T-FleX: A mobile SDR platform for TVWS flexible operation

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Outline

- Cognitive radio and the TVWS context
- Test platform requirements
- Hardware specifications
- Architecture and features
- Conclusion
Cognitive Radio and the TVWS context

Measurements in NYC from Aug. 31 to Sept 1st 2004

WiFi ISM band

GSM

Bandes TV (14-20)

TV bands (38-51)
Cognitive Radio and the TVWS context

Environment aware, self reasoning and learning capable radio that can change any of its parameters functions or protocols based on interaction with the environment in which it operates in order to optimize some QoS parameter(s) [J. Mitola]

Requires a flexible radio
Cognitive Radio and TVWS context

Main roadblocks:

- Adoption by regulation bodies of a new allocation scheme.
- Business models need to be clarified… why should stakeholders move to a new paradigm? What is the market benefit?
- Current license holders see Dynamic Spectrum Access (DSA) as a potential threat.
- There is a need for trials to validate the technology

Television bands:

- TV bands have been open to unlicensed secondary access in the USA (FCC), and is being discussed in other countries (e.g. in the UK)
- TV band operation is permitted provided that non interference with TV and PMSE equipment is guaranteed. I.e.: in channels not occupied by these systems (TV White Spaces)
Particular scenarios are of interest in the FP7 QoSMOS project:

- ‘Cognitive femtocell’ (e.g.: private wireless access of the same type as WiFi) (1)
- ‘Cellular extension in the whitespace’ (e.g.: increased mobile broadband coverage) (2)
- ‘Cognitive ad-hoc network’ (e.g.: emergency first responder) (3)

CR systems are characterized by very strong requirements on flexibility

- Tuneable RF stage to address different portions of the TVWS spectrum.
- Large bandwidth though high dynamic A/D and D/A conversion
- Flexible hardware, i.e. Field Programmable Array (FPGA), with digital-signal-processing capabilities for the implementation of the digital physical layer mod/demod, FEC codec, and spectrum sensing functionalities.
- An embedded microprocessor to complement the FPGA in order to control and configure the PHY as well as execute application and MAC.
- Fast data interface should link the platform to provide a network connection, and interface to a host display, and a Graphical User Interface (GUI).
Flexible TV channel usage

40 MHz

RF TX band

OC₁   OC₂   IC₁   OC₃   IC₂

8 MHz

f_c
Architecture and Features

RF Transmitter Front-End Architecture

- Frequency-agile architecture
- Digitally tuneable band pass and low pass filters
- Digitally tuneable attenuators for gain adjustment
- Linear power amplifier
- Broadband antenna
RF Transmitter Front-End Features

- Board dimension: $7.7 \times 6.8 \text{ cm}^2$
- Input frequency (IF): 280 MHz
- Signal bandwidth: 40 MHz
- Output frequency range (RF): 470 ... 860 MHz
- Max. output power: +17 dBm
- OIP3: +34 dBm
- Spurious emissions: < -45 dBm
RF Transmitter Front-End: Digitally Tuneable Bandpass

- Tuning range: 470 ... 860 MHz
- Resolution: 5 bit
- 1-dB bandwidth: 40 MHz
- Insertion loss: 7.5 ± 0.5 dB
- Suppression at 1\textsuperscript{st} harmonic: > 30 dB
RF Receiver Front-End Architecture

- Frequency-agile architecture
- Optimised to high sensitivity and high input dynamic range
- Digitally tuneable band pass and low pass filters
- Digitally tuneable attenuators for gain adjustment and AGC
- Broadband antenna
Architecture and Features

RF Receiver Front-End Features

- Board dimension: 7.7 \times 6.8 \text{ cm}^2
- Input frequency range (RF): 470 ... 860 MHz
- Output frequency (IF): 280 MHz
- Signal bandwidth: 40 MHz
- Sensitivity (10 dB SNR): -90 dBm
- IIP3: -7 dBm
- SFDR (CW): > 75 dBm
- Noise Figure: < 4 dB
Digital board Architecture

- **Texas DM3730**
  - TiWi-R2 WiFi module
  - DVI Digital Visual Interface
  - Camera Connector
  - Quartz: 32,768 kHz
  - 2 Gbits LPDDR SDRAM
  - 4 Gbits Nand Flash
  - External Flash Memory µSDcard
  - PHY MAC LAN9220
  - USB Link OTG
  - JTAG ARM
  - Ethernet 10/100 Mbits/s
  - High-speed USB 480 Mbd

