Center of Excellence
WIRELESS AND
INFORMATION TECHNOLOGY

# Design Drivers for a 3.5G Cellular Modem Optimized for High Performance Mobile Broadband Communications

Robert A. DiFazio, Ph.D.
Fellow, Chief Technology Office
InterDigital



InterDigital®

# Abstract

This presentation provides a brief overview of the latest cellular standards and then focuses on design considerations for a 3.5G cellular modem that includes the new High Speed Downlink and High Speed Uplink Packet Access modes, HSDPA and HSUPA. InterDigital's SlimChip™ product provides the framework. The architecture of the baseband modem is presented along with performance advantages of an advanced receiver with receive diversity. A reference platform is described that establishes the conformance of the end product to industry standards, highlights features of the baseband solution, and demonstrates the feasibility of meeting standard form factors. The initial prototype in an ExpressCard 34 form factor is shown along with evolution to the new Half-Mini Card.

# Biography

- **Robert A. DiFazio**
  InterDigital
- Dr. Robert DiFazio manages the CTO Office at InterDigital where he contributes to advanced 3G & 4G cellular modems, technology planning, expansion/evaluation of the patent portfolio, and collaborative research with universities. He has over twenty-eight years experience in research, design, implementation, and testing of commercial and military wireless systems, including over twenty years at BAE Systems (previously GEC Marconi-Hazeltine). Dr. DiFazio has a Ph.D. from Polytechnic Institute of NYU where he is an adjunct professor. He serves on Industry Advisory Committees for Polytechnic and NYIT, is a Senior Member of the IEEE, and holds over twenty-five issued or pending US patents.

# InterDigital


**35 Year Digital Cellular Technology Pioneer**

Thousands of patents worldwide

Inventions used in every mobile device

**Provider of Mobile Broadband Modem**

High performance baseband ICs, mobile broadband IP, and complete reference platforms

**Key Contributor to Standards**

2G, 3G, and the future – 4G and beyond

Wireless LAN & Mobility/Convergence

**Highly Successful Licensor**

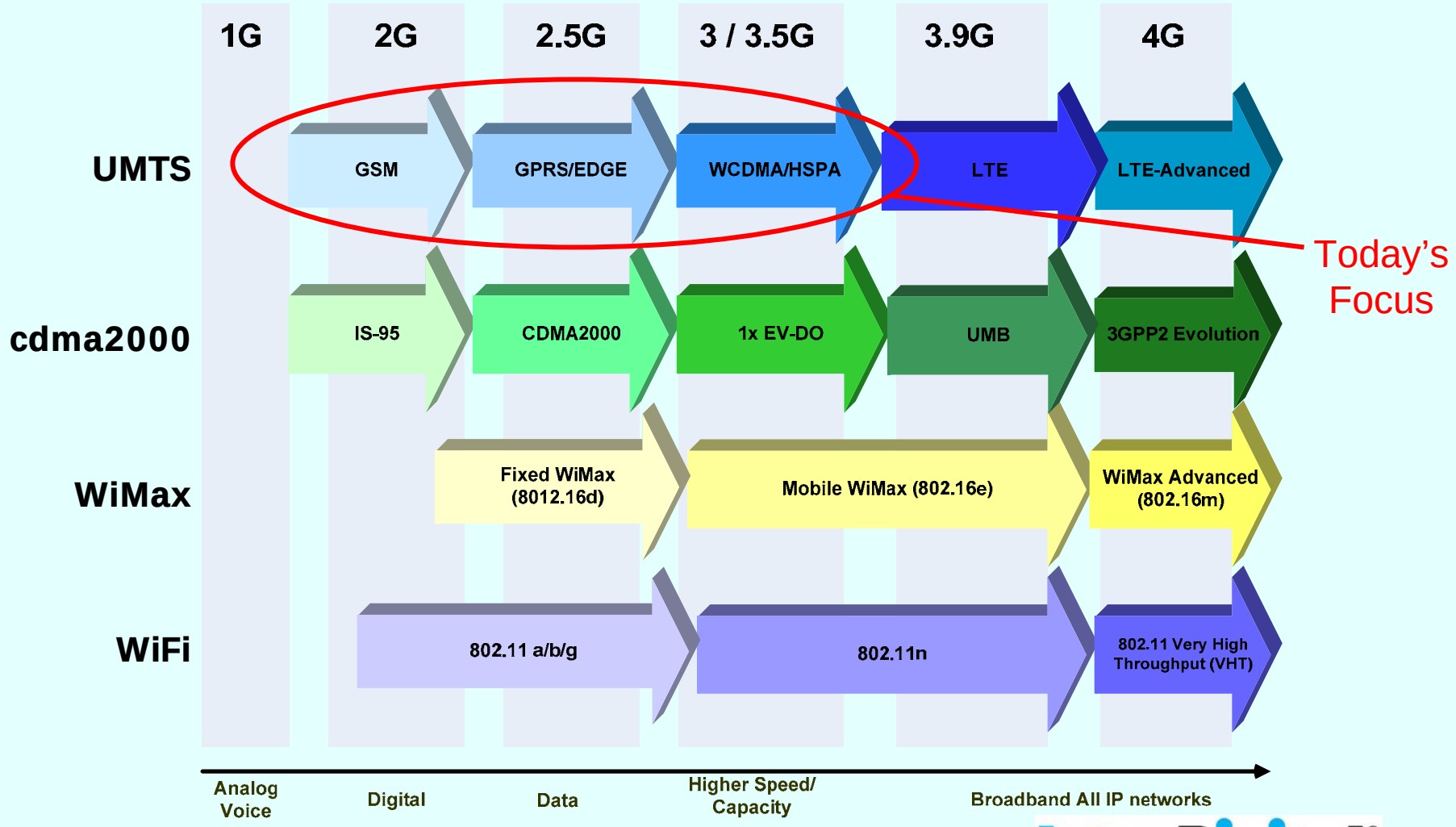
Patents have generated ~ $1.5 billion in cash

