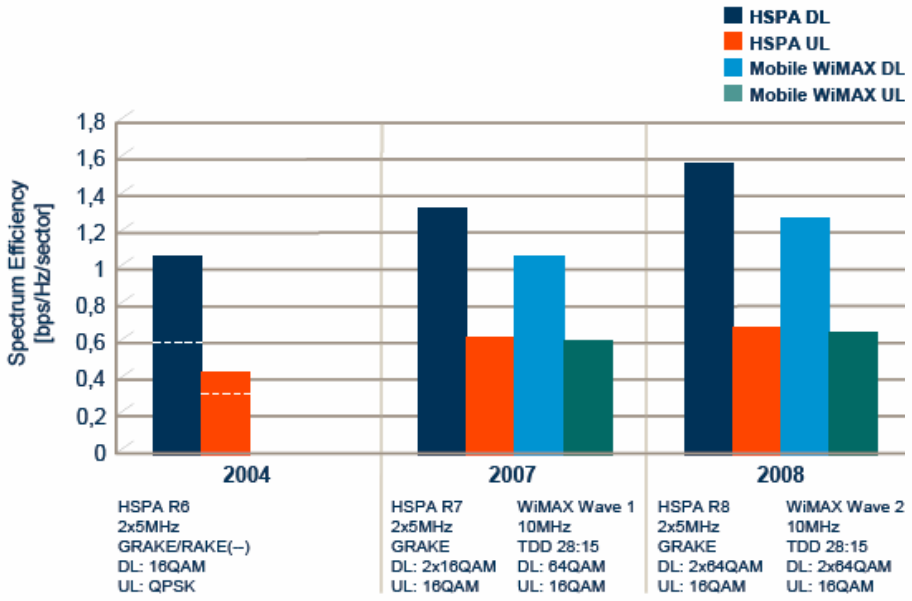


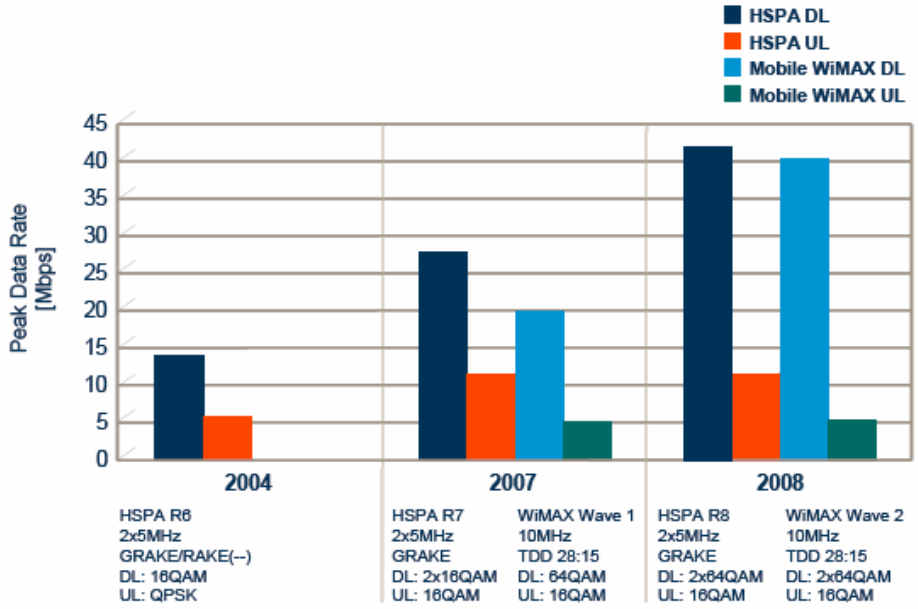
3GPP	R99/1999	R5/2002	R6/2005	R7/2007*	R8/2008**
Peak	0.384 Mbps DL	14 Mbps DL	14 Mbps DL	28/42 Mbps DL*	160 Mbps DL
Data Rate	0.064 Mbps UL	0.384 Mbps UL	6 Mbps UL	12 Mbps UL	50 Mbps UL
Commercial Availability	2001	2005	2006	2008	2009

*Expected: 28Mbps with MIMO, 42 Mbps with MIMO + 64QAM
**Expected: LTE specification ready end 2007

Source: Ericsson White Paper "HSPA, the undisputed choice for mobile broadband", May 2007

