Prediction of IEEE802.16 performance for emergency vehicles to indoor from radio channel measurements in the 4.9 GHz band

S. Salous[1], R. Bultitude[2], K. Mehra[1], O. Oghre[1] Y.L.C. de Jong[2], and J. A. Pugh[2]

1. Centre for Communications Systems, Durham University, Durham, DH 1 3LE, U.K

2. Communications Research Centre, 3701 Carling Ave, Ottawa, Canada K2H 8S2

Abstract

Work reported herein contributes to the prediction of achievable performance of the IEEE 802.16 standard using time series of 50 Mchps PN channel sounder measurements at 4.9 GHz on radio channels in a scenario in which emergency vehicles are parked outside a building and operate as a centre for communications with rescue crews and equipment inside the building. Predicted error rates are presented for different modulation schemes used in accordance with the standard, including QPSK, 16QAM and 64QAM and for different coding rates. Probability of error rates are presented for Rician channels that exhibited envelope fading with different K ratios.

1. Introduction

The IEEE802.16-2004 standard defines the air interface specifications for wireless metropolitan area networks for the 10–66 GHz band and the 2–11 GHz band [1]. The WiMAX forum for fixed broadband services adopted three of the standard's mandatory air interfaces specified for the license exempt band with 256 carrier-orthogonal frequency division multiplexing (OFDM). OFDM schemes offer resilience against frequency selectivity and the simplicity of frequency domain channel equalisation. Performance evaluation of the standard has so far been reported either in additive white Gaussian noise (AWGN) [2] or using the Stanford University interim (SUI) or the 3GPP outdoor channel models [3–6] or from measured channels in rural/semirural environments in the UK [7]. The SUI model, adopted by the WiMAX forum, provides six channel models from measurements at 1.9 GHz in the US for different environments [8,10] with rms delay spreads ranging from 103 ns for SUI model 1 to 5.2 ms for SUI model 6, Doppler spreads from 0.2–2 Hz and various Rician K ratio. The model assumes that a channel's power delay profile consists of a main spike set at zero delay with 0 dBr and two other taps with an exponential decay with adjustments for receiver antenna directivity [9-10]. The three tap delay profile was also proposed by Hong et al. [11] based on measurements in the UK at 3.5 GHz with sectored antennas. The model assumes rms delay spreads on the order of 75–130 ns [12] and taps at 0, 200 and 400 ns with relative amplitudes equal to 0, -20 and -25 dB. Other measurements performed at 2.45 GHz with directional and omni-directional antennas reported 90 ns rms delay spreads for directional antennas and 700 ns for omnidirectional antennas [13].

In this paper, we report on the standard's performance using vehicle to indoor measurements performed in the 4.9 GHz band. The scenario is that for an emergency vehicle parked outside a building and acting as a centre for communications with personnel and equipment inside the building.

2. Measurements

Outdoor-to-indoor measurements were conducted in a 100 MHz bandwidth centred at 4.95 GHz. The transmitter was housed in a large van, parked in front of a 4-story brick building, as shown in Fig. 1.a. The transmitter output at a power of +34 dBm was fed to a vertically-polarised standard gain horn having a gain of 10 dBi and 3 dB beamwidths of 35 and 50 degrees in E and H planes, respectively. The horn was mounted at a height of 4.2 m above ground level on a pneumatic mast extended upwards from the rear of the van. Reception was via a 2-10 GHz bi-conical antenna mounted on wooden support extended to a height of about 1.5 m from the top of a typewriter table having 4 small wheels. Measurement runs were made during silent hours at 21 grid points on each floor of the building, as shown in Figure 1.b. During each measurement run, 16, 256 chip-long, 50 Mchps PN sequence were recorded, at a rate of 250 snapshots/sec while the antenna table was pulled by an operator.

