HSMM Experiments on the 6M Amateur Band

Progress Report on VHF OFDM Modem submitted by John B. Stephensen, KD6OZH

1. Introduction

The purpose of this project is to test wide bandwidth digital transmission for applications such as image transmission in the Amateur Service on its VHF allocations. John B. Stephensen, KD6OZH is doing development and testing, under the auspices of the HSMM Working Group. If this system proves successful, the ARRL may petition the FCC for use of up to 200 kHz bandwidth in the VHF amateur band. The current petition for regulation by bandwidth requests 100 kHz maximum bandwidths on the VHF bands.

Current regulations limit bandwidths to 20 kHz on VHF amateur bands so testing is authorized under an FCC Special Temporary Authority (STA) that is effective until September 10, 2006. It authorizes emissions with a bandwidth up to 200 kHz in the band 50.3-50.8 MHz. This frequency range is consistent with both ARRL national voluntary band plans and applicable local band plans in the Fresno, California area where testing will be done. Specifically, in those band plans, the segment 50.3-50.6 MHz is designated for all modes and the segment 50.6-50.8 MHz is designated for nonvoice communications. The STA authorizes 1.5 kW peak, a 200 kHz maximum bandwidth and 384 kbps maximum data rate.

2. Description

The modem being developed is a modification of the UHF offset frequency division multiplexed (OFDM) modem tested on the 70-cm amateur band. OFDM splits a high-rate data stream into multiple parallel low-rate streams transmitted on multiple subcarriers. As the signal propagates, it is reflected and refracted, giving rise to multiple echoes that corrupt data. OFDM slows the rate so those echoes are confined to small gaps between transmitted symbols. The technology is similar to that used on HF bands, but the data rate of each subcarrier is higher as the maximum path length is considerably shorter.

This modem consists of software written in Verilog, assembly and C language that runs on a DCP-1 card containing a Xilinx XC3S400 field-programmable gate array (FPGA) and Oki Semiconductor ML67Q5003 microcontroller. One DCP-1 attaches to the intermediate frequency (IF) output of a modified ATR-2000 receiver at one end of the link and another attaches to small printed circuit board with a quadrature modulator IC (Atmel U2790) and the power amplifier from the ATR-2000 at the other end of the link. The transmitter is in a fixed location (Lat: 36d 46m 30s N, Lon: 119d 46m 22s W) and can generate 150 WPEP into an 8 dBi gain vertical antenna (Diamond Antenna DP-GH62). The receiver is mobile and uses a Ham-stick antenna mounted on the roof of a SUV.

The DCP-1 and ATR-2000 are documented in articles published in QEX. The UHF OFDM modem specification is on the ARRL web site and a new version, covering VHF operation, of the document will be published as part of this testing. Documentation of the modem hardware and source code will be made available to radio amateurs after testing.

Three data formats will be tested. These are designed for 50, 100 and 200 kHz channels. Initial tests will use 750 Hz subcarrier spacing with an inter-symbol guard interval of 1/8 symbol period. This combination was selected to support relatively small channels and still have a guard interval that allows rejection of inter-symbol interference in any conceivable operating environment. Field testing of ATSC (digital) television systems showed a maximum delay spread of 90 μs and the resulting guard interval for the VHF OFDM modem is 166 μs. The resulting system should be able operate over LOS or NLOS paths in most terrain with directional or omnidirectional antennas. The signal formats use a central pilot carrier and upper and lower sidebands with 24, 48 or 96 data subcarriers plus 2 trellis-terminating subcarriers each. The subcarriers use differential 8-ary phase shift keyed (PSK) modulation with rate 2/3 convolutional coding. The resulting encoded data rates are 96, 192 and 384 kbps with user data rates of 64, 128 and 256 kbps.

3. Progress

Verilog code has been generated for the VHF OFDM modem and 95% of it has been successfully simulated. Simulation has taken longer than expected due to problems associated with IP (intellectual property) upgrades in the Xilinx development software. Modifications to the original UHF modem included:

1. Reducing the size of the finite impulse response (FIR) digital low-pass filters to allow 3 programmable filter stages instead of 2. 2. Increasing filter coefficient precision from 18 to 24 bits. 3. Writing a new encoder and Viterbi decoder to convert from the Ungerboeck trellis-coded modulation (TCM) using a 4-state encoder in the UHF modem to a bit-independent coded modulation (BICM) with 8-states. 4. Modifying the fast Fourier transform (FFT) implementation to support 17-bit data and reduce memory requirements. The FFT multiplexes and demultiplexes the subcarriers. 5. Modifications in multiple modules to allow different numbers of subcarriers. 6. Converting interfaces between circuits using different clock rates from using block RAM (random access memory) in the FPGA to distributed RAM in the FPGA to free block RAM for additional filtering.

The change from TCM to BICM was made to increase performance over fading paths. The TCM scheme was originally designed for additive white Gaussian noise (AWGN) channels as encountered with telephone modems. This will be incorporated into the UHF modem specification. The filtering changes were required to support higher decimation and interpolation rates and provide a better shape factor to limit occupied bandwidth.

Once all the code has been simulated, it will be loaded onto a DCP-1 and the output checked with a spectrum analyzer. Of particular interest is the level of high-order intermodulation distortion (IMD), or splatter, that will be generated in the power amplifier. A signal generator and arbitrary function generator is also available for receiver testing.

The final test will be one-way over-the-air with measurement of bit error rates, allowable SNR (signal to noise ratio) and coverage area. Testing will also be done on the 70-cm band, either before or after the STA expires, to compare coverage areas and amplifier IMD.