Licensing leading manufacturers

# Agenda

- Evolution of wireless standards
  - UMTS, cdma2000, WiMAX, and WiFi
- Broadband cellular modem design drivers
  - 3.5G high-speed packet data
- Building a reference design
  - Requirements, testing, and certification
- Miniaturization
  - Fitting it all in a Half-Mini Card

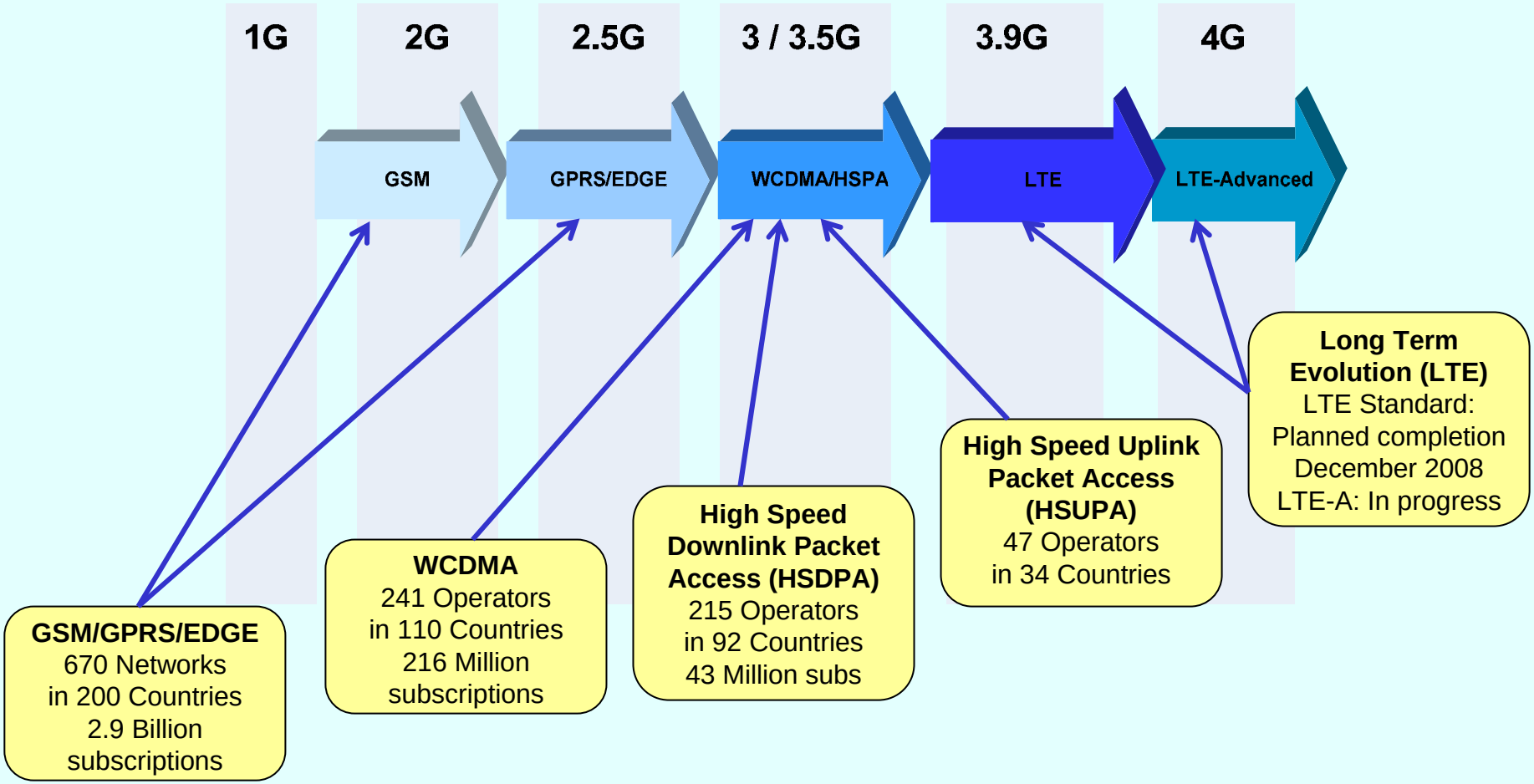
# Evolution of Wireless Standards






InterDigital®

# UMTS Air Interfaces



# HSDPA + HSUPA Enable a Rich Set of Applications

**Downlink intensive services**

- Web browsing, FTP (file download), video/music downloads
- HSDPA boosts downlink throughput and capacity
- Addition of HSUPA enables faster TCP downloads through reduction of latencies

**Uplink intensive services**

- FTP (file upload), MMS, camera picture upload
- HSUPA enables lower latency, higher capacity and throughput

**Symmetric and delay sensitive services**

- Gaming, peer to peer traffic, VoIP, video conference
- HSDPA reduces latency in downlink, HSUPA in uplink
- The addition of HSUPA provides a better balance of links

# High Data Rates, Multicode Operation, and Low Latency Challenge the Modem Design

## HSDPA

| Category | Min Inter-TTI Interval | Max Codes & Modulation | Maximum Data Rate |
|---|---|---|---|
| 11 | 2 | 5 / QPSK | 0.9 Mbps |
| 1,2 | 3 | 5 / 16QAM | 1.2 Mbps |
| 12 | 1 | 5 / QPSK | 1.8 Mbps |
| 3,4 | 2 | 5 / 16QAM | 1.8 Mbps |
| 5,6 | 1 | 5 / 16QAM | 3.6 Mbps |
| 7,8 | 1 | 10 / 16QAM | 7.2 Mbps |
| 9 | 1 | 15 / 16QAM | 10 Mbps |
| 10 | 1 | 15 / 16QAM | 14 Mbps |

