BitWave SEMICONDUCTOR ™

Wireless Made Simple

SDR`09

Technical Conference and Product Exposition

Architectural Decisions for SDR in MIMO Applications

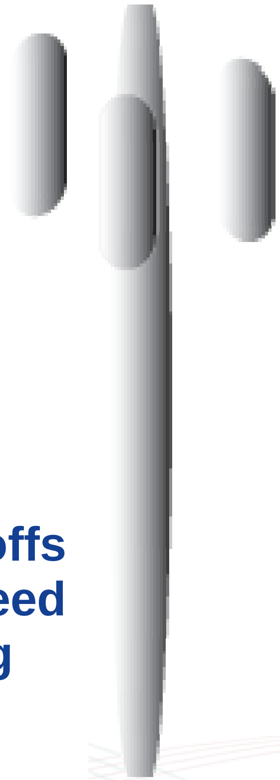
SDR Forum Tech Expo

December 1 - 4, Washington DC

Russell Cyr, Erik Org

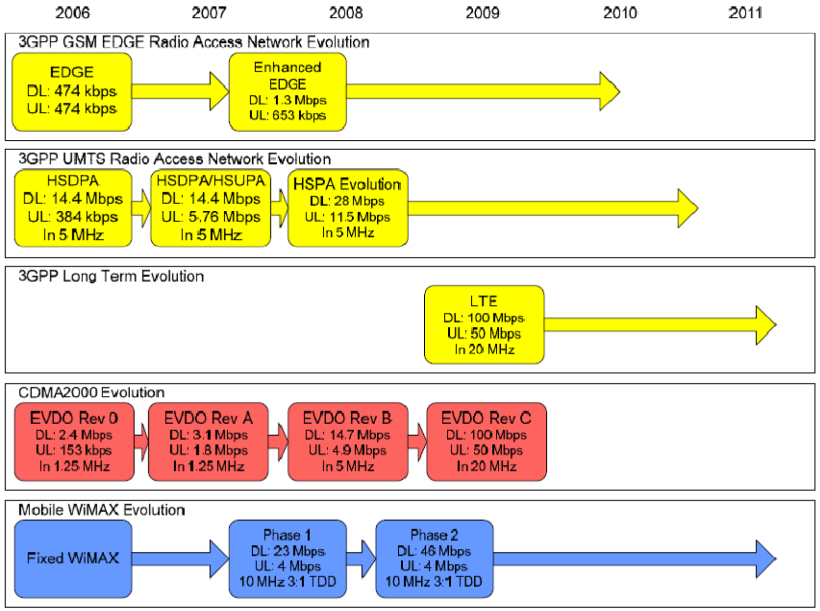
Overview

- As commercial SDR matures, new applications will look to SDR approaches in an effort to lower costs and simply designs.
- At the same time as SDR is gaining traction, so are consumer devices requiring MIMO technologies such as 802.11n, 802.16e and LTE.

