Field Programmable Digital and RF technologies driving innovation in wireless networks
Introduction

1. What is Field Programmable RF (FPRF) Technology?
2. Software Defined Radio
3. FPRF Technology – Details
4. FPRF Applications
1. What is FPRF Technology?
What is FPRF?

- The FPRF is a radio frequency transceiver IC that mimics the concept of an FPGA in the RF domain to deliver a multi-standard, multi frequency device

- The FPRF transmitter takes a digital data stream and converts it into wireless signals, while the receiver perform the inverse operation

- The FPRF transceiver offers the capability to program key parameters like the RF frequency, gain, and bandwidth

- All major elements within FPRF could be powered down and/or bypassed

- All major elements within FPRF could be isolated and used as individual circuits

- Main features:
  - The FPRF is programmed by customers, not in the factory
  - The tools allow customers to experiment and change parameters on the fly
  - The applications are limited only by the imagination of the user
FPRF Transceiver Block Diagram

High level of integration, including dual 12-bit ADC and DAC

Transceiver Signal Processor block and LimeLight interface

Frequency
100KHz – 3.8GHz

Highly configurable RF gain and IF filter with numerous bypass options
The FPRF Company – Ultra flexible RF solutions

The FPRF Transceiver Signal Processing (TSP) block
2. Software Defined Radio
Software Defined Radio – The Dream!

Gentlemen, What would you like to do?

No Problem!
Software Defined Radio – The Nightmare!

Gentlemen, What would you really like to do?

Hmmm, can’t make everyone happy all at once!

1mW DC Power In
Phased Array Antennas
SRIO Multi Channel
Colocation Mobile/GNSS
10Gbps Ethernet
$0.01 Chip

16 BIT I/O 1Gs/s
QAM 4096 OFDM
USB3 -170dBc Far Out Phase Noise
IP3 +30dBm

Blocker Friendly
ZeroIF IP2 +60dBm
Digital Predistortion
Auto Calibrate
Multipath Fading
FDD

FIR
CPRI
200kHz GSM
4kV ESD
10Gb/s Ethernet

-170dBc Far Out Phase Noise
IP3 +30dBm
SPI Echo Cancelling
100M chips Tomorrow!

Frequency Hopping
AGC
RSSI
Spread Spectrum
RS232
I2C
CPR
TDD

Gentleman, What would you really like to do?

Hmmm, can’t make everyone happy all at once!
Components of a Software Defined Radio

- Antenna
- SAW Filters
- RF Switches
- PAs
- FPRF
- TRX
- FPGA
- Network
- Software
- Multicore GHz Processor
- Memory

Boundaries of these blocks increasingly blur
Dongle based Software Defined Radio

FPRF TRX

Multicore GHz Processor
Memory

Network

FPGA free approach.
How much faster does my Raspberry Pi need to be to do 20MHz LTE, WiFi, DVB-T2 and GNSS for £60
As transistor geometries reduce and cost of fabrication and complexity of test program development increase. FPGA with IP library will become increasingly attractive over a full custom ASIC for baseband.
The digital Interface problem

Application specific interfaces
- PCIe
- SRIO
- RS232
- CPRI
- DigRF
- USB
- Ethernet

PC Cards/Rack Systems
Some GNSS Receivers
RF Baseband
Dongle Products
Networks

General Wireless
- I2C
- SPI
- CMOS
- LVDS

Point-Point Indoor Repeater
- I2C
- SPI
- CMOS
- LVDS

IP Blocks available in FPGA

The FPRF Company – Ultra flexible RF solutions
Typical Software Defined Radio (RF)

LNAs generally narrow band so need several inputs
TX outputs generally broadband -10dBm <2.5GHz. Not all PAs broadband!
High Dynamic Range Requirements

Colocation of Mobile/WiFi with W-CDMA and GNSS Leads to challenges

Receiver must be able to work with a spread spectrum signal buried in the noise floor of a receiver in the presence of jamming signals.