## HSUPA

| Category | Max Data Rate TTI: 10 / 2 ms | Max Codes | Min SF |
|---|---|---|---|
| 1 | 0.7 Mbps | 1 | 4 |
| 2 | 1.5 / 1.5 Mbps | 2 | 4 |
| 3 | 1.5 Mbps | 2 | 4 |
| 4 | 2.0 / 2.9 Mbps | 2 | 2 |
| 5 | 2.0 Mbps | 2 | 2 |
| 6 | 2.0 / 5.8 Mbps | 4 | 2 |

# HSPA Evolution

## Higher rates, lower delay, greater spectral efficiency, & low power packet-optimized operation

*New UE categories reflect higher data rates using MIMO & 64QAM in the downlink, plus 16QAM in the uplink.*

| HSDPA / HSUPA | New Feature | Category | Max Data Rate |
|---|---|---|---|
| HSDPA | 64QAM | 13 | 17 Mbps |
| | | 14 | 21 Mbps |
| | MIMO | 15 | 23 Mbps |
| | | 16 | 28 Mbps |
| | 64QAM or MIMO | 17 | 64QAM: 17 Mbps<br>MIMO: 23 Mbps |
| | | 18 | 64QAM: 21 Mbps<br>MIMO: 28 Mbps |
| | 64QAM and MIMO | 19 | 35 Mbps |
| | | 20 | 42 Mbps |
| HSUPA | 16 QAM | 7 | 11.5 Mbps |

# The Next Step: Long Term Evolution (LTE)

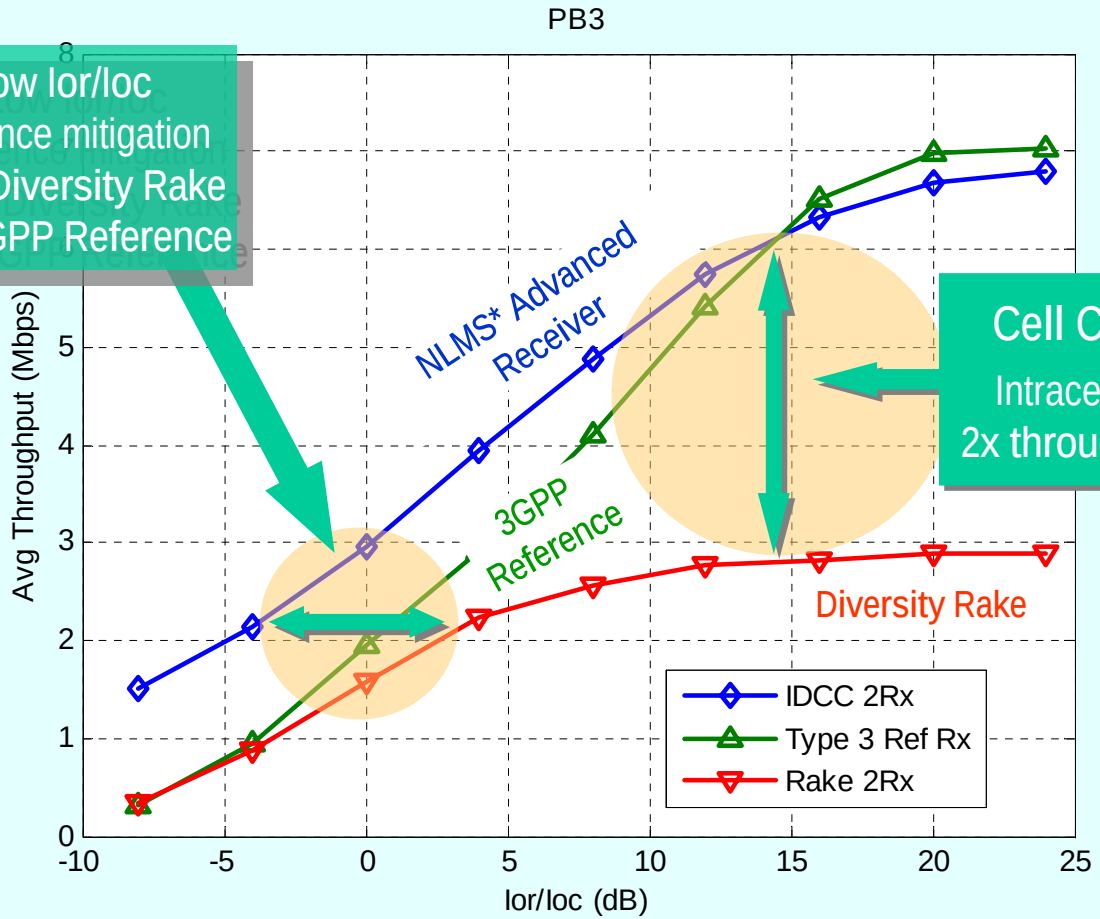
## Wider bandwidths, OFDMA & MIMO

- Air interface parameters promise higher rates and lower latency
  - UE categories with peak data DL rates to 300 Mbps and UL to 75 Mbps
  - Supported bandwidths: 1.25, 2.5, 5, 10, 15, 20 MHz
  - MIMO up to 4x4
  - Radio access network latency goal of under 5ms
- All-IP core network evolves to support seamless interworking
  - Among 3GPP and non-3GPP systems
- Standards approaching maturity
  - Design & performance standards completed in 2008, test requirements in 2009
- Deployment ~2011
  - Field trials and prototypes happening soon
- Work has started on LTE-Advanced
  - Targeting 1 Gbps downlink (8x8 MIMO), 500 Mbps uplink & 100 MHz bandwidth

