



Cellular Baseband Development Platform with an open RF Interface

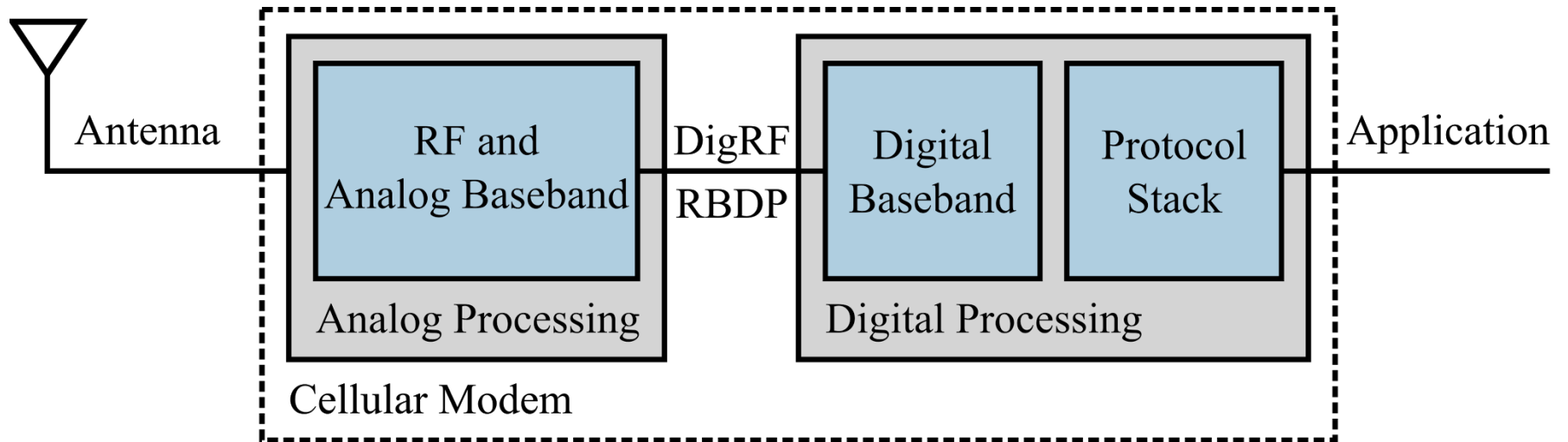
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Outline

- Motivation: Need for an open cellular development platform
- Fundamentals: FMC standard
- Contribution: Cellular RF FMC modules and drivers
- Application: GSM/Evolved EDGE Implementation
- Conclusion/Outlook

Cellular Modem Architecture



Cellular Modem Design Space

- Cellular modems have distinct architectural demands



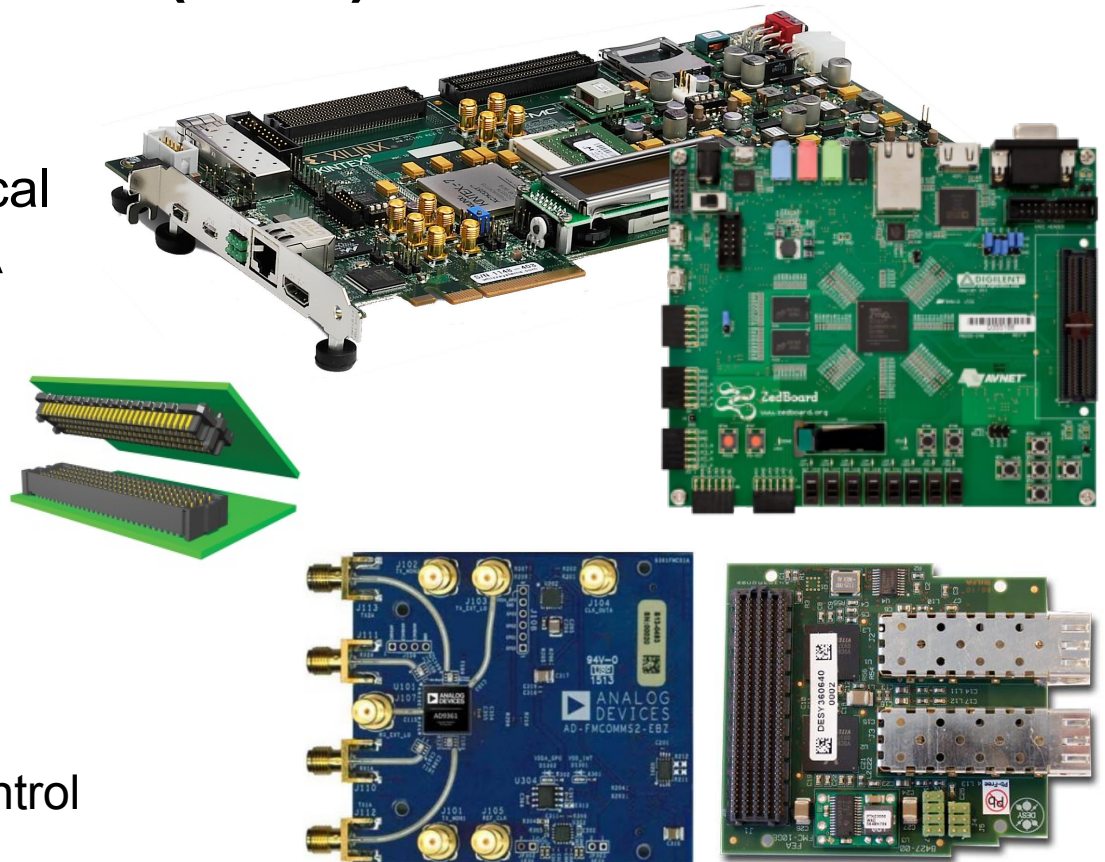
Residential cellular router	cellular IoT (cIoT) node
low latency	latency independent
high throughput	extremely low throughput
plug-in powered	years of battery life