- **Xilinx XC7K325T**
  - Oscillators
  - Clocks generator AD9516-0
  - 2 dual ADC AD9643
  - Quad DAC AD9148
  - JTAG Xilinx
  - Flash PROM Xilinx XCF128X

- **RF Board**

- **PC**
  - JTAG ARM: XDS560 Emulator
  - JTAG Xilinx: USB Xilinx Probe
## QOSMOS digital boards vs ETTUS E110

<table>
<thead>
<tr>
<th></th>
<th>ETTUS RESEARCH USRP E110</th>
<th>QoSMOS Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ADC</strong></td>
<td>Dual 64 MSPS</td>
<td>Quad 250 MSPS</td>
</tr>
<tr>
<td></td>
<td>12-bit ADC</td>
<td>14-bit ADC</td>
</tr>
<tr>
<td></td>
<td>max IF freq. 400-MHz</td>
<td></td>
</tr>
<tr>
<td><strong>DAC</strong></td>
<td>Dual 128 MSPS</td>
<td>2 Dual 1000 MSPS</td>
</tr>
<tr>
<td></td>
<td>14-bit DAC</td>
<td>16-bit DAC</td>
</tr>
<tr>
<td><strong>FPGA</strong></td>
<td>Xilinx Spartan 3A (XC3SD3400A)</td>
<td>Xilinx Kintex 7 (XC7k325t)</td>
</tr>
<tr>
<td><strong>Embedded Processor</strong></td>
<td>720 MHz ARM Cortex A8 C64 DSP</td>
<td>1 GHz Arm Cortex A8 C64 DSP</td>
</tr>
<tr>
<td><strong>Comm. Interface</strong></td>
<td>Ethernet 10/100 Base-T</td>
<td>Ethernet 10/100 Base-T WiFi 802.11a/b/g Bluetooth</td>
</tr>
<tr>
<td><strong>Power Consumption</strong></td>
<td>Approx. 9 W (6 VDC, 1.5 A)</td>
<td>Approx. 10.6 W (3.8 VDC, 2.8 A)</td>
</tr>
<tr>
<td><strong>Dimensions (Case included)</strong></td>
<td>22 x 16 x 5 cm</td>
<td>16.5 x 7.8 x 4.3 cm</td>
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</table>
OFDM is the initial choice for CR PHY

- OFDM is deployed in broadcast applications, as well as in mobile wireless communication
- Simple equalization and high bandwidth efficiency.
- Narrowband flexible subcarriers, Cyclic Prefix combined with channel coding → robust and reliable systems.
- Multicarrier scheduling realize the frequency diversity with scattering

Why post-OFDM waveforms?

- OFDM is well localized in the time domain which results in easy time sync. but poorly localized in the freq. Domain
  - Leakage issued in adjacent channels
  - Uneasy to exploit fragmented spectrum

ACLRT and fragmented spectrum usage for Dynamic Spectrum access are key drivers in WP4
## Preliminary FBMC tests

<table>
<thead>
<tr>
<th>Parameter</th>
<th>OFDM modulator</th>
<th>FBMC modulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channelization</td>
<td>8MHz</td>
<td>8MHz</td>
</tr>
<tr>
<td>SC spacing</td>
<td>15kHz</td>
<td>15kHz</td>
</tr>
<tr>
<td>Numb. of SC</td>
<td>1024</td>
<td>1024</td>
</tr>
<tr>
<td>Numb. of active SC</td>
<td>481</td>
<td>481</td>
</tr>
<tr>
<td>Active bandwidth</td>
<td>7.2MHz</td>
<td>7.2MHz</td>
</tr>
<tr>
<td>Output level</td>
<td>17dBm</td>
<td>17dBm</td>
</tr>
</tbody>
</table>
OFDM vs FBMC TX spectrum
Conclusion

- Platform specification derived from TVWS scenarios
- Analysis of available platform against these requirements has been performed
- Need for RF flexibility, high computational power, though compact form factor
- A specific platform ‘T-FleX’ has been designed and manufactured in the framework of the QoSMOS project
- Main feature are a Flexible TVWS RF front end, Kintex 7 FPGA and an OMAP Cortex 8 processor
- The board is being programmed with flexible PHY for white spaces based on Filter Bank Multi-Carrier scheme
Acknowledgment

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http://www.ict-qosmos.eu/