Spectral Efficiency and Peak Data rates of LTE vs. WiMAX





Source: Ericsson White Paper "Technical overview and performance of HSPA and Mobile WiMAX", September 2007

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LTE vs. WiMAX

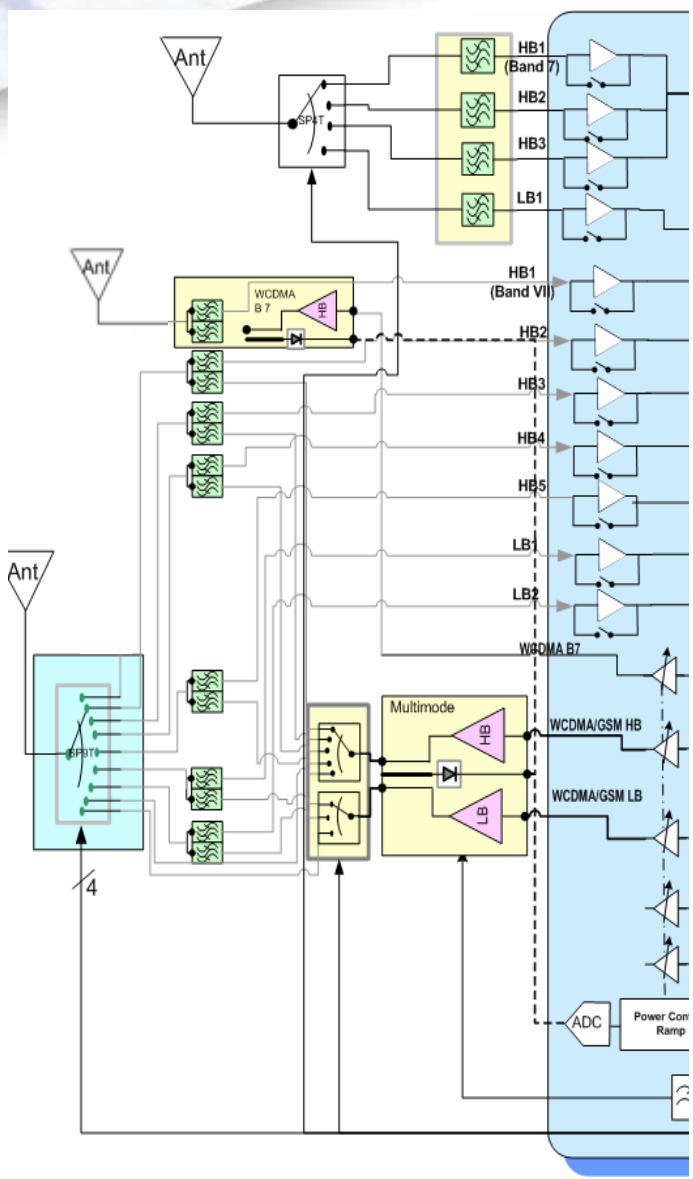
- **Similar: Network architecture, peak data rates, spectral efficiency**
- **Superior for LTE:**
  - Coverage (~2X fewer base stations required for equivalent BW)
  - Link budget
    - **Higher power 24dBm vs. 23dBm**
    - **FDD vs. TDD: higher average power due to continuous transmission**
  - Existing GSM network sites, Software upgrade to existing WCDMA network
  - HSPA: proven technology deployed in >100 networks worldwide
  - Lower cost of deploying the network (70% cost of land to place the BS's)

	HSPA	Mobile WiMAX
Physical signal format	DL code aggregation, UL DS-CDMA	OFDMA for both DL and UL
Hybrid ARQ with soft combining	Adaptive IR + Chase combining	Chase combining
Multi-level QoS	√	√
Link adaptation	QPSK, 16QAM, 64QAM Lowest code rate: 1/3	QPSK, 16QAM, 64QAM Lowest code rate: 1/2
Duplex scheme	FDD	TDD
Frequency bands	850MHz to 2,600MHz	2.3GHz, 2.6GHz and 3.4–3.8GHz
Handover	Hard handover, Soft handover	Hard handover
Frequency reuse one	√	√
Advance antenna technologies	• Closed- and open-loop transmit diversity • Spatial multiplexing • Beam-forming	• Open-loop transmit diversity • Spatial multiplexing • Beam-forming