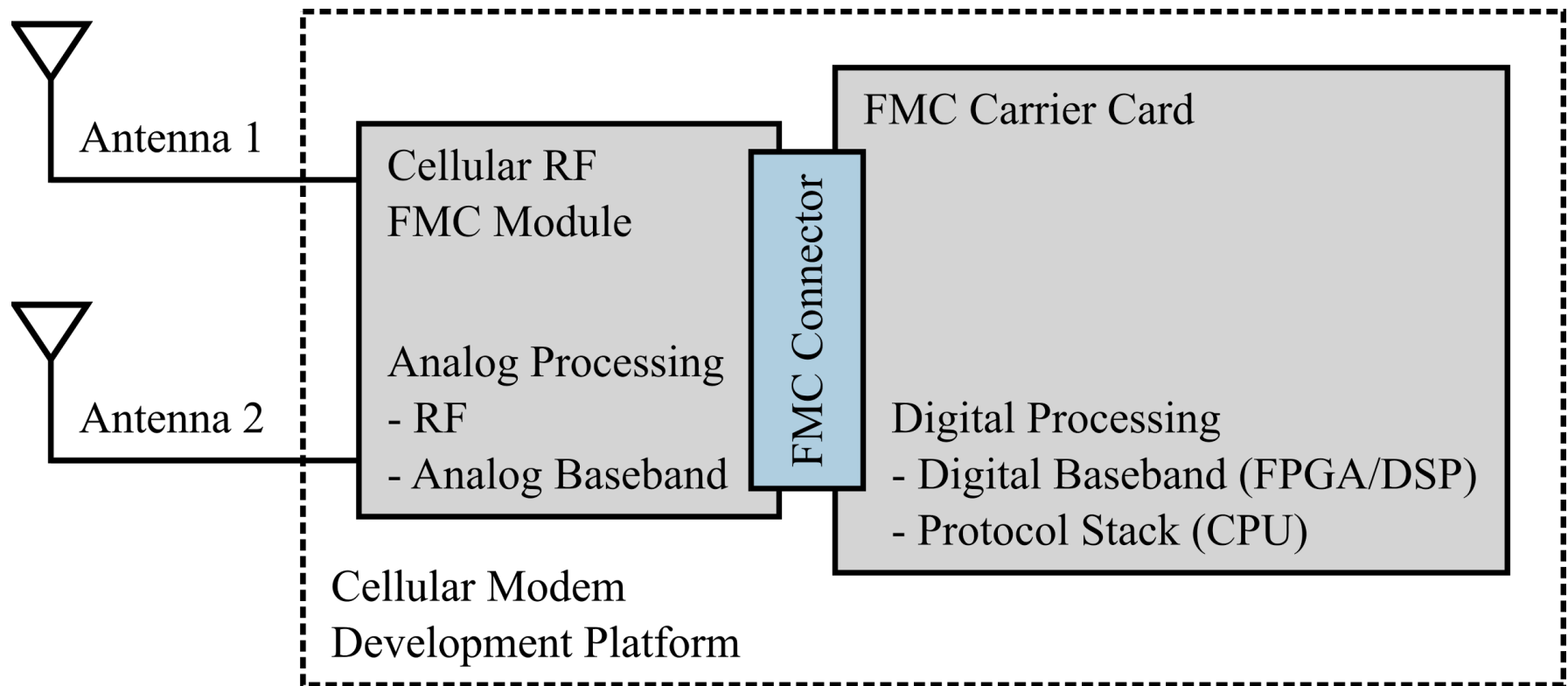
- Baseband architecture tailored to application
- Cellular development platform needed