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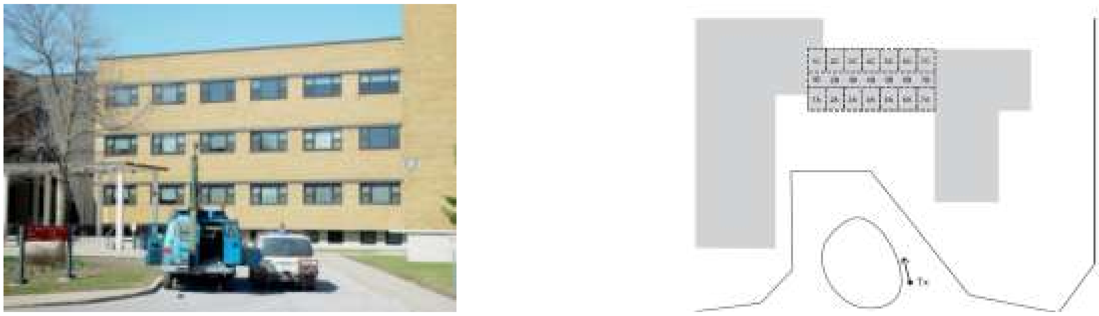


(a) (b)

Fig. 1 Transmitter antenna configuration (a) and layout of measured locations (b).

Excess transmission losses were estimated fromAverage Power Delay Profiles (APDPs), by comparison against a calibration reference, and appropriately accounting for free space loss and measurement system gains and losses. Excess loss varied from floor-to-floor and depending on whether the receiver was on the illuminated or back side of the building or in the hallway. In summary, such losses varied from 20-50 dB and were greater (> the measurement system dynamic range) in the basement, 10-30 dB on the ground floor, 7-27 dB on the second floor, and from 7-32 dB on the third (top) floor. Rms delay spreads varied similarly with measurement location, but their minimum and maximum values were about the same on all floors, being 9 ns and 30 ns, respectively for -20 dB noise threshold, with 16 ns median values except on the second floor, where the median was 21 ns. Equivalent CW envelope fading distributions were estimated from the variations in single spectral lines in measured channel transfer function time series. The results indicated that Rayleigh fading was exhibited in only 16 out of the 72 measured locations while the other locations exhibited Rician characteristics, with K ratios from –1 dB to + 11 dB. The coherence bandwidths for Rayleigh channels would be approximately equal to the reciprocal of rms delay spreads which is about 1/(30 ns) or 33 MHz. On Rician channels, where the reciprocal rms delay spread-coherence bandwidth relationship does not apply, coherence bandwidths would be even greater.

3. Simulated WiMAX standard

A time domain Mathworks SIMULINK simulator was used to study the different modulation schemes used in the IEEE 802.16.d WiMAX standard. The simulator was first adapted to implement each modulation scheme and coding rate independently rather than run in the adaptive mode. The standard uses 256 OFDM carriers, and concatenated coding schemes consisting of Reed Solomon block codes to handle burst errors and convolution codes to correct for random errors. Modulation schemes and coding rates studied include QPSK with ¾ rate coding, 16 QAM with ½ and ¾ rate coding and 64 QAM with ¾ and 2/3 rate coding. The channel block takes a delay vector with corresponding gain vector, K ratio and maximum Doppler shift. The simulator can be run for each SNR to a pre-determined error rate or maximum number of bits.

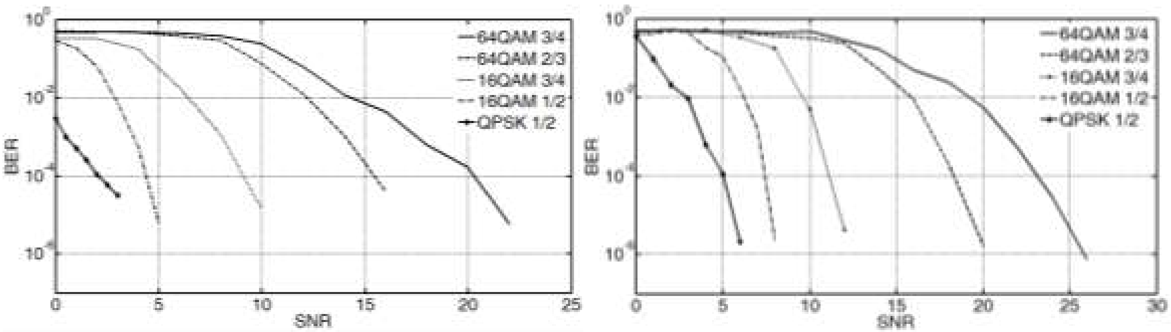
4. Simulation results

The simulator was run for different modulation schemes and different coding rates. The channel data were first filtered with a Bessel filter down to 20 MHz bandwidth which is the highest bandwidth of the standard. Figure 3 shows the unfiltered and the filtered back to back response. A -30 dB below the peak noise threshold was then applied to the filtered data to identify the multipath components in time delay and relative amplitude in dB.