LTE Adoption, Frequency Bands

- **Initial Deployment targeting Band VII (2.6 GHz)**
  - First LTE phone call by EMP (Feb 2008, 3GSM)
  - Nokia “real world” LTE testing in 2.6GHz band
- **Followed by adoption in other bands is expected**
- **Recent US Auction of 700 MHz spectrum will result in accelerated LTE development and deployment in Bands XIII and XII**
  - $16B spent by Verizon and AT&T on licenses
  - Participation and strong push by Google for “open access” zone

Front-End Architectures Including LTE



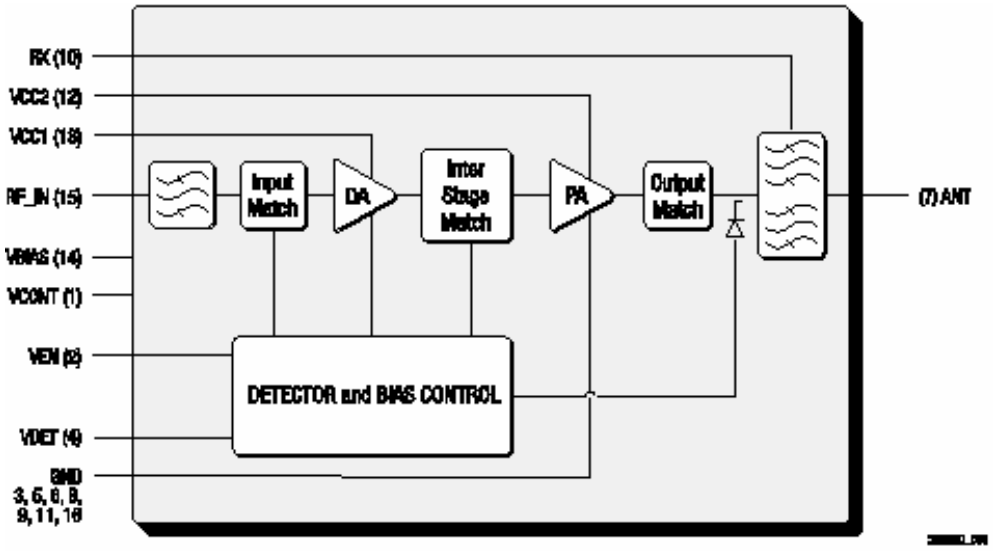
- **Dedicated Band VII RFIC output and Amplifier chain**
- **Likely a dedicated Antenna for Band VII: 2.6GHz hard to match with all other bands on one Antenna**
- **Diversity RX supporting LTE MIMO**
- **Long-Term: Multi-Mode and Multi-Band PA's supporting LTE in multiple bands**

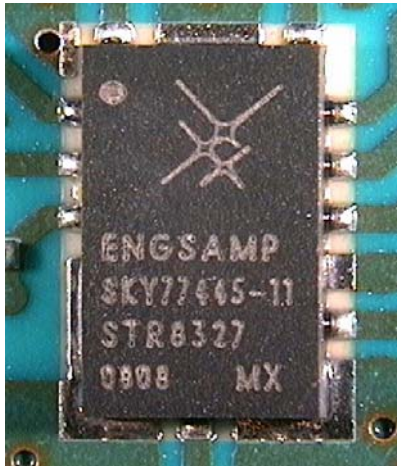
RF Hardware Requirements

- **Transceivers**
  - MIMO: Lower noise floor → higher RX sensitivity required
  - 2.6GHz: higher frequency and more difficult to get high linear power with low cost Si technology
- **Linear Power Amplifiers**
  - More stringent linearity requirements, compared to HSDPA
  - Higher Peak-to-Average-Ratio
  - More challenging linear efficiency requirements
- **Linear Front-End Switches**
  - Higher Linearity (IMD, IP3) required, compared to WCDMA, because of higher RX sensitivity and lower RX noise floor
- **High Quality Filters**
  - Higher and lower frequency than conventional WCDMA with as challenging % BW and narrow TX-RX separation
  - Higher Linearity required, as in the case of switches