FPGA Mezzanine Card (FMC) Standard

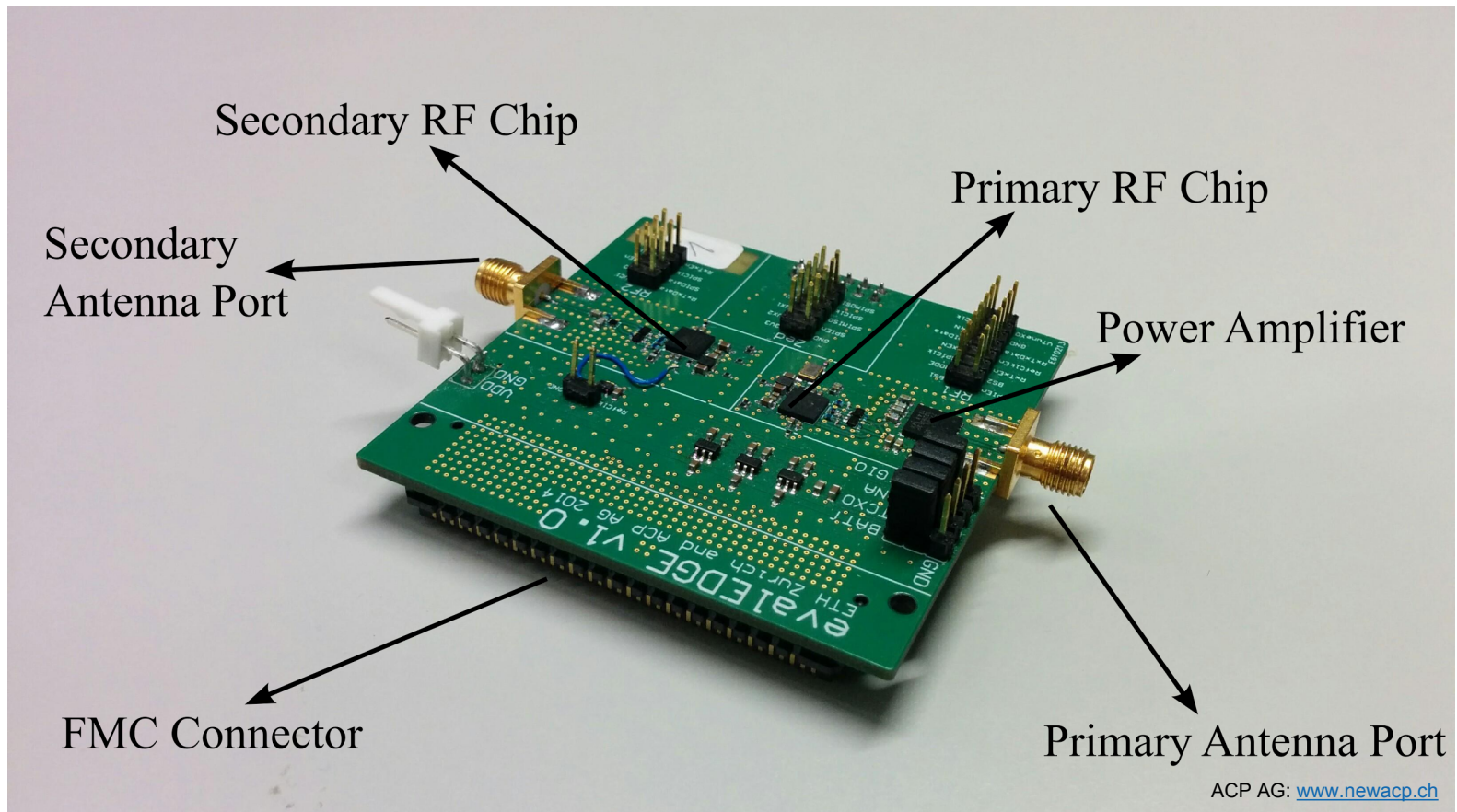
- Electrical and mechanical specifications for FPGA extension modules
- Carrier vs Module
- HPC vs LPC
 - Reference clocks
 - Gigabit signals
 - JTAG
 - I2C bus
 - Power supply and control
 - User defined signals
- ANSI/VITA 57.1 2008