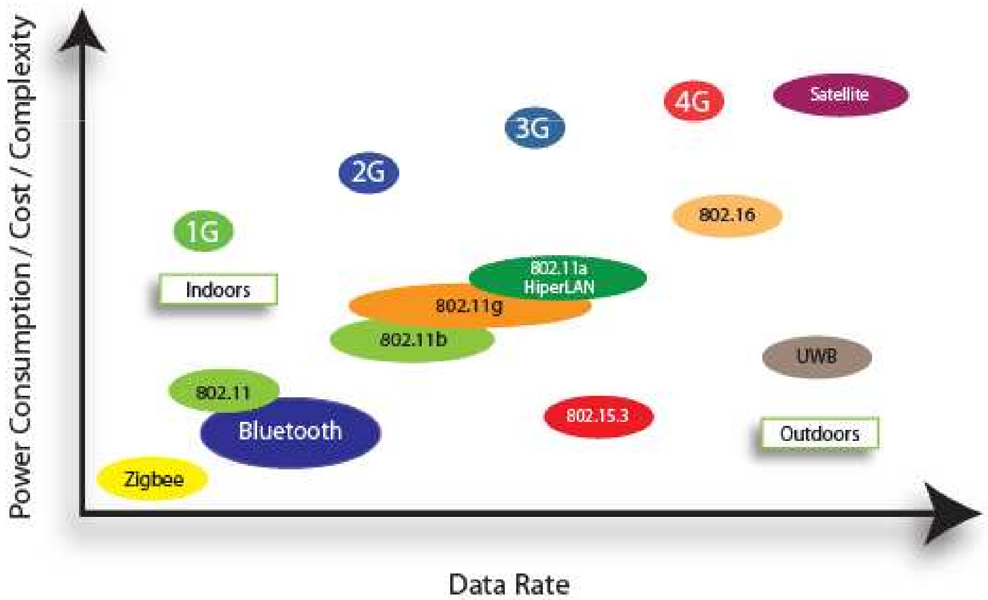


The question is;
What transceiver level trade-offs will SDR System architects need to consider when designing next generation RFICs.

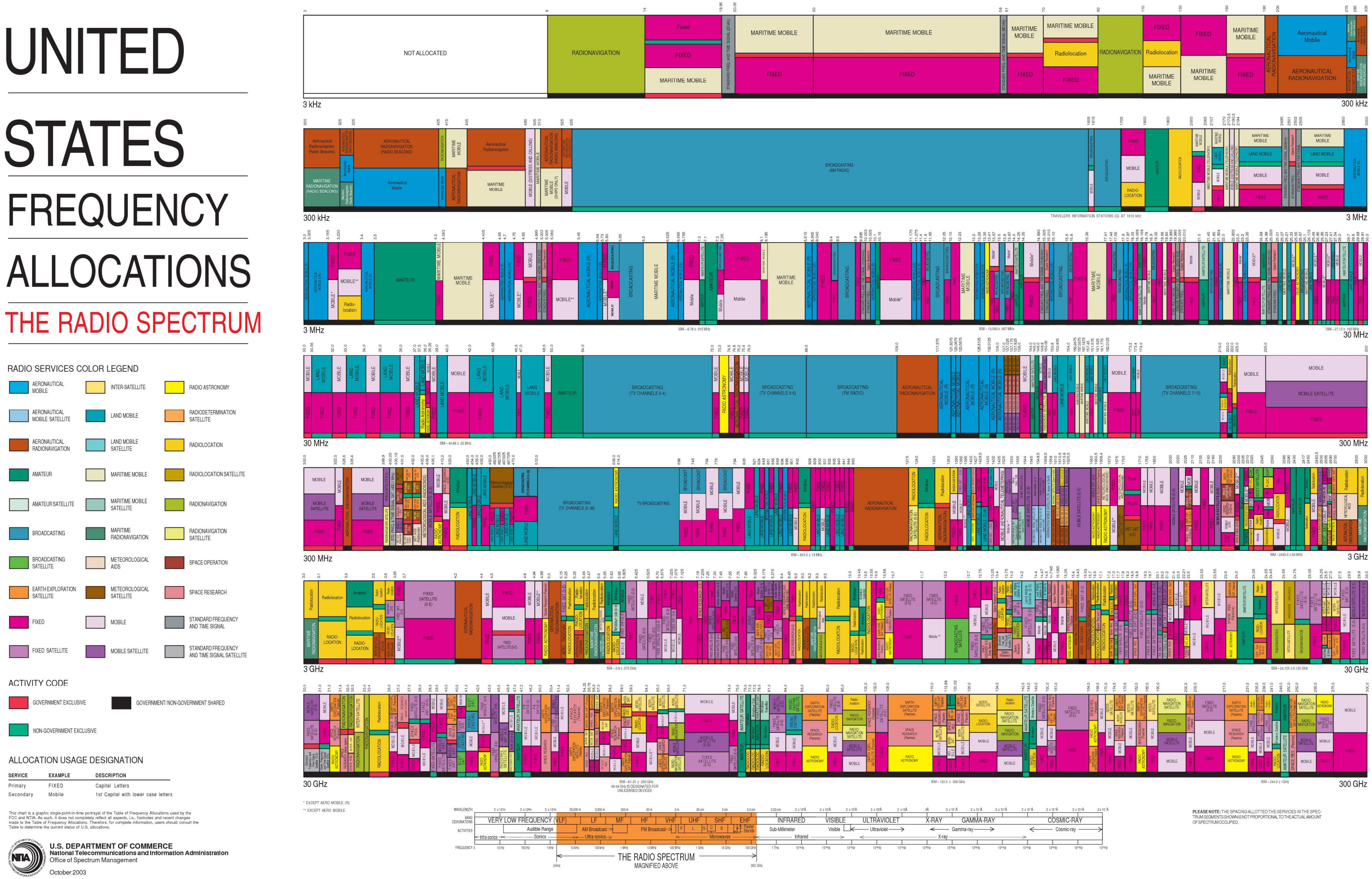
There is A Proliferation of Wireless Technologies



