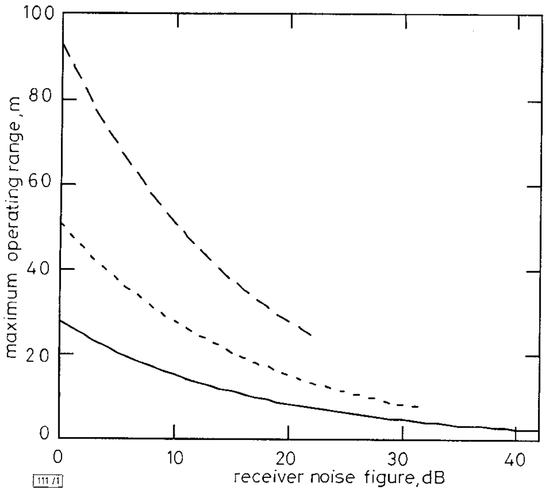

Fig. 1 *Noise limited range of HIPERLAN receivers*

——— 10dBm transmitted power (class A)
- - - - - 20dBm transmitted power (class B)
– – – – 30dBm transmitted power (class C)

Time dispersion also limits receiver range. Class A equipment has reduced dynamic range, reducing the noise limited range of the receiver. However, the delay spread seen at the receiver is also significantly reduced as much more of the power delay profile falls below the sensitivity limit, reducing the complexity of the required equaliser. Such an equaliser operating in a 25ns RMS delay spread environment is described in [10]. The equaliser may ultimately be eliminated if the RMS delay spread is < ~10% of the bit period [11], an RMS delay spread of 4.3ns.

Conclusions: HIPERLAN class C equipment is suited to providing mobility within a building or a campus site, requiring a range of several tens of meters. The power delay profile observed at the receiver covers multiple bit periods, necessitating the use of an equaliser. There is also considerable value in mobility on a desk top, within the reach space of a person e.g. a wireless PC docking station. Directed infrared traditionally targets this area. HIPERLAN class A equipment could provide a solution which has greater ease of use as it would have a range of several metres and would not suffer from the directionality of infra-red solutions. Also, an equaliser would not be required in the receiver, consequently, this equipment would be relatively inexpensive.

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Upper bound performance of adaptive modulation in a slow Rayleigh fading channel

J.M. Torrance and L. Hanzo

Indexing terms: Rayleigh channels, Fading, Adaptive systems, Modulation

The upper bound bit error rate (BER) performance of a time division duplex (TDD) system, where the number of modulation levels is adapted on a very short term basis, depending upon the channels conditions, is derived and solved by numerical integration. The performance shows very close correspondence with simulated results.

Introduction: Recently there has been considerable interest in adaptive modulation schemes [1] that can near-instantaneously vary the number of modulation levels in response to the prevailing channel conditions. Adaptive modulation level schemes exploit the fluctuating nature of the received signal level without increasing the effect of co-channel interference. This is most conveniently achieved in a time division duplex (TDD) system exhibiting low normalised Doppler frequency. The signal power of a TDD frame, received at one end of the TDD link, is used to estimate the level of fading that will be experienced in the reverse link time slot. The number of modulation levels is then selected for the reverse link on the basis of this estimate of the reverse link fading and the level of bit error rate (BER) which is acceptable to the overall system. This Letter evaluates the performance of such an adaptive scheme relative to fixed modulation level schemes and evaluates the performance upper bound of such a scheme by a numerical solution.

BER performance equations: The BER performance of coherent modulation schemes with 1, 2, 4 and 6 bits per symbol (BPS) assuming perfect clock and carrier recovery, in a Gaussian channel are known [2]. The corresponding expressions are given below:

$$P_b(\gamma) = Q(\sqrt{2\gamma}) \tag{1}$$

$$P_q(\gamma) = Q(\sqrt{\gamma}) \tag{2}$$

$$P_{16}(\gamma) = \frac{1}{4}\left[Q\left(\sqrt{\frac{\gamma}{5}}\right) + \left(3Q\sqrt{\frac{\gamma}{5}}\right)\right] + \frac{1}{2}Q\left(\sqrt{\frac{\gamma}{5}}\right) \tag{3}$$