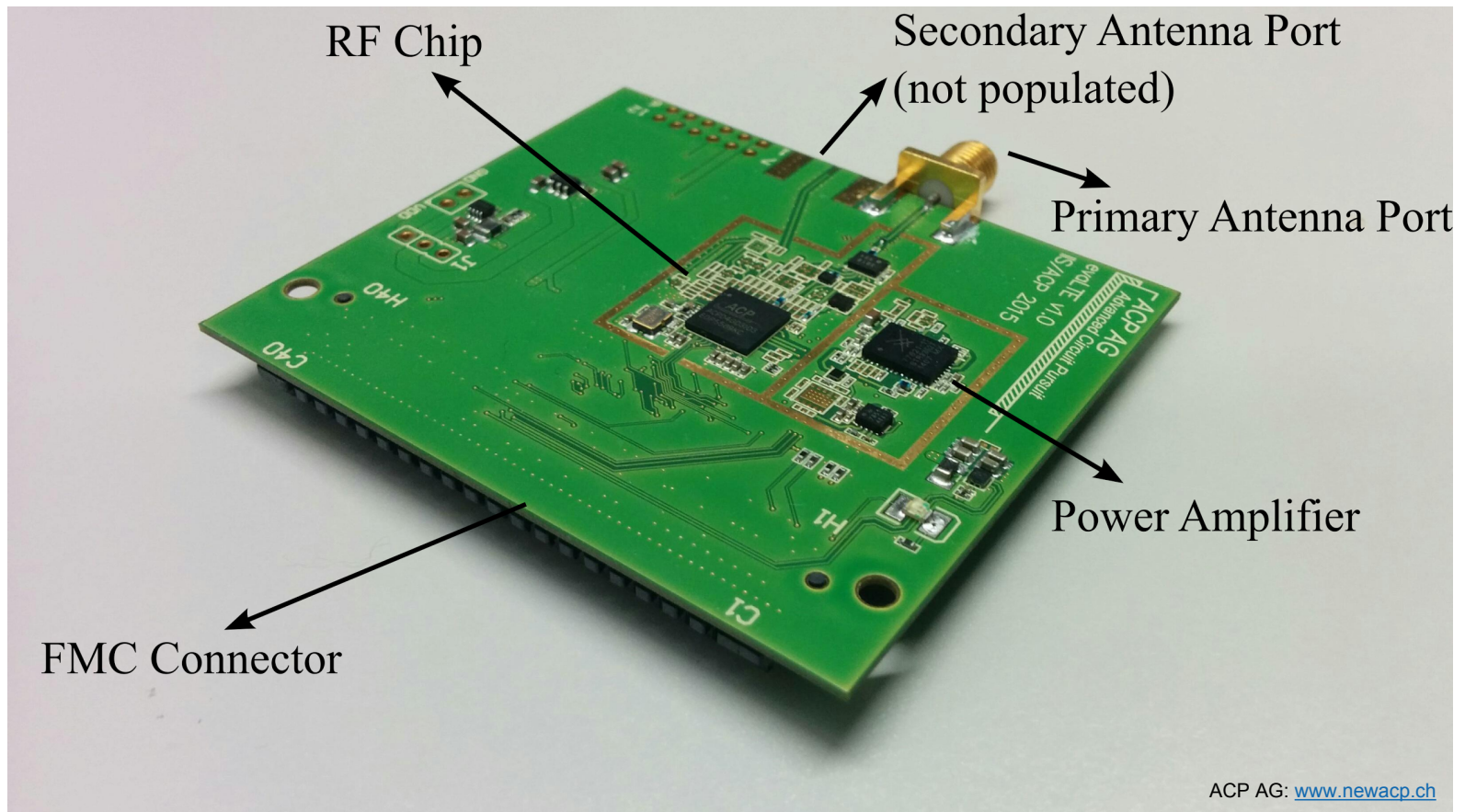
Cellular FMC based Development Platform



Single-Mode 2G RF FMC Module: evalEDGE



Multi-Mode 2G, 3G, 4G RF FMC Module: evalLTE



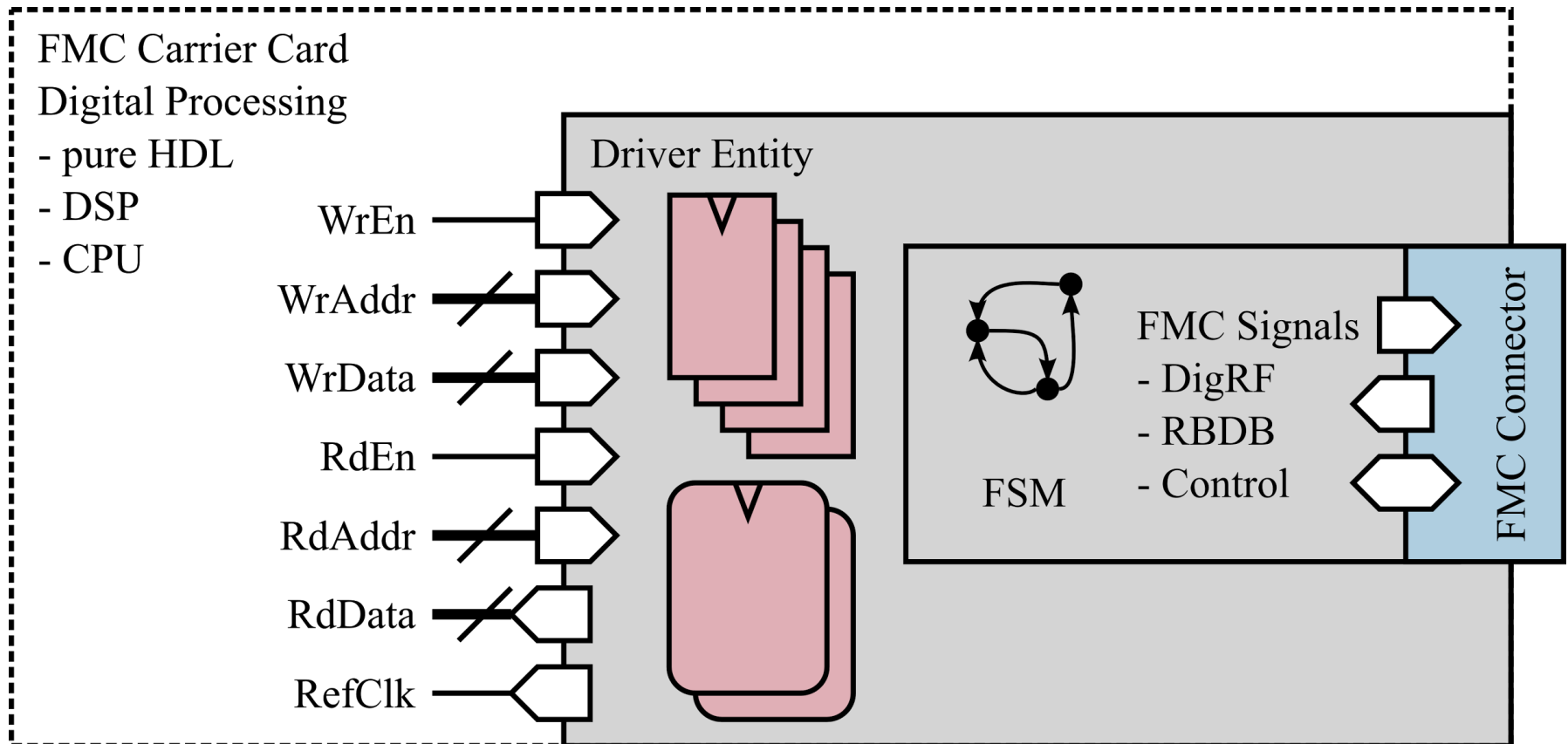
FMC Signals and Pin Mapping

Signal Description	FMC Signal Name	Comments
Power connections	predefined positions	
Global reference clock	CLK_M2C	provided by FMC module
DigRF v1.12 and RBDP control Plane	LA00, LA02	3-Wire SPI, reset
DigRF v1.12 data plane	LA04	2 bidirectional signals
RBDP data plane	LA01, LA03, LA05-LA16	2 clocks, 2 burst control 2 bidirectional 12 bit buses
Power control, auxiliary signals	LA17-LA25	18 single ended signals