(a) (b)

Figure 3. Back to back impulse response of sounder (a) unfiltered, (b) filtered

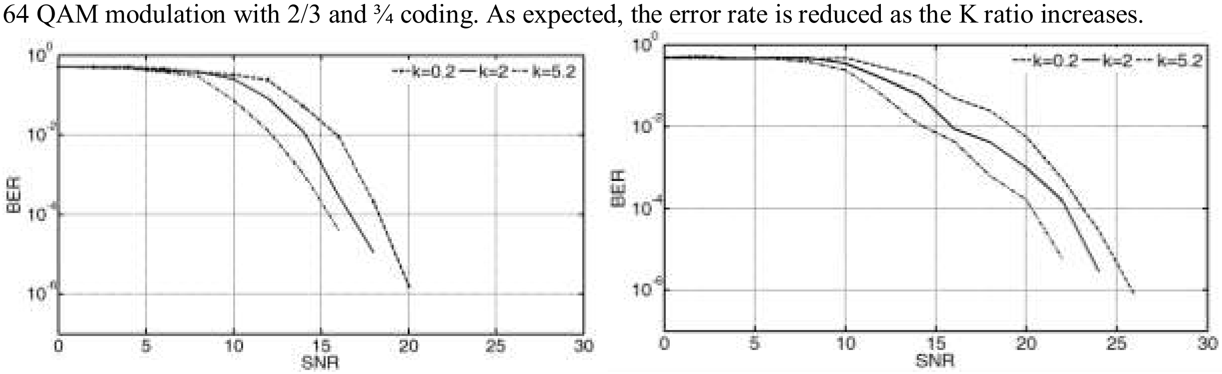
In this paper we present results from three data files with K ratios equal to 0.2, 2 and 5.2 with corresponding gain vectors: [0, -16.7 -17.88], [0 -12.5 -26.9] and [0 -20.6 -28.49] dB. The channel was simulated with 0.5 Hz maximum Doppler. The results for the two files with K ratio of 5.2 and 0.2 are displayed in Figure 4 for the different modulation schemes and the different coding rates. The figures show that, as expected, the lower modulation schemes give better performance than the higher order modulation schemes. Comparing the 64 QAM for ¾ and 2/3 coding rates, the 2/3 coding rate gives lower error rate results due to the puncturing in the coding scheme. Also the figure shows that the file with the lower k factor gave rise to a higher error rate.



(a) (b)

Figure 4. Bit error rate for different modulation schemes and coding rates for two files (a) file with k factor equal to 5.2 and (b) file with k factor equal to 0.2.

The relationship between error rate and the K ratio can also be seen from Figure 5 for the three profiles for 64 QAM modulation with 2/3 and ¾ coding. As expected, the error rate is reduced as the K ratio increases.



(a) (b)

Figure 5. Bit error rate 64 QAM modulation for three files with different k-factor (a) 2/3 coding rate and (b) ¾ coding rate.

5. Conclusions

In this paper, the possible application of the WiMAX standard for emergency applications was investigated. In these scenarios the maximum expected Doppler shift is within the range specified in the standard which was designed for fixed wireless access. The results show that the maximum bandwidth used in the standard of 20 MHz can be easily employed for the present scenario of outdoor to indoor propagation. For an error rate of $1x10^{-3}$ modest SNR levels are required with the worst case being 22 dB for 64QAM with ¾ coding for delay profile with a K ratio equal to 0.2. This requirement is relaxed to 17.2 dB for a channel with a K ratio of 5.2.

Further simulations will be performed to study the possibility of enhancing the data rate using wider bandwidths and the limitations of the standard for such scenarios.

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