SKY77445 – Industry's First Band VII Front-End Module for LTE/EUTRAN 3.9G

- **Fully matched, highly integrated 4x7x1.2 mm module containing:**
  - Inter-stage filter
  - Input matching
  - Power amplifier
  - Output matching
  - Power detection
  - Duplexer
- **Supports Band VII LTE/EUTRAN requirements:**
  - QPSK, 16QAM, 64QAM modulations
  - 1.25, 2.5, 5, 10, 20MHz bandwidths
  - Up to 100 resource blocks
  - >23dBm linear power at 3.3V
  - Excellent isolation: typ. >50dB TX-RX
  - Excellent linearity: typ. EVM<3%
- **State-of-the-art technologies:**
  - BAW Filters
  - InGaP BiFET PA
  - MCM Packaging

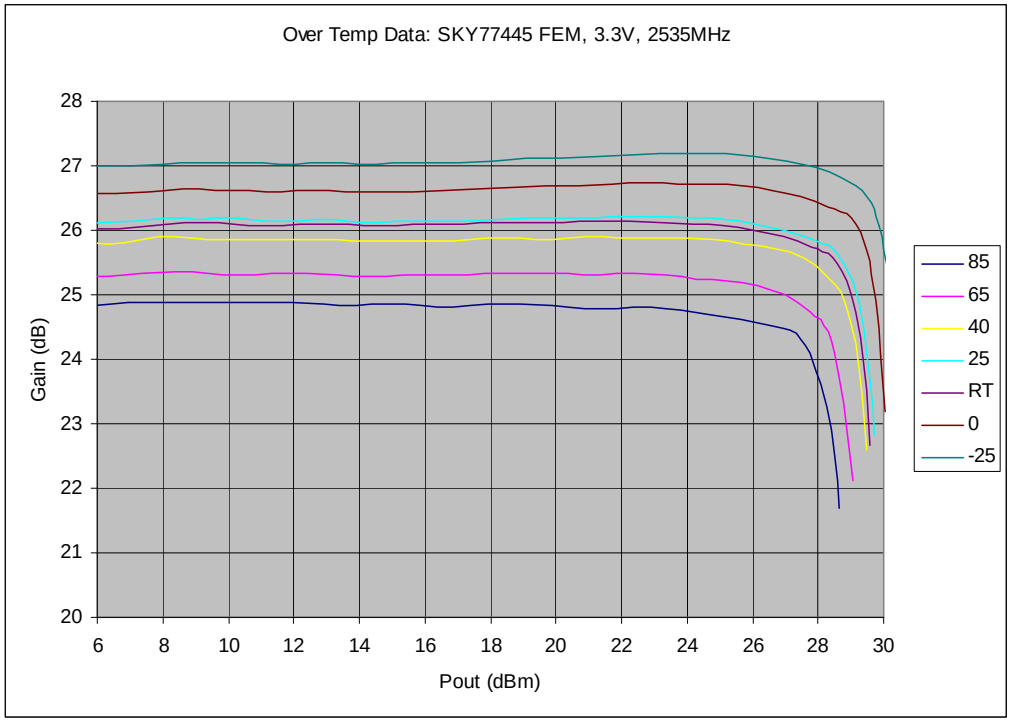




State-of-the-Art FEM, 50% smaller than individual components combined

Optimization for High Gain

- **FEM integration:**
  - allows optimal in-band and out-of-band matching between individual components
  - not necessarily at 50 Ohms
- **Results in improved link budget and high gain**
- **Individual components don't need to be over-specified (e.g. meet all specs over VSWR)**
- **Less stringent Transceiver requirements**



Linear Operation at 4-5dB back-off from P1dB

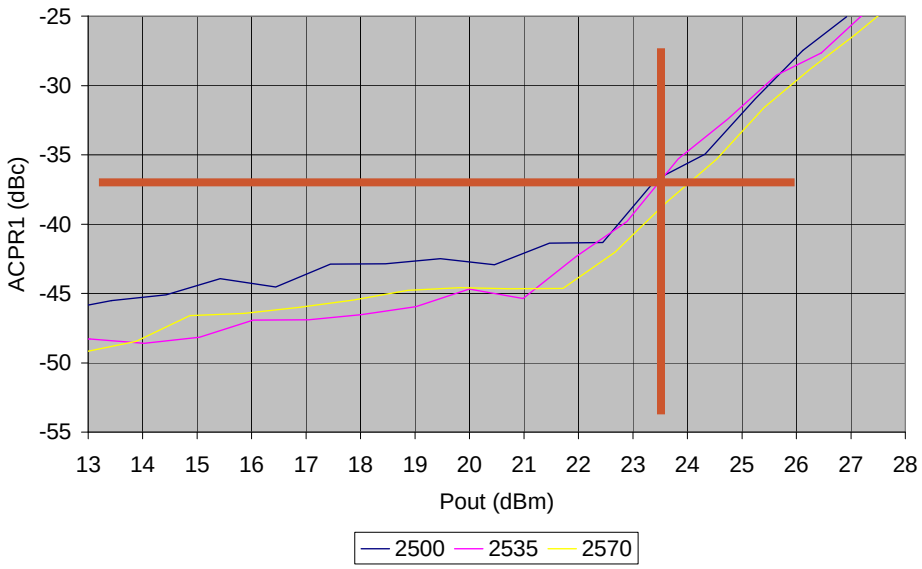
Integration Resulting in Optimal Performance