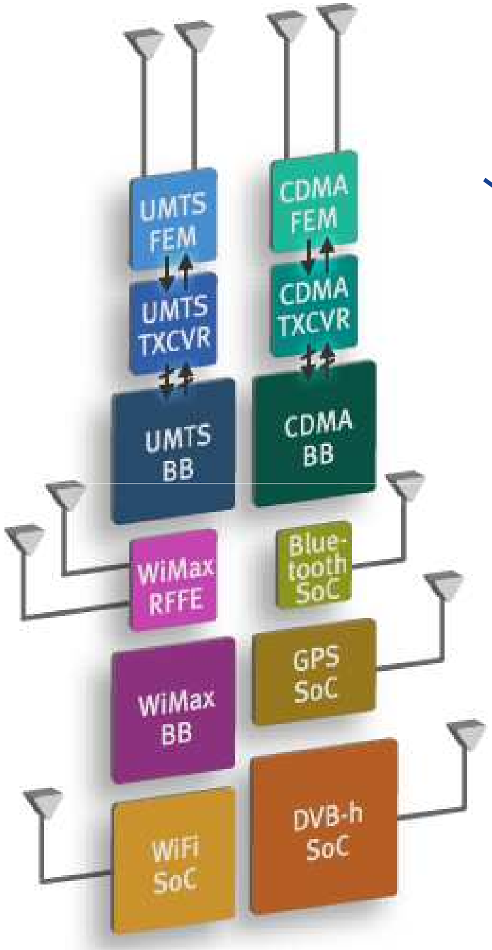
Note: throughput rates are peak network rates. Radio channel bandwidths indicated.
Dates refer to initial network deployment.



And Bands


UNITED
STATES
FREQUENCY
ALLOCATIONS
THE RADIO SPECTRUM
RADIO SERVICES COLOR LEGEND
AERONAUTICAL MOBILE
INTER-SATELLITE
RADIO ASTRONOMY
AERONAUTICAL MOBILE SATELLITE
LAND MOBILE
RADIODETERMINATION SATELLITE
AERONAUTICAL RADIONAVIGATION
LAND MOBILE SATELLITE
RADIOLOCATION
AMATEUR
MARITIME MOBILE
RADIOLOCATION SATELLITE
AMATEUR SATELLITE
MARITIME MOBILE SATELLITE
RADIONAVIGATION
BROADCASTING
MARITIME RADIONAVIGATION
RADIONAVIGATION SATELLITE
BROADCASTING SATELLITE
METEOROLOGICAL AIDS
SPACE OPERATION
EARTH EXPLORATION SATELLITE
METEOROLOGICAL SATELLITE
SPACE RESEARCH
FIXED
MOBILE
STANDARD FREQUENCY AND TIME SIGNAL
FIXED SATELLITE
MOBILE SATELLITE
STANDARD FREQUENCY AND TIME SIGNAL SATELLITE
ACTIVITY CODE
GOVERNMENT EXCLUSIVE
GOVERNMENT/NON-GOVERNMENT SHARED
NON-GOVERNMENT EXCLUSIVE
ALLOCATION USAGE DESIGNATION
SERVICE
EXAMPLE
DESCRIPTION
Primary
FIXED
Capital Letters
Secondary
Mobile
1st Capital with lower case letters
U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management
October 2003
3 kHz
300 kHz
300 kHz
3 MHz
3 MHz
30 MHz
30 MHz
300 MHz
300 MHz
3 GHz
3 GHz
30 GHz
30 GHz
300 GHz
THE RADIO SPECTRUM
MAGNIFIED ABOVE

