Wideband Spectrum Sensing Experiments in Indoor Wireless Channels

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***Abstract*-In this work, spectrum sensing experiments are conducted in indoor wireless channels using state-of-the-art commercial software radio transceivers. The objective is to evaluate the performance of cooperative spectrum sensing of wideband channels and determine achievable gains against the limiting effects of multipath interference, frequency-selective and correlated fading. To this end, the energy and temporal correlation metrics of narrowband signals embedded in a wideband transmit signal are examined with varying transmitter-receiver positions. It is shown that whereas the energy metric of signal carrying bands becomes indistinguishable from that of empty bands with increasing distance and in non line-of-sight conditions, the temporal correlation features of modulated active channels are retained when sensing relatively longer distances from the transmitter, even in a highly multipath environment.**

I. Background

Spectrum sharing between primary and secondary users in cognitive radio networks can be enabled by continuous monitoring of the channels available for sharing with timely updates on channel status and subsequent distribution of available channels to secondary users. This dynamic channel allocation problem is conditioned on minimizing the interference caused to nearby receivers of active primary user channels. In indoor environments multipath interference, frequency-selective fading and hidden terminals can contribute to a failure in detecting a primary source at a sensing node. A multi-sensor detection utilizing data from spatially distributed sensing nodes may offer an improved performance in such situations. The performance of detectors with cooperative spectrum sensing has been presented in many studies [1], [2], [3]. Since cooperative sensing can incur significant overhead, the optimal selection of cooperative nodes is critical to avoid performance degradation due to correlated fading. In this work, two commercial software-defined-radio (SDR) platforms are configured as a transmitter and/or receivers to evaluate some of the practical issues in implementing spectrum sensing in an indoor environment.

II. Experimental Setup

The experiments are conducted indoors in an office and laboratory space of dimensions $16.5\ m\ (L) \times 10.26\ m\ (W) \times 3.15\ m\ (H)$. The transmitter and receiver nodes each consist of three connected components: (i)Pentek 7741 dual multiband software radio transceiver; (ii) RF Front End; and (iii) Directional Antenna. Pentek 7741 is a PCIe module that includes a 16 bit, 500 MSPS D/A converter (TI DAC 5686), two 14 bit, 125 Mhz, A/D converters (LTC 2252), a Xilinx Virtex-II Pro^{TM} XC2VP50 FPGA, and a 100 Mhz onboard crystal oscillator. The controllable parameters of the software radio modules include the data rate, modulation, waveform shaping, signal power level and the intermediate frequency (IF) of the output that is fed to the RF module. At the receiver, the signal decimation rate in the ADC and the IF to baseband down-conversion can be adaptively controlled. The RF front ends connected to the transceivers are built from Mini-Circuits components that include a mixer (ZX05-C60LH-S+, 1600-6000 Mhz), a voltage controlled oscillator (ZX95-3800A-S+, 1900-3700 Mhz) and band-pass filter (VBFZ-2340-S+, 2020-2660 Mhz) for up and down conversion to 2.4 Ghz ISM band transmission. The directional transmit and receive antennas are mounted at top of 1.7 meter PVC tubes and connected to the RF front-end modules with low loss coaxial cable.

III. Results

The transmitter is configured to produce a set of sixteen amplitude modulated narrowband (NB) signals, each of which can be made active or inactive with a binary phase-shift keyed symbol sequence. The sixteen channels labeled CH0: CH15 have center frequencies starting from 0 with increments of 3.125 Mhz. The group of NB channels is combined into a single wideband (WB) transmission signal using a quadrature-mirror-filter (QMF) bank, with each filter being 256 points in length. The WB signal is single-sideband (SSB) modulated to an IF of 25 MHz. For the results demonstrated here, CH10 is made active and all other channels are inactive. The WB signal is upconverted to a 2.4 Ghz radio signal in the RF front end. The received signal is down converted to IF by the RF front end at the receiver and acquired by the Pentek software radio receiver, digitized and processed to examine the energy and correlation. The received signal