FEM Linearity Performance (ACPR1)

LTE and WCDMA: 3.3V, 2500, 2535 and 2570 MHz

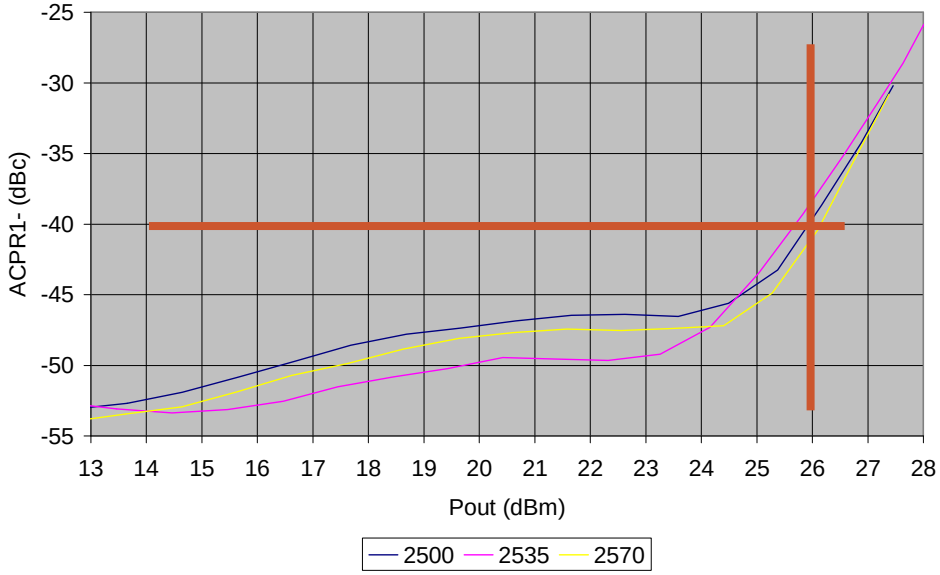
LTE

ACPR1: LTE-16QAM-10MHz-50RB



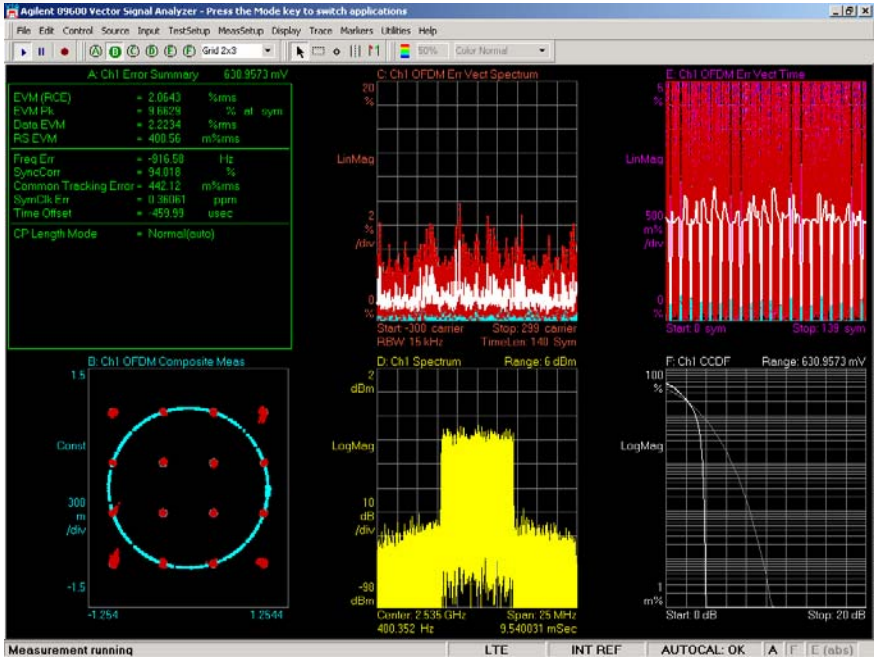
WCDMA

ACPR1: WCDMA