And We Want It All Rolled Into One Device



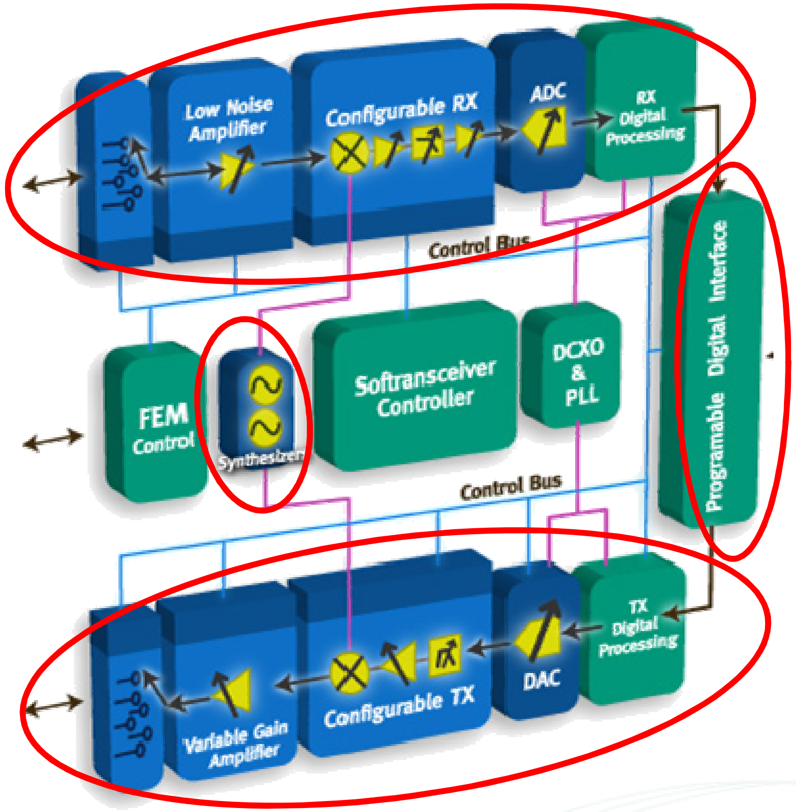
SDR Is Making Progress In Several Applications

- **Historical Success**
  - Steinbrecher's MiniCell – 1994

- **Current Commercial and Military SDR Implementations**
  - BTS
    - Vanu
    - JTRS
    - ZTE
    - Huawei
  - Public Safety
    - Thales
    - Harris