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sample rate is 100 Mhz and SSB demodulation is performed to downconvert the IF signal to baseband. The WB signal is then decimated by a factor of one to match the 50 Mhz sample rate generated at the transmitter. The resulting signal is decomposed into the narrowband channels using the QMF analysis filters. The energy metric $E[n]$ of each NB channel is computed by cumulative summation of the received samples over time, where n is the sample time index. Fig. (1) depicts $E[n]$ for CH10 and for comparison an inactive band CH14 is also shown. The curves in red show the energy growth in time for CH10 in line of sight (LOS) case and the drop in energy as the distance from the transmitter increases from 1.22 to 4.88 meters. The results for CH14 in blue reside in the noise floor for both cases. Also shown (green) is the energy captured under non-LOS transmission for a distance of 1.22m, which is seen to yield results close to the noise level. Fig. (2) depicts the normalized autocorrelation function for CH10 band and CH14 band for different receiver positions, estimated using a received signal length of 0.3 milliseconds. The figure shows that in LOS cases, the long-range correlation is retained even as the transmit-receive distance is increased. The result for NLOS transmission shows that the signal loses short-range correlation but retains the long-term coherence, which can be utilized for effective sensing. The figure also shows that a clear distinction can be made in the magnitude and decay rate of correlation functions between the signal carrying and inactive channels. Fig. (3) depicts the normalized autocorrelation function for CH10 (active) band and CH6 (inactive) band for power levels of -46.25 dB, -53.26 dB and -56.99 dB and shows that detection is possible even at lower power levels.

IV. Conclusions

The sensing of NB signals using energy and correlation metrics in indoor wireless channels was examined with software radio experiments. Selected NB channels were activated and embedded in a wideband signal and transmitted to receivers at varying distances and in LOS and NLOS conditions. The performance of energy and correlation detection was compared. The robustness of temporal correlation feature in multipath environment with increasing transmitter-receiver distances and under NLOS reception and transmitter powers was identified.

V. Acknowledgements

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References

[1] I. Akyildiz, B. F. Lo, and R. Balakrishnan, "Cooperative spectrum sensing in cognitive radio networks: A survey," *Physical Communication* **4**, pp. 40–62, 2011.

[2] G. Ganesan and Y. Li, "Cooperative spectrum sensing in cognitive radio, part i: Two user networks," *IEEE Trans. on Wireless Commun.* **6**(6), p. 2204:2213, 2007.

[3] J. Unnikrishnan and V. Veeravalli, "Cooperative spectrum sensing and detection for cognitive radio," in *Proc. GLOBECOM'2007*, p. 2972:2976, 2007.

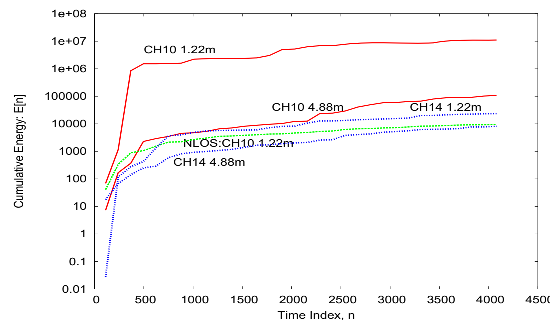

Fig. 1. Cumulative energy with time for active and inactive channels.

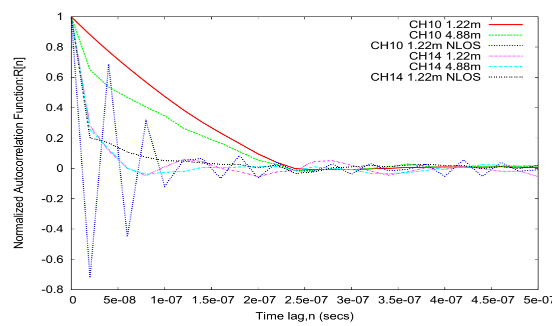

Fig. 2. Autocorrelation function for CH10/CH14 (active/inactive channel) for different positions.

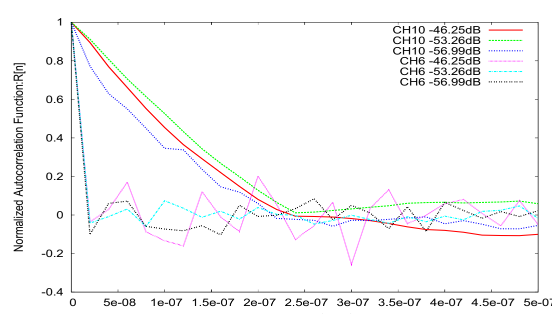

Fig. 3. Autocorrelation function for CH10/CH6 (active/inactive channel) for different power levels.