Open Driver for FMC Carrier Card

- HDL code to facilitate RF FMC module access
 - Driver for common FMC carrier cards
- Register access for receive and transmit
 - Frequency
 - Bandwidth
 - Gain
 - Data buffers
- Register access to
 - start/stop receiver/transmitter
 - control reference clock
- Global reference clock

Driver Architecture

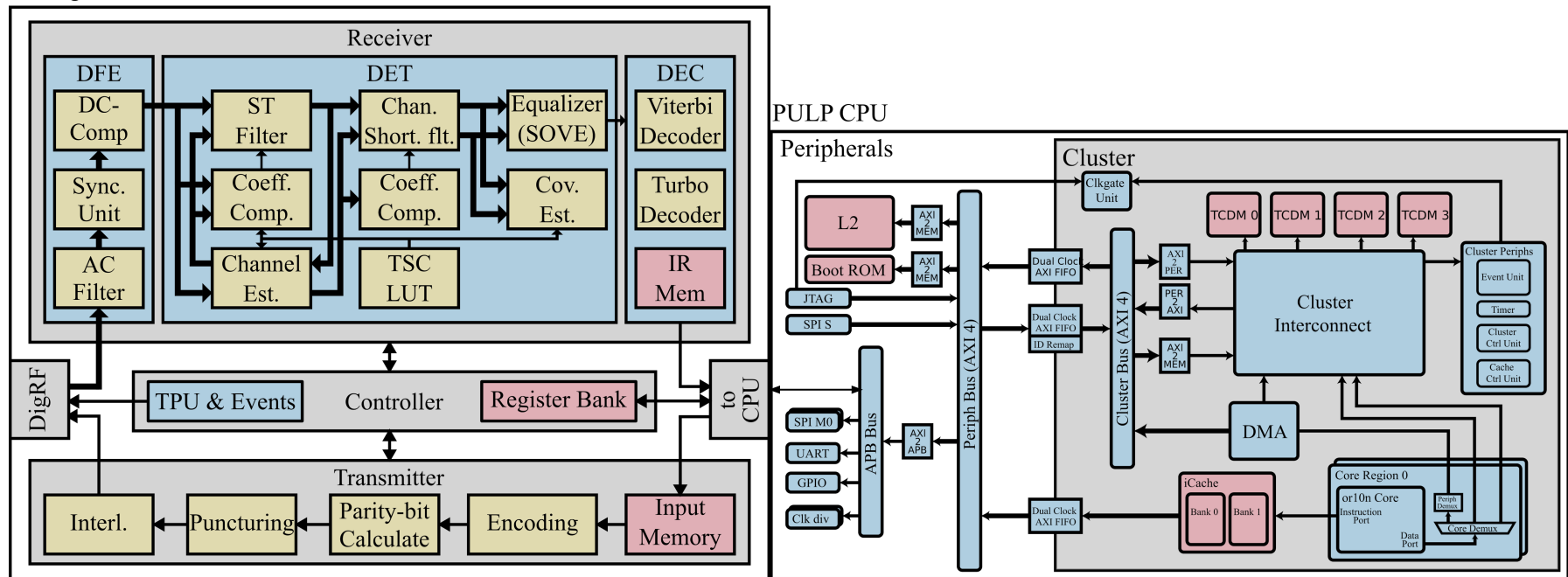