# An HSPA Modem: Design Considerations and Opportunities

- Air interface performance
  - Scalable advanced receiver structures
    - Chip or symbol-level equalizers
  - Multiple antennas and RF chains
    - Receiver diversity
  - Interference cancellation
- Optimize implementation across layers
  - High-speed processing, memory access and data flow throughout the protocol stack
    - Tight coupling between hardware and software
    - Hardware acceleration supports all layers and minimizes MIPs
  - Power management
    - Active and stand-by power comparable to GSM/GPRS/EDGE

# Advanced Receiver and Receive Diversity Provide Superior Performance Throughout the Cell



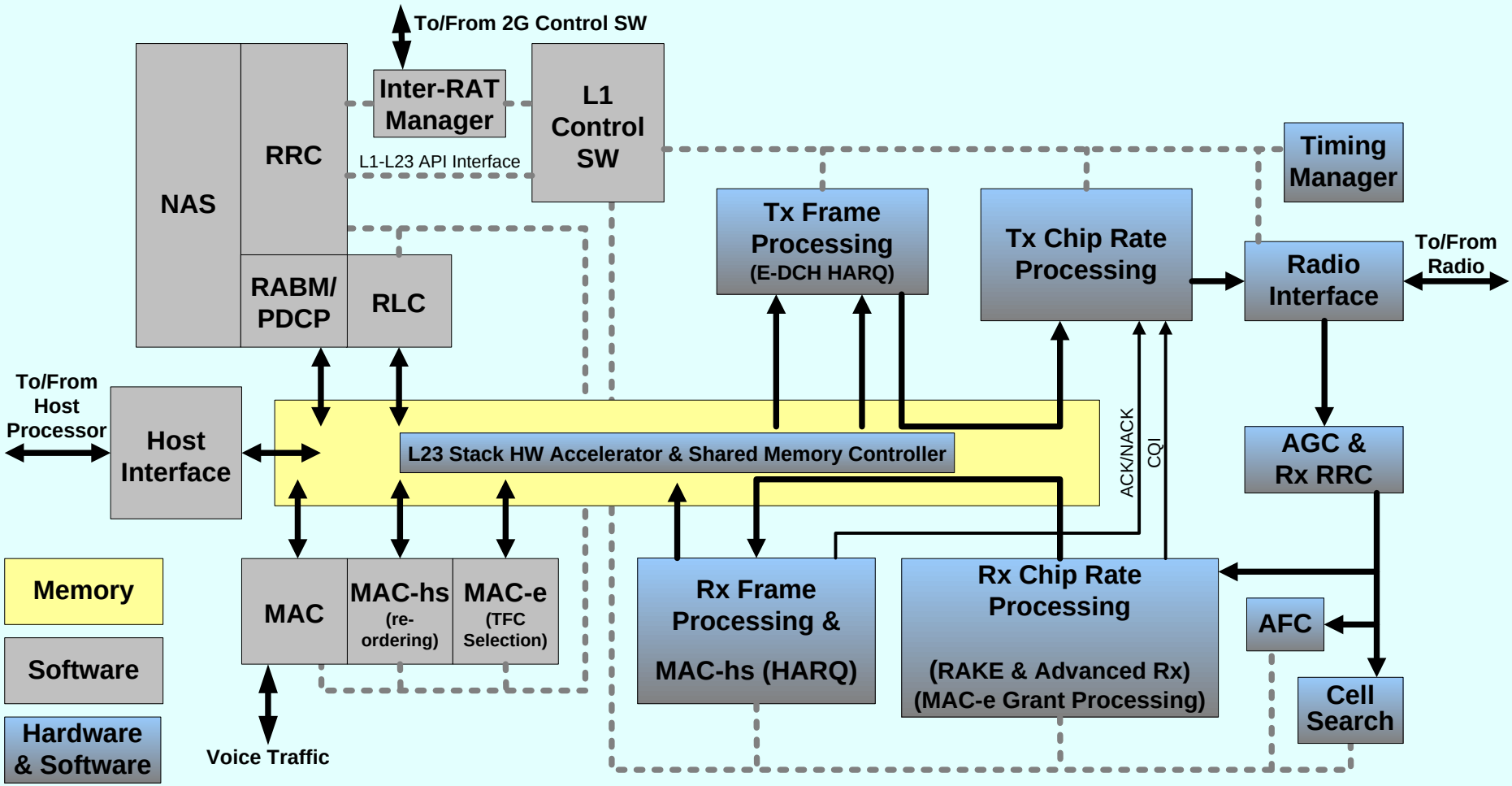

Cell Edge - Low Ior/Ioc
Intercell interference mitigation
~ 7.5 dB gain vs. Diversity Rake
~ 5 dB gain vs. 3GPP Reference

Cell Center - High Ior/Ioc
Intracell interference mitigation
2x throughput vs. Diversity Rake

* Normalized Least Mean Square

HSDPA Cat 8, Pedestrian B Channel, HARQ & AMC ON

# HSPA Modem Block Diagram



# From an HSPA Modem to a Full Set of Dual Mode Reference Design Requirements

## *2G*

- ***GSM / EGPRS (EDGE)***
- Quad-band
  - 850 / 900 / 1800 / 1900 MHZ
- Handoff to/from 3G
- Packet-switched data
  - Multislot (E)GPRS Class 12
  - (E)GPRS Class A Type 2 Mobile Terminal
- Conversational, streaming, background, & interactive QoS classes
- Circuit-switched data
- Single antenna interference cancellation (SAIC)
- Dual transfer mode (DTM Class 11
- Voice codecs
  - Full rate (FR, Half rate (HR), Enhanced full rate (EFR), Advance multi-rate (AMR)