In Progress Applications Are Mostly SISO

Tunable Receiver With ADC



Wideband Frequency Generation

Flexible Digital Interface

DAC With Tunable Transmitter

BitWave SEMICONDUCTOR™
Wireless Made Simple

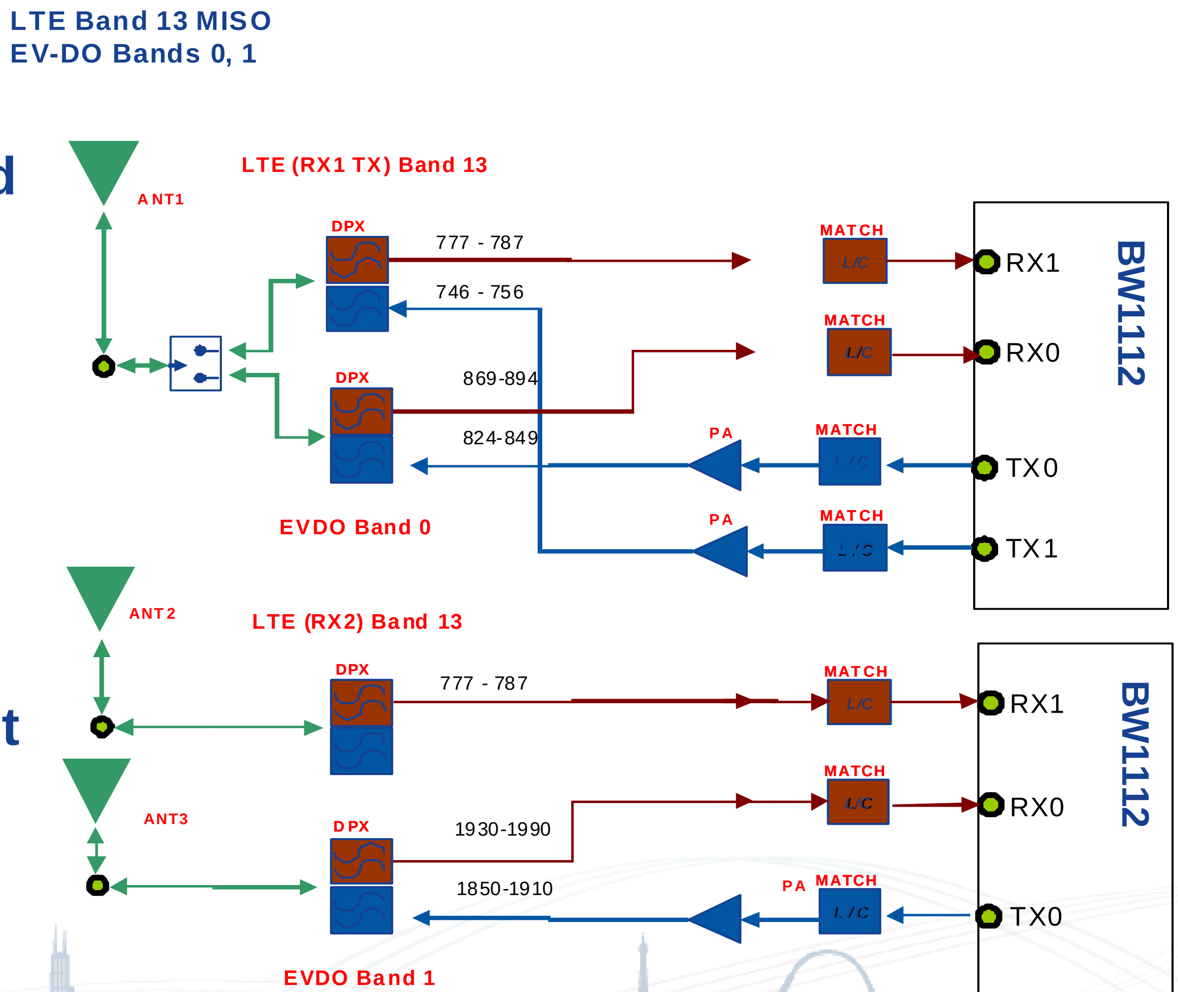
4G and Beyond Will Be MISO and MIMO

- **Some Product Choices Are Easier Than Others**
  – Number of Receivers
  – Number of Transmitters
  – Operating Bands
  – Wireless Protocols
- **Some Product Choices Are A Bit Tougher**
  – Simultaneous Operation of Multi-mode
  – Legacy Support
  – Fixed Function Support
  – Spectrum Efficiency
  – Power Efficiency
  – COST: Size/Integration/Node/Chip Count
- **All Of These Will Affect Technology Architectural Choices**