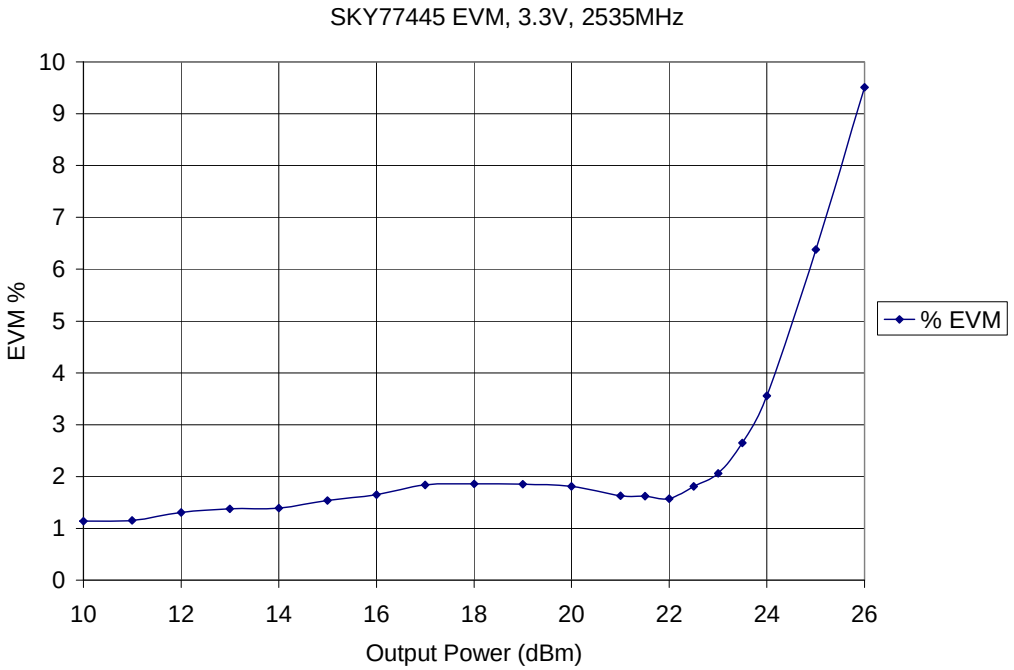


~2.5-3dB higher WCDMA linear power required to meet LTE linearity

FEM EVM Performance
16QAM, 10MHz BW, 50 Resource Blocks



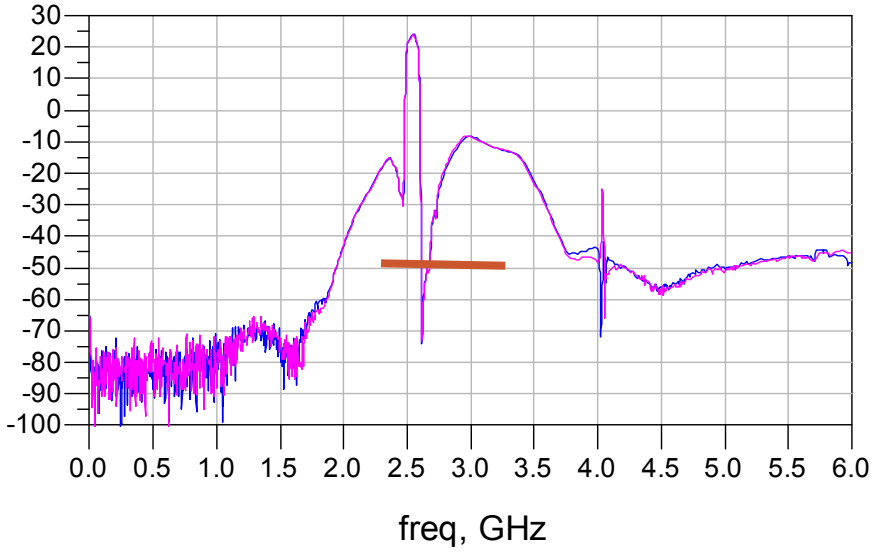
Pout = 23dBm