## *3G*

- ***UMTS / HSDPA / HSUPA Release 6***
  - HSDPA Category 8: 7.2 Mbps peak
  - HSUPA Category 3: 1.5 Mbps peak
- Tri-Band
  - US Cellular 850 MHz
  - US PCS 1900 MHZ
  - International UMTS 2100 MHZ
- Advanced Receiver & Receive Diversity for improved cell edge performance
- Legacy WCDMA dedicated channels
  - Voice, 384 kbps UL, 384 kbps DL
- Handoff to/from 2G
- Base Station Transmit Diversity
- UE Power Class 3 (+24 dBm)
- Multiple PDP contexts
- UMTS QoS traffic classes, PPP, IP transparent and non-transparent modes, RFC 2507 IP Header Compression

# Many Devices Can Benefit from Broadband Connectivity

**Mobility Applications**

Smart Phones

**Traditional "Computing"**

Notebooks

**Voice and SMS**

Basic Phone

**Machine-to-Machine**

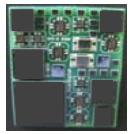
Wireless "Machines"

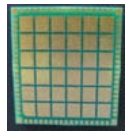
**Multimedia Entertainment**

Consumer Electronics

# Reference Design Form Factors

## Wireless Module





- *LGA Package*
- *Usable area: ~600 mm²*
- *Overall height: ~2.5 mm*

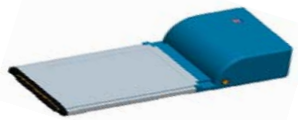
## PCIe Half-Mini Card

- *Dimensions: 26.8mm x 30mm*
- *Usable area: 1206 mm²*
- *Overall Height < 5mm*

## USB Card

- *ExpressCard34 design portable to USB, but the smaller the better!*

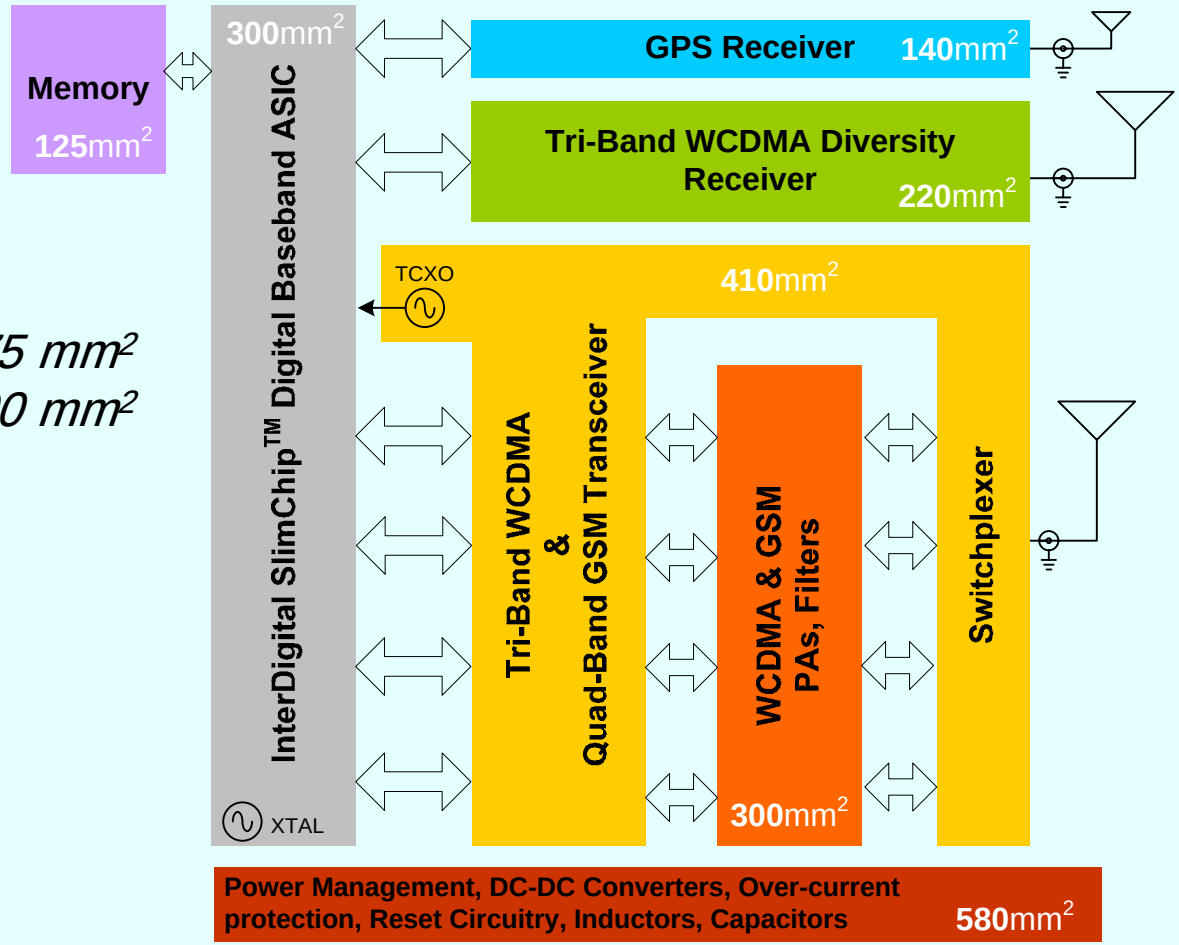
## ExpressCard 34



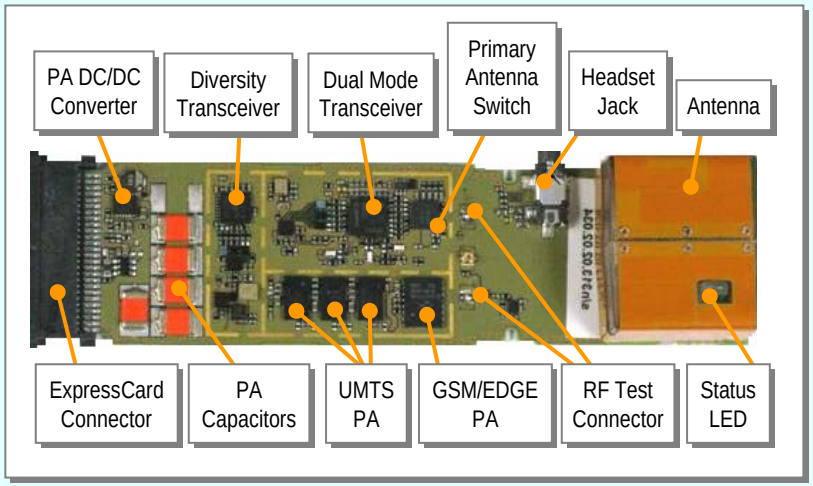
- *Dimensions: 34 mm x 75 mm (plus extension for antenna)*
- *Usable area: ~4200 mm²*
- *Height < 5 mm*

# ExpressCard 34 Fit Study

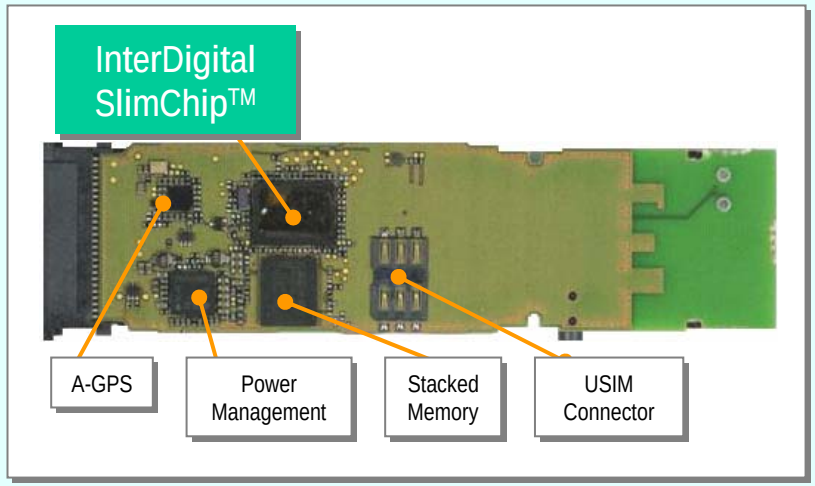
*Required space: 2075 mm²*
*Available space: 4200 mm²*