An Example of SDR & MIMO

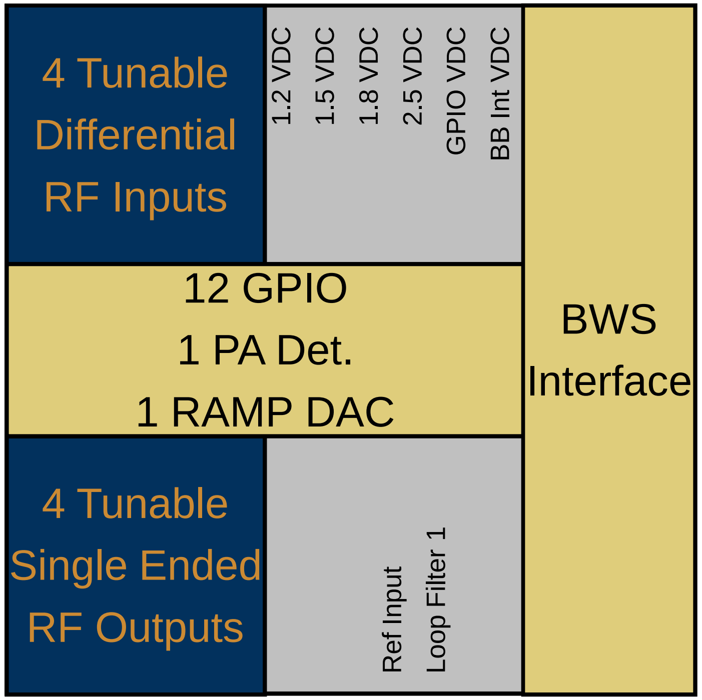
Consider a MISO LTE handset with dual band EVDO Legacy Compatibility

Look At The Issues of Commercialization of the Technology and not Just an R&D Project



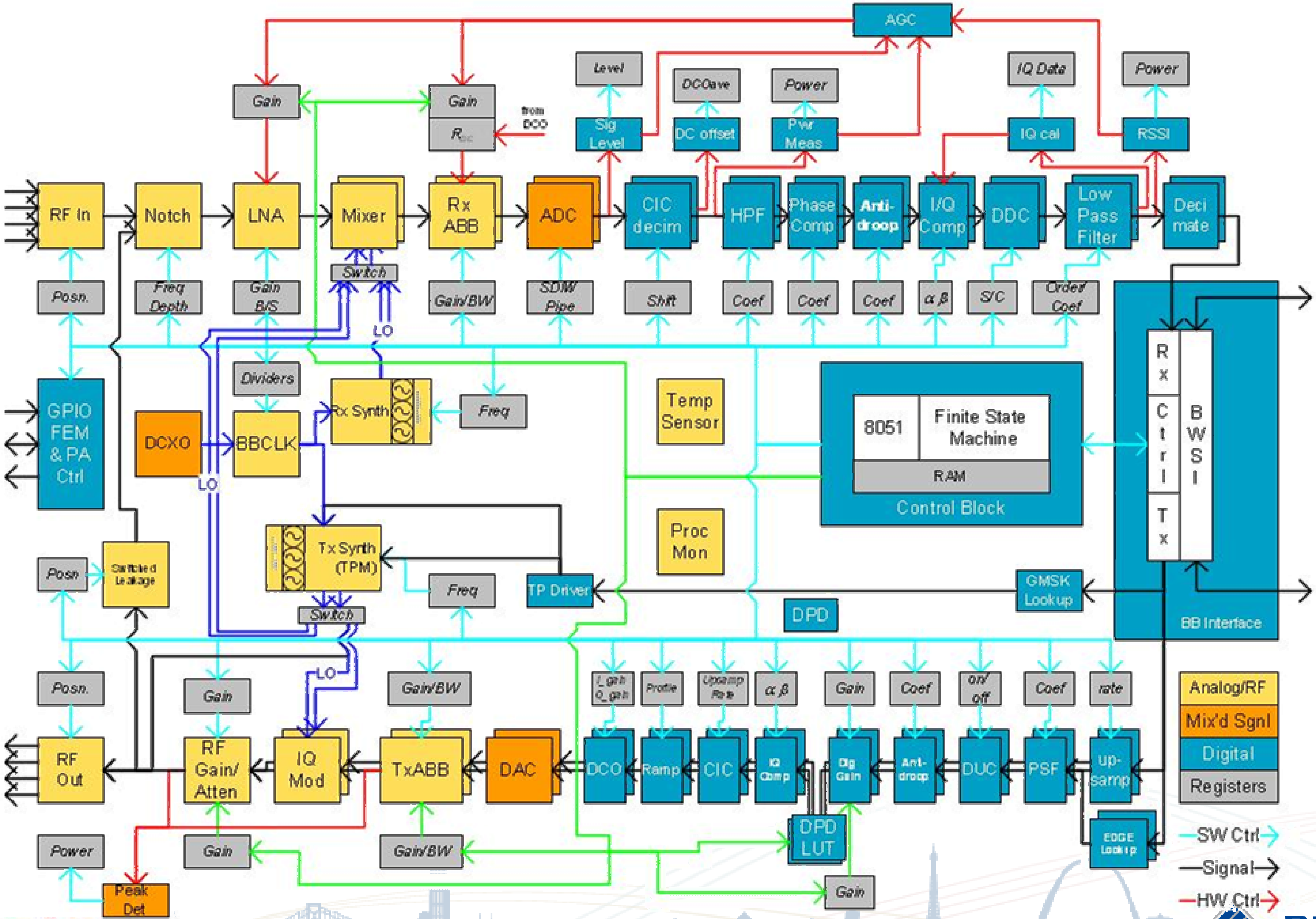
BW1112 Softransceiver RFIC 3rd Generation