GaAs BiFET Technology – Key Enabler to Achieving PA Linearity

Small-Signal Performance

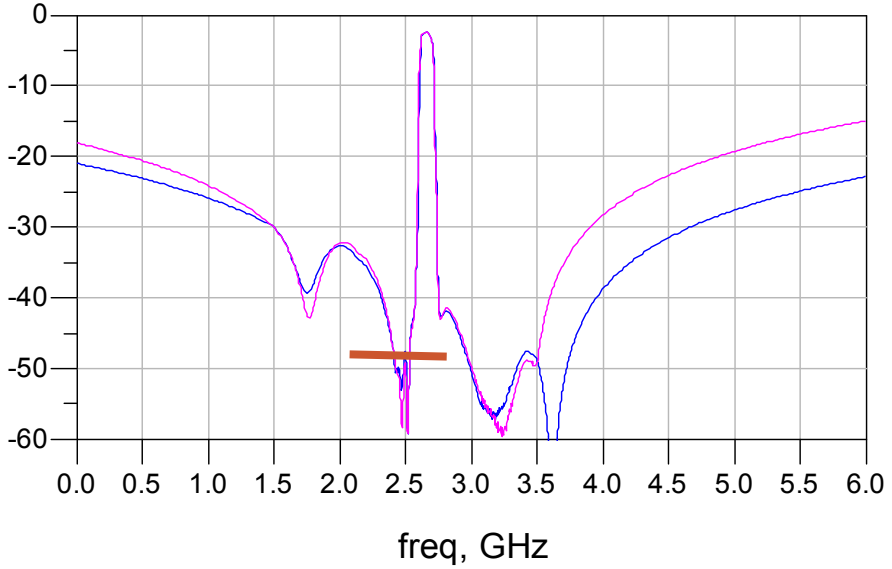
TX



>70dB transition over 50MHz !

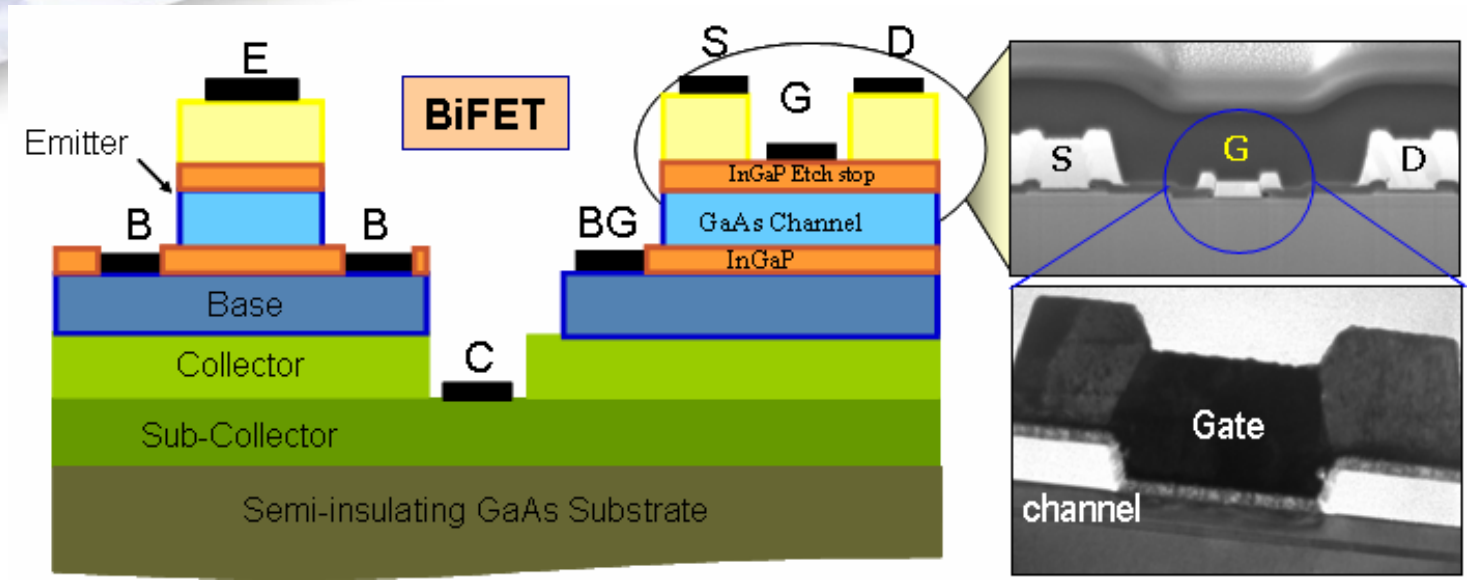
To achieve excellent TX attenuation in RX Band