GSM/Evolved EDGE Implementation



GSM/Evolved EDGE Implementation

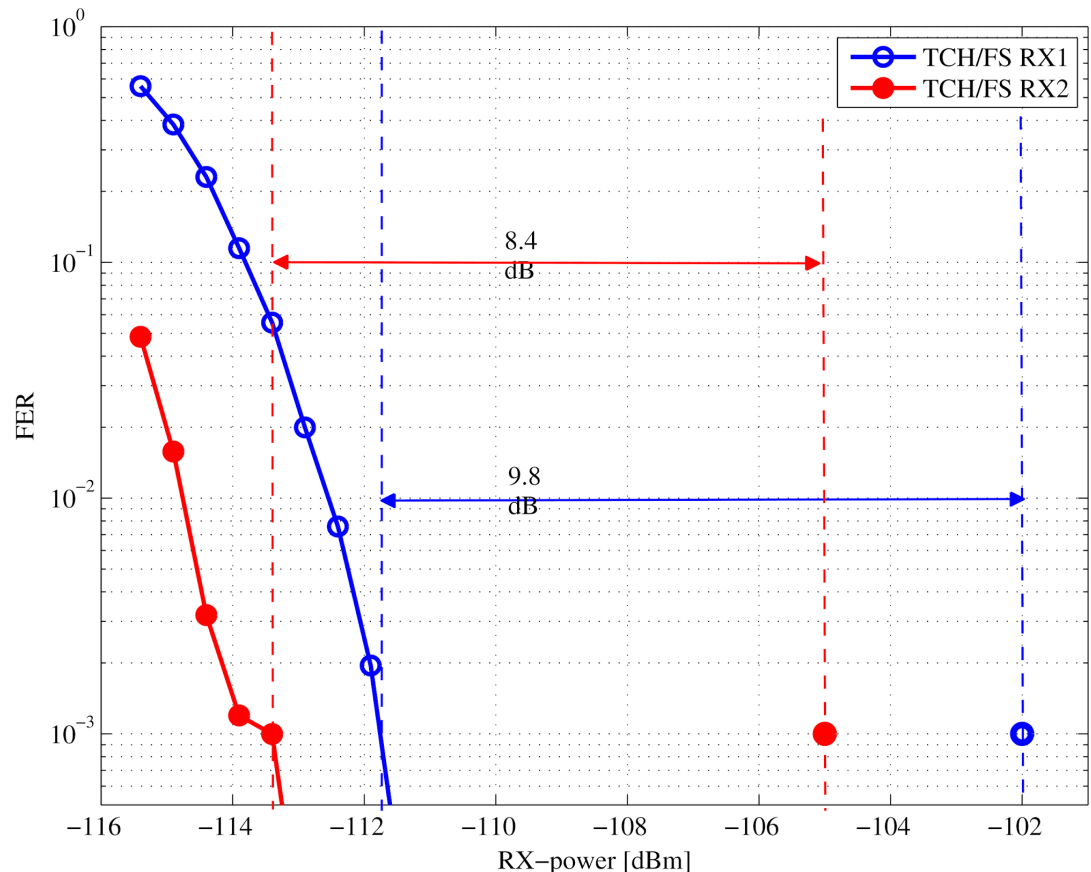
2G Digital Baseband



- Kröll et al., An Evolved GSM/EDGE Baseband ASIC Supporting Rx Diversity, IEEE JSSC, 2015.
- Rossi et al., A -1.8V to 0.9V Body Bias, 60 GOPS/W 4-Core Cluster in Low-Power 28nm UTBB FD-SOI Technology, IEEE S3S, 2015.