- Applications
  - Handsets, Femtocells, CPE, Laptops and SDR Radio



- Architecture
  - Single Receiver and Single Transmitter
- Frequency
  - 700 MHz to 2.7 GHz, Continuous Coverage
- Compliant Protocols
  - LTE, HSPA, EVDO, WCDMA, CDMA2K, DECT, GSM, GPRS, EDGE, DECT, 802.11b/g, 802.16d/e, other
- Front End Module Interfaces
  - 4 Differential RF Inputs
  - 4 Single Ended RF Outputs
  - 12 GPIO for Control
  - 1 PA Power Detect
  - 1 PA Ramp DAC
- Baseband Interfaces
  - 12 Bit Parallel Rx I/Q Interface
  - 12 Bit Parallel Tx I/Q Interface
  - 4 Definable Strobes
  - SPI Control
- Mechanical
  - 7x7 PBGA, 144 Balls, 0.5 Spacing
- Environmental
  - -30° C to +85° C

BW1112-2A Detailed Block Diagram



Some Architectural Considerations

- **Multi-band Support**
  - Over 20 currently defined LTE bands range from 698 MHz up to 2690 MHz
  - 20 currently defined band classes for CDMA2K in ITU from 411 MHz up to 2170 MHz
- **Protocol Support**
  - LTE FDD and/or LTE TDD
  - CDMA2K and/or EVDO and/or EVDO RevA
  - Simultaneous or non-simultaneous
- **Operational Bandwidth**
  - Narrow bandwidth with high stop band attenuation for legacy 2G protocol support. 3G protocols have medium bandwidth and 4G has multiple bandwidths including very wide bandwidths for LTE
- **Clocks**
  - Clocks synchronized for multiple inputs and outputs, varying frequency needs as well as varying symbol and interface rates
- **Sensitivity**
  - Differences in target protocols modulation requires a wide range of SNR in order to achieve the desired data throughput.
- **Gain Balance**
  - Maintain minimal gain difference between MIMO receive path #1 and MIMO receive path #2
- **Adjacent Channel Power (ACP)**
  - Suppress ACP while supporting multiple frequency bands - 700 MHz to 2.7 GHz
- **On Chip Calibration**
  - IQ balance and DC carrier suppression algorithms vary with BW, frequency and temperature
- **On Chip Isolation**
  - Managing 4 receivers and transmitters on the same substrate requires a very effective isolation strategy

Multi-band Support

- **Design Concern**
  - Possible increase transceiver front end die size
  - Possible increase RFFE chip count
  - Possible decrease sensitivity and Pout
- **SDR Opportunity**
  - Replace multiple fixed RFICs with a single programmable RFIC
- **Practical Tradeoffs**
  - Smaller node geometries
    - Enabled the replacement of analog circuits with programmable digital logic that is smaller than the analog circuits it replaced
  - Close cooperation with RFFE providers
    - Still no tunable RF Rx filters

