Nutaq
OFDM Reference Design

FPGA-based, SISO/MIMO OFDM PHY Transceiver
PRODUCT SHEET
The Nutaq OFDM Reference Design is a complete SISO/MIMO OFDM PHY-layer implementation on Nutaq μSDR42x/PicoSDR Multimode tunable RF SDR Systems. The powerful Virtex-6 FPGA of the μSDR42x/PicoSDR kit (Perseus 601X) is used to implement the baseband OFDM modulator/demodulator. The tunable RF section (Radio420x), from its Zero-IF architecture, takes the digital-baseband OFDM modulated packets and brings their spectral content on a frequency range configurable from 300 MHz to 3 GHz. Demodulated data are exchanged with external host (Matlab) or embedded host (PPC/x86) for analysis and/or for the upper communication layers. An application showcases continuous wireless HD video transmission between two μSDR42x/PicoSDR system (or between RX and TX antennas of the same system).

The Nutaq OFDM Reference Design is not compliant to a current telecommunication standard but is strongly based on the successful IEEE STD 802.11a (R2003) physical layer specifications. It features two different antenna schemes: Single Input Single Output (SISO) and Two-by-Two Multiple Input Multiple Outputs (2x2 MIMO). The MIMO capacity, enabled by the Radio420x Nutaq RF module, mitigates the effects of fading and results in improved bit error rate at the receiver.

The baseband implementation exploits the high bandwidth capabilities of the FMC Radio420 by using 20 MHz of modulation bandwidth, which is an actual requirement for the next generation telecommunication standards, such as Long Term Evolution (LTE). Both the transmitter and the receiver can be implemented in a single FPGA (Perseus 601X), enabling a complete low-cost solution in a single board.
THE TRANSMITTER

Using the RTDEx (Real-time Data Exchange Host <-> FPGA) core of the Nutaq Perseus 601X, the compressed video data is fed from the host PC (using VLC software) and sent through the FPGA-based OFDM modulator. The following physical layer operations are performed before going over the air:

- The video stream bits are serialized and scrambled for Peak to Average Power Ratio (PAPR) reduction and then, convolutional coding is performed. The resulting bits are mapped using the Quadrature Amplitude Modulation (QAM) technique. The size of the constellation can be modified at runtime, depending on the actual signal quality and environment. If required, the Space-Time Block Coding (STBC) is performed using the Alamouti’s transmission scheme matrix. An OFDM training symbol for Block Boundary Detection (BBD) and coarse Carrier Frequency Offset estimation (CFO), followed by channel estimation pilots, are inserted in front of the payload. The Inverse Discrete Fourier Transform (IDFT) of the data is efficiently performed using the Inverse Fast Fourier Transform (IFFT) algorithm, provided by the System Generator block library. Cyclic prefix and suffix is inserted and each OFDM time symbol is routed to their respective antenna, if MIMO transmission scheme is required. An FIR filter interpolation is performed to match the 40 MSPS sampling rate of the FMC Radio420 ADC’s, followed by I&Q interleavers, to match the ADC’s required data input mechanic.

THE RECEIVER

In a free radio receiver, the BBD is used to correct the packet and FFT algorithm is used to extract symbols. The symbols are sent to the stream...
THE RECEIVER

In a free running manner, the FMC Radio420 digitizes and moves down the 20 MHz RF bandwidth to baseband. In the receiver, the following physical layer operations are performed on the received digitized samples:

- I&Q data deinterleaving
- CFO Correction
- Decimation Filters
- Automatic Gain Control
- Coarse CFO Estimation
- Channel Estimation
- FFT
- Cyclic Prefix Removal
- Block Boundary Detection
- Equalizer/Pilot Remover
- Space Time Block Decoder
- QAM Demapper
- Error Correction
- Data Descrambler
- Data Streaming to Host PC

From FMC Radio420

In the Perseus 601X FPGA, the I&Q data are de-interleaved and filtered by a matched filter, for BBD purpose. When the BBD threshold is met, a coarse CFO estimation is made, using the same OFDM training symbol. A Direct Digital Synthesizer (DDS) frequency is configured on-the-fly by the provided CFO estimate and a complex multiplier is used to correct the offset. Using the BBD pulse signal, we can remove the cyclic prefixes and suffixes from the OFDM packet and proceed to the Discrete Fourier Transform algorithm. Again, the DFT is implemented using an efficient FFT algorithm from the System Generator block library. Being now in the frequency domain, channel estimation is made using the received OFDM pilot symbols and the equalization is performed on the received OFDM payload symbols. Depending on the QAM constellation size, de-mapping is performed and the resulting QAM symbols are sent to the error correction block. Finally, the payload bits are descrambled and parallelized into 32 bits samples, for streaming over the Perseus 601X’s RTDEx interface, back to a host VLC (video player) application.
<table>
<thead>
<tr>
<th>Features</th>
<th>NOW</th>
<th>2013 ROADMAP</th>
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<tbody>
<tr>
<td>Data Modulation</td>
<td>QAM 64</td>
<td>QAM 4 / 16 / 64</td>
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<tr>
<td>Data rates</td>
<td>&gt; 10 Mbps</td>
<td>TBD</td>
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<td>Video streaming example</td>
<td>HDTV</td>
<td>HDTV</td>
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<td>SISO version</td>
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<td>Yes</td>
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<tr>
<td>Diversity scheme (2x2 MIMO)</td>
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<td>Yes</td>
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<tr>
<td>Channel Estimation</td>
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<td>Yes</td>
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<td>Data Scrambler</td>
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<td>Carrier Frequency Offset Correction</td>
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<td>Yes</td>
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<td>AGC</td>
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<tr>
<td>Uplink – Downlink</td>
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<td>Uplink &amp; Downlink</td>
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<td>EEC scheme</td>
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<td>Data Interleaver</td>
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<td>QAM demapper</td>
<td>Hard decision based</td>
<td>Soft decision based</td>
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<td>FFT Size</td>
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<td>Bandwidth</td>
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