This simultaneously requires low NF, very low far out phase noise, high P1dB and good IIP2 and IIP3

Your TX is usually your worst blocker in FDMA and colocated radios

Jammers approx -20dBm after SAW

SAW FILTER

Spread spectrum signal -130dBm

Noise Floor
Fast Frequency Hopping

Frequency hopping used for privacy and avoiding channel conflicts. E.g. Bluetooth

PLL Settling time fairly slow, typically 50us
And not always predictable, e.g. cycle slipping.
Phase noise penalty due to increased loop filter bandwidth

Numerical controlled oscillator (NCO) can change frequency in one clock cycle allowing frequency hopping to be <1us.
No Phase noise penalty.
Digital Predistortion Bandwidth

Baseband generates predistortion.
Have to transmit x5 bandwidth.
Baseband has to run at x5 sample rate.
20MHz LTE Example
Requires >50MHz IF Bandwidth
Requires >100Ms/s data rate
Emerging Requirements – DVB-T2

Emerging high capacity data links such as Digital TV and mobile backhaul use 1024 QAM based OFDM. Require very low integrated phase noise. Plateau region phase noise limits the certainty of the modulated point. Often described by Error Vector Magnitude (EVM).
Emerging Requirements – 5G Beam Steering

- Three approaches
  - Traditional MMIC programmable phase shifters and attenuators. Limited frequency band.
  - Amplitude and phase modulation at baseband in MIMO equipment. Any frequency.
  - Amplitude and phase shifting in the OFDM FFT for MIMO. Can simultaneous steer blocks of subcarriers for different users.

- These approaches require special calibration to make it work well at the antenna.

- Antenna Array
  - RF MMIC Phase Shifter
    - 6 Bit, Band Specific
  - NCO Phase Shifter
    - 16-24 Bit
  - OFDM FFT Phase Shifter
    - 16-24 Bit

- Up/Down Conversion
3. Field Programmable RF - Details
FPRF Tx RF Gain Block

- The transmitter RF gain has control range of 52 dB
- The receiver RF gain has control range of 30 dB
- The receiver baseband gain has control of 31 dB
- Further gain control available in digital – approx. 54 dB
- AGC in Digital
FPRF Tx/Rx PLL Phase Noise

- Two synthesizers for FDD
- Single synthesizer mode for TDD
- PLL Range 30MHz-3800MHz
- Down to 100kHz with NCO
- Frequency Resolution 24.8 Hz
- Reference clock: 10-61.44MHz

<table>
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<th>PN@1kHz, dBC</th>
<th>PN@10kHz, dBC</th>
<th>PN@100kHz, dBC</th>
<th>PN@1MHz, dBC</th>
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</tr>
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</table>

*Integrated PN measured from 1 kHz to 1 MHz. Low integrated phase noise leads to good EVM.*
FPRF Tx/Rx LPF (Antialias) Bandwidths

Measured LMS7002M Tx LPFL Filter Response

Measured LMS7002M Rx LPFL Filter Response

Measured LMS7002M Tx LPFH Filter Response

Measured LMS7002M Rx LPFH Filter Response
FPRF Rx Noise Figure and Linearity over Absolute Gain

LMS7002M Receiver Noise Figure and IP3 over Gain@800MHz

Active LNA - LNAW

LMS7002M Rx Noise Figure and IP3 over Gain@1850MHz

Active LNA - LNAN
Automatic Calibration

- Radio chips require a number of calibrations
  - LO Leakage cancelling
  - Image Rejection calibration
  - Analogue Filter calibration
  - PLL Locking
- Many possible approaches
  - RF and BB Loop back paths
  - State Machine
  - Dedicated Microcontroller

Specifications

8-bit microcontroller.
Industry standard 8051 instruction set compatible.
Running up to 60 MHz.
Memory

- 8 KB SRAM program memory
- 2 KB SRAM working memory
- 256 B dual port RAM
4. Applications of FPRF Technology
Serving a Wide Range of Markets

These are served by variety of digital solutions in the form FPGAs and GPPs
Integrated Field Programmable RF solution

- Brings the programmability of Digital to RF and wireless
- Covers all cellular standards from 2 to 4G and beyond