Multi-Protocol Support

- **Design Concern**
  - Simultaneous or non-simultaneous operation
- **SDR Opportunity**
  - Retune transceiver to reduce number of transceiver chips
- **Practical Tradeoffs**
  - With two 1x1 chips, LTE will need to be 1x1 during Simultaneous operation
  - Increased interference depending upon which bands are on simultaneously
  - Effect on baseband(s) with 2 data streams
  - Different clock rates for different standards

Operational Bandwidth

- **Design Concern**
  - Supporting multiple bandwidths
  - Baseband VGS and ADC power consumption scales with bandwidth
  - Receiver power consumption scale with linearity
    - Blockers
- **SDR Opportunity**
  - Balance the required analog rejection using scalable analog filter bandwidths (and resulting power consumption) with ADC dynamic range and digital filtering
- **Practical Tradeoffs**
  - Minimize ADC sampling rate for each protocol
  - VGA linearity & transfer function and ADC dynamic range and digital filter response

Clocking

- **Design Concern**
  - Different protocols, different clock trees
  - Switching protocols switches the clock rates
  - Simultaneous operation has two different clock rates
- **SDR Opportunity**
  - Reprogramming clock tree for different operation
  - Working with baseband partner to do re-sampling to minimize different clocks
- **Practical Tradeoffs**
  - RFIC function vs BB function
  - Reducing the number of clocks reduces spur generation
  - Increased post ADC activity for resampling

Sensitivity

- **Design Concern**
  - Improved linearity and lower noise figures
  - Power consumption
- **SDR Opportunity**
  - Allowing for each component's operating point to be set based upon mode of operation and performance requirements can help balance power consumption with performance.
- **Practical Tradeoffs**
  - Wideband LNA vs tuned narrowband LNA
    - Integrate traditional low noise LNAs with digital control logic to get low NF but with wide range of control
  - Variable operating point LNA
    - Gains and gain step dependent upon mode
  - Balance amount of control logic and target frequency range
    - Die area with power consumption.

MISO Gain Balance

- **Design Concern**
  - Two Receive paths need to closely match each others performance
    - Same Die
    - Two Chips
  - Gain table matching, step size and (in)dependence
- **SDR Opportunity**
  - Programmable architecture means circuits can be calibrated on-chip for matched performance at minimal power consumption.
- **Practical Tradeoffs**
  - A Work in progress

Adjacent Channel Power

- **Design Concern**
  - SAW-less operation
  - Transmitter linearity
  - Power consumption
- **SDR Opportunity**
  - Reprogrammable circuits
  - Digital transmit pre-distortion circuitry
- **Practical Tradeoffs**
  - Noise control
  - Pout of transceiver vs power consumption
  - 1 dB compression point
  - Gain table control
    - Digital, Baseband, RF

Calibration

- **Design Concern**
  - In-field calibration vs factory calibration
  - Each protocol will require separate calibration tables.
  - Time of calibration
  - Effect upon switching modes
- **SDR Opportunity**
  - Softransceiver is capable of generating its own test tones on chip
  - Enhance calibrations using SDR baseband
- **Practical Tradeoffs**
  - Lots
  - Additional testing for a MIMO RFIC will complicate the on-chip routing of test signals

Isolation

- **Design Concern**
  - Managing multiple receivers and transmitters
  - Simultaneous multiband and multi-clock operation
  - On die, on substrate, on PCB
- **SDR Opportunity**
  - Minimize total number of receivers (and the size of the problem) to that required for concurrent operation (MIMO).
  - Reprogram clocks for optimal non-interference
- **Practical Tradeoffs**
  - RFIC clock tree management
  - BB or RFIC re-sampling
  - Circuitry placement
    - On die, on substrate, on PCB

Summary

- **New MIMO technologies require:**
  - More radios, more antennas, higher data rates, new frequency bands
  - Semiconductor vendors will make fundamental changes in integration strategies
- **Architectural decisions can be divided into two general classes**
  - Pre-silicon
  - Post-silicon
- **SDR allows architectural decisions to be made which can quickly lead to lower cost, smaller and more power efficient transceivers**
- **Carefully monitoring of platform cost / size for commercial considerations is a must**
- **Having a SDR baseband with the SDR transceiver allows for more flexibility**