RX



BAW Filter Technology – Key Enabler to Achieving Low Filter Loss with Excellent Out of Band Attenuation and Isolation

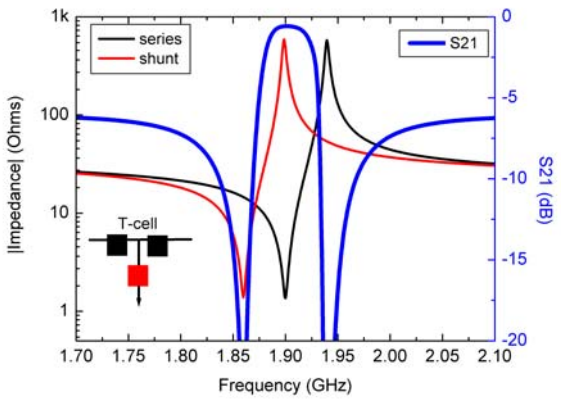
BiFET Technology

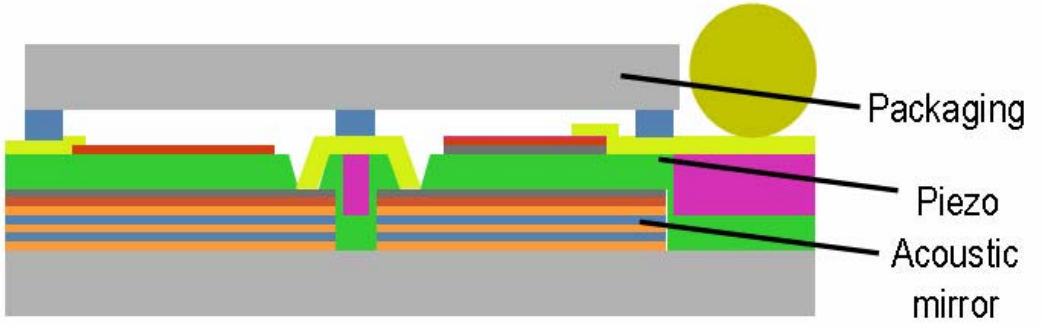


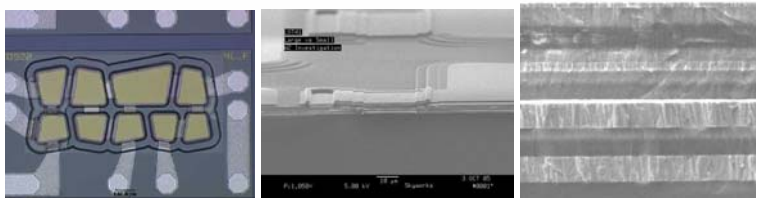
- **MESFET added to baseline HBT process with minimal cost/yield impact**
- **Additional masking layer for channel definition, gate definition integrated into HBT flow**
- **Enables advanced bias network approaches for low voltage high linearity amplifiers**
- **Is extensively used in CDMA, WCDMA, WiFi, WiMAX and LTE PA and FEM products**

Enables Excellent FEM Linearity/Efficiency Performance

Bulk Acoustic Wave (BAW) Filter Technology







- <u>Electromechanical filter technology:</u>
- Electrical signals and vibration are coupled in piezoelectric materials (like Quartz.)
- BAW resonators are piezo-based sound-trapping structures fab'd using VLSI methods.
- Thickness of resonators dictate at which frequencies electrical signals can pass.
- Layout of resonator network into a filter determines specific pass/reject characteristics.

Enables Excellent FEM Loss/Rejection Performance

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Summary

- LTE is the next big standard (4G) after GSM and WCDMA
- Industry's First Front-End-Module for Band VII LTE applications was introduced
- State-of-the-art performance is achieved via integration and optimal matching of individual components and use of advanced technologies, such as GaAs/InGaP BiFET and BAW Filter