# The SlimChip™ ExpressCard34 Reference Design

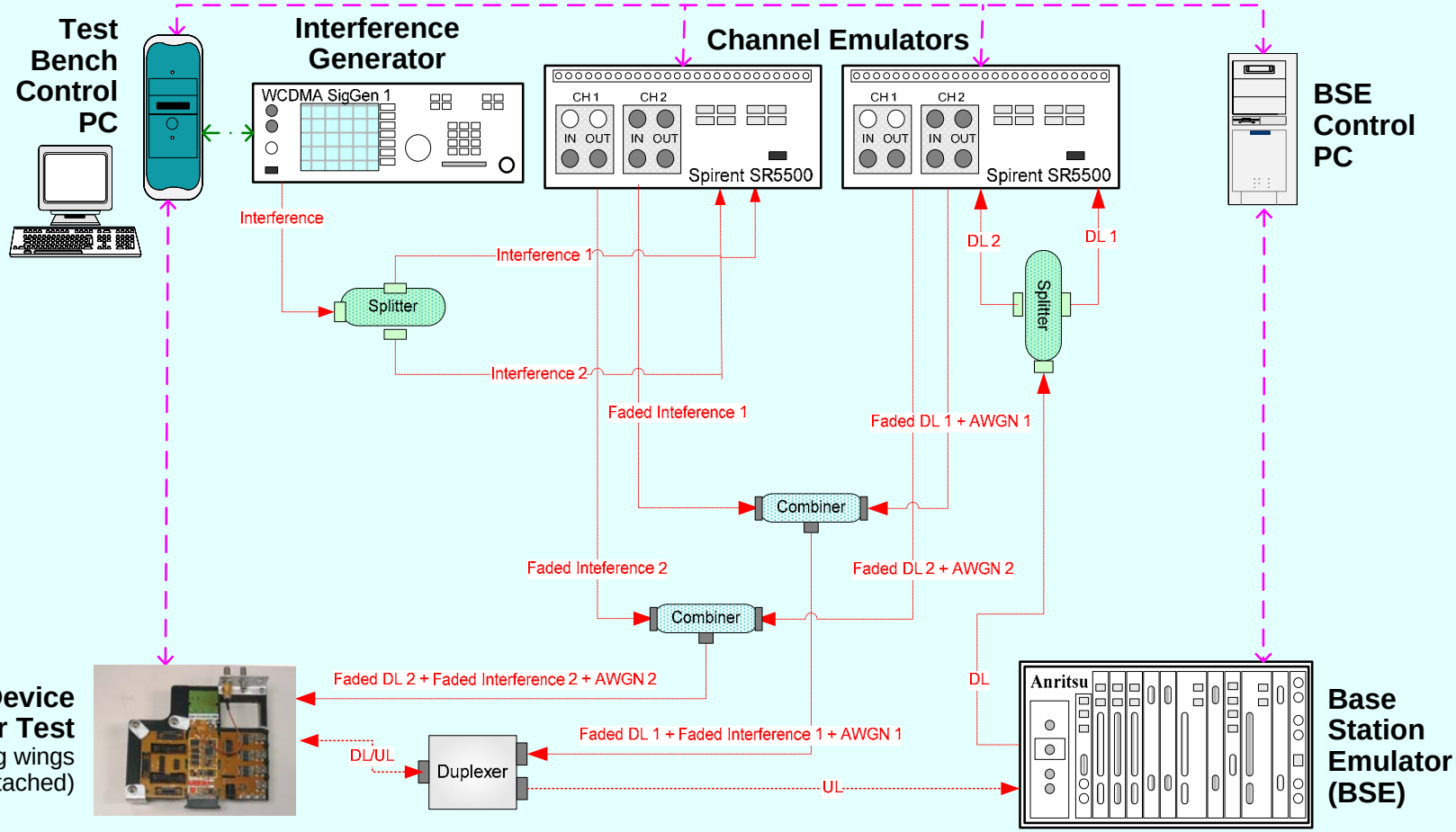



Top




Bottom

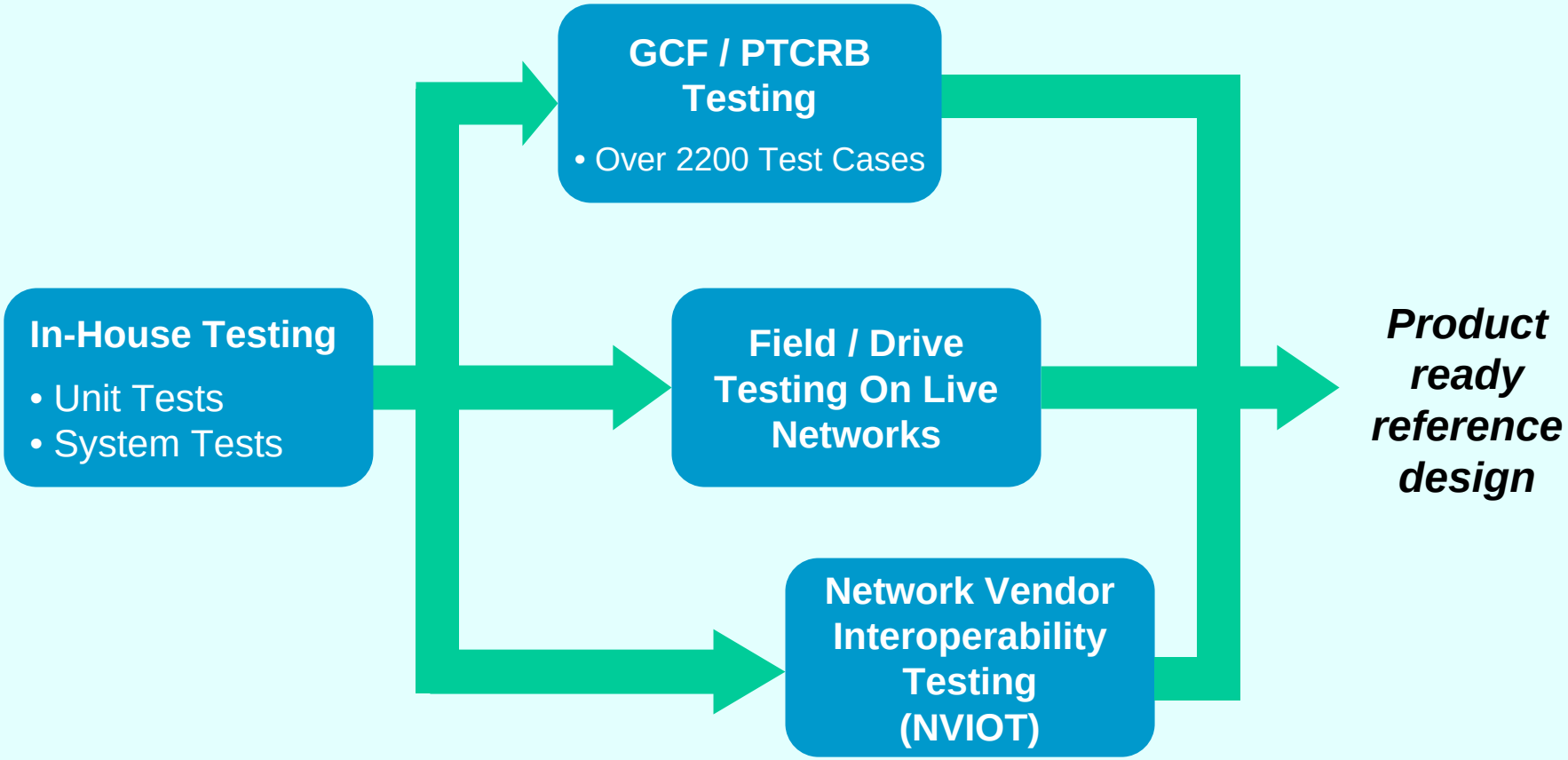
# Lab Test Setup for WCDMA/HSPA






InterDigital®

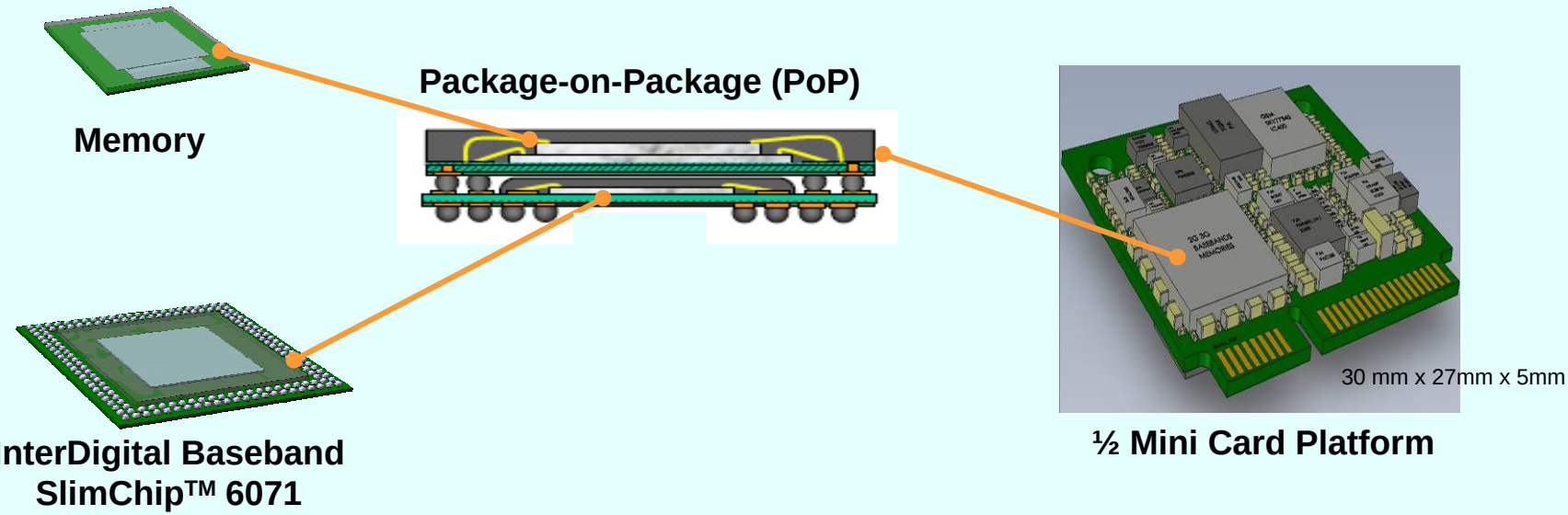
# Certification Testing



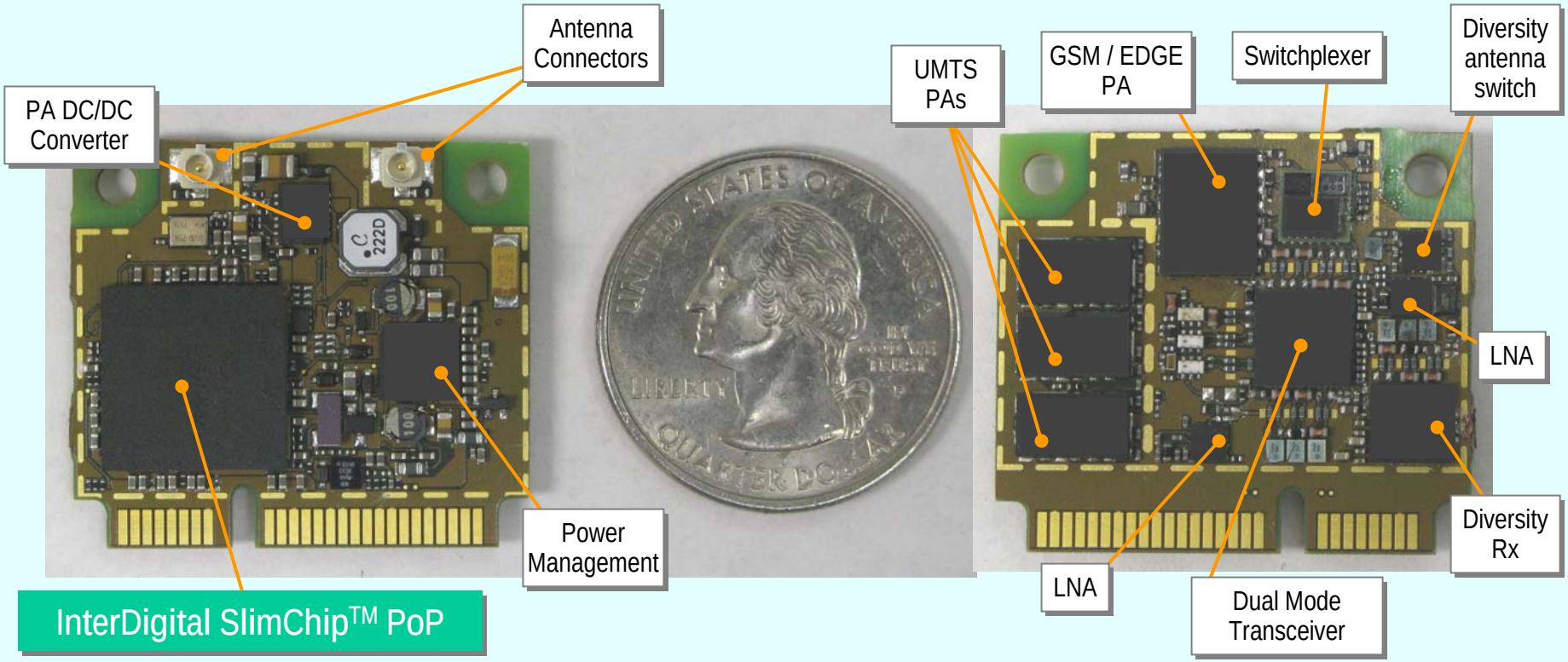

GCF: Global Certification Forum
PTCRB: PCS Type Certification Review Board

# Evolving to the Half-Mini Card

- Advanced packaging technology reduces required board area
  - Baseband + memory Package-on-Package (PoP)



# The SlimChip™ Half-Mini Card Reference Design



# What's Next?

- Support for evolving air interfaces
  - HSPA+
  - Long Term Evolution (LTE)
- Programmable / reconfigurable hardware
  - Increased hardware sharing among operating modes
  - Software defined radio (SDR) techniques
- Higher levels of integration and smaller reference designs
  - Combined RF/Baseband packaging
  - RF/Baseband Silicon Integration

# Thank you for your attention

- For further information, please contact:
  - Robert A. DiFazio
  - robert.difazio@interdigital.com
  - www.interdigital.com
  - ☎ +1-631-622-4395

# Questions & Answers