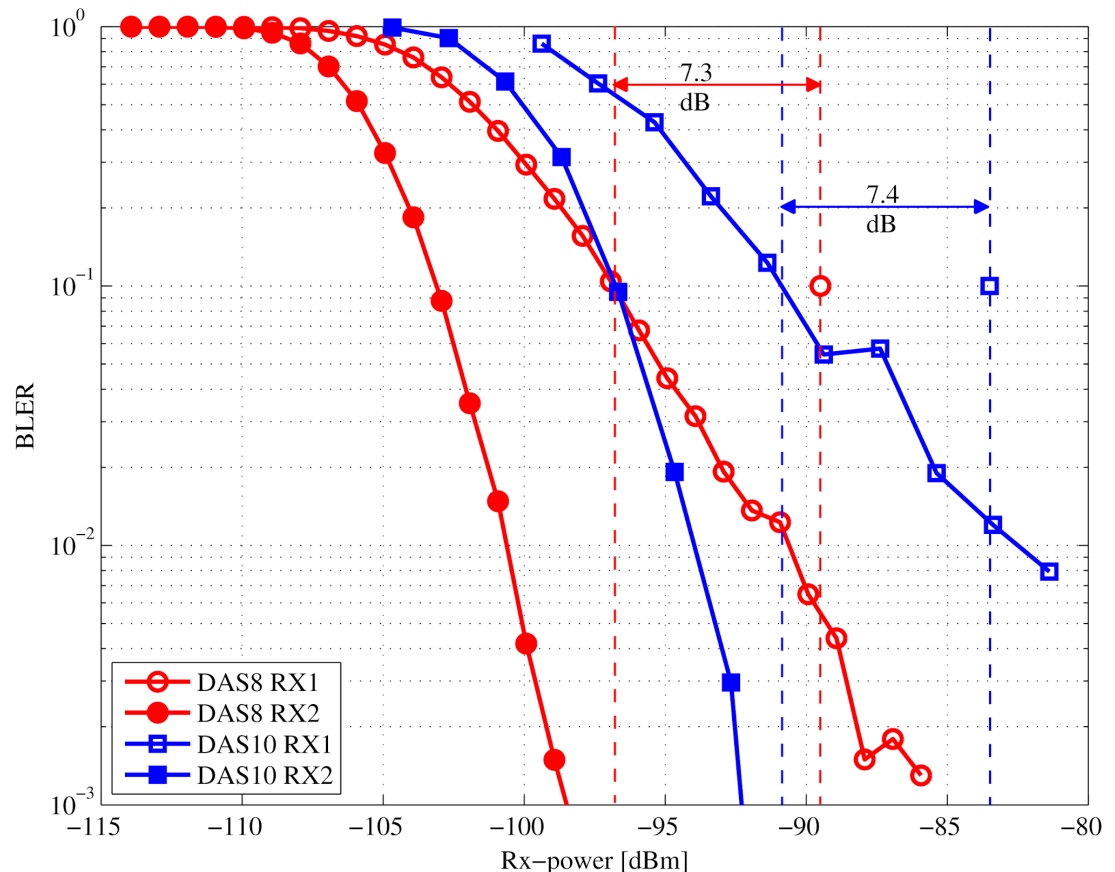
GSM Measurements

- 3GPP Scenario
 - Static channel
 - no FH
 - GMSK (TCH/FS)
- Requirements
 - $\text{FER} < 10^{-3}$ at -102 dBm RX-power
 - $\text{FER} < 10^{-3}$ at -105 dBm RX-power with receive diversity
- Hardware
 - Agilent 8960 protocol tester
 - PropSim C8 channel emulator



Evolved EDGE Measurements

- 3GPP Scenario
 - TU50 channel
 - no FH
 - 16-QAM (DAS8)
 - 32-QAM (DAS10)
- Requirements
 - $\text{BLER} < 10^{-1}$ at -89.5 dBm RX-power for 16-QAM DAS8
 - $\text{BLER} < 10^{-1}$ at -83.5 dBm RX-power for 32-QAM DAS10



Conclusions

- Prototype of open cellular development platform
 - Regular FMC carrier card
 - Custom RF FMC modules
 - 2G RF FMC module evalEDGE
 - 4G RF FMC module evalLTE
- Prove of concept
 - GSM/Evolved EDGE modem prototype
 - Outperforms 3GPP requirements by far

Outlook

- HDL drivers for a variety of FMC carrier cards
- Thorough evaluation of multi-mode RF FMC module
 - Extreme modem configurations
 - Residential cellular router
 - cloT node
- Commercialization
 - FMC modules
 - Open HDL drivers

Thank you for your attention



References of Photos

<http://www.dlink.com/uk/en/home-solutions/connect/broadband-modems-and-routers/dwr-921-4g-lte-router>

<https://store.openpicus.com/openpicus/prodotti.aspx?cprod=OP014031>

<http://www.xilinx.com/products/boards-and-kits/ek-k7-kc705-g.html>

<http://zedboard.org/product/zedboard>

http://fe.desy.de/fea/projects/10g_developments/10g_fmc_module/

<http://www.analog.com/en/design-center/evaluation-hardware-and-software/evaluation-boards-kits/eval-ad-fmcomms2.html>

<http://www.em.avnet.com/en-us/design/featuredpromotions/Pages/Samtec-Vita-57-SEARAY-Connectors.aspx>