$$\begin{aligned} P_{64}(\gamma) = {} & \\ & \frac{1}{12}\left[Q\left(\sqrt{\frac{\gamma}{21}}\right) + Q\left(3\sqrt{\frac{\gamma}{21}}\right) + Q\left(5\sqrt{\frac{\gamma}{21}}\right) + Q\left(7\sqrt{\frac{\gamma}{21}}\right)\right] \\ & + \frac{1}{6}Q\left(\sqrt{\frac{\gamma}{21}}\right) + \frac{1}{6}Q\left(3\sqrt{\frac{\gamma}{21}}\right) + \frac{1}{12}Q\left(5\sqrt{\frac{\gamma}{21}}\right) \\ & + \frac{1}{12}Q\left(7\sqrt{\frac{\gamma}{21}}\right) + \frac{1}{3}Q\left(\sqrt{\frac{\gamma}{21}}\right) + \frac{1}{4}Q\left(3\sqrt{\frac{\gamma}{21}}\right) \\ & - \frac{1}{4}Q\left(5\sqrt{\frac{\gamma}{21}}\right) - \frac{1}{6}Q\left(7\sqrt{\frac{\gamma}{21}}\right) + \frac{1}{6}Q\left(9\sqrt{\frac{\gamma}{21}}\right) \\ & + \frac{1}{12}Q\left(11\sqrt{\frac{\gamma}{21}}\right) - \frac{1}{12}Q\left(13\sqrt{\frac{\gamma}{21}}\right) \end{aligned} \tag{4}$$

where γ is the signal-to-noise ratio (SNR), $Q(x) = 1/\sqrt{[2\pi]}\int_x^\infty e^{-x2/2}dx$, and $P_b(\gamma)$, $P_q(\gamma)$, $P_{16}(\gamma)$ and $P_{64}(\gamma)$, are the mean BERs of BPSK, QPSK, square 16 point square QAM, and square 64 point QAM, respectively. The PDF of the fluctuations in instantaneous received power, s, in a Rayleigh channel are given by

$$F(s,S) = \frac{2s^{\frac{1}{2}}}{S}e^{-s/S} \qquad (5)$$

where S is the average signal power. Assuming a sufficiently low normalised Doppler frequency in order to maintain a near-constant fading envelope and hence Gaussian conditions for the duration of a modulation symbol and employing pilot symbol assisted modulation (PSAM) [3], upper bound BER performances can be obtained for the above four modulation schemes through a Rayleigh channel. For any of the modulation schemes, if $X_g(\gamma)$ is the Gaussian BER performance, as given in eqns. 1 – 4, then $X_r(S/N)$ given below will be the upper bound for the BER performance in a Rayleigh channel

$$X_r(S/N) = \int_0^\infty X_g(s/N)\cdot F(s,S)ds \qquad (6)$$

Therefore, the narrowband upper bound BER performance of an adaptive modulation scheme similar to that described in [4] may be computed from:

$$P_a(S/N) = B^{-1}\begin{bmatrix} & 1 & \cdot\int_{l_1}^{l_2} P_b(s/N)\cdot F(s,S) & ds \\ + & 2 & \cdot\int_{l_2}^{l_3} P_q(s/N)\cdot F(s,S) & ds \\ + & 4 & \cdot\int_{l_3}^{l_4} P_b 16(s/N)\cdot F(s,S) & ds \\ + & 6 & \cdot\int_{l_4}^{\infty} P_{64}(s/N)\cdot F(s,S) & ds \end{bmatrix} \qquad (7)$$

where l_1, l_2, l_3, l_4 and B are the thresholds between transmission off, BPSK, QPSK, square 16 point and square 64 point QAM, and B is the mean number of BPS. The value of B is given by

$$B = 1\cdot\int_{l_1}^{l_2} F(s,S)ds + 2\cdot\int_{l_2}^{l_3} F(s,S)ds + 4\cdot\int_{l_3}^{l_4} F(s,S)ds + 6\cdot\int_{l_4}^{\infty} F(s,S)ds \qquad (8)$$

Simulation results and conclusion: Eqn. 7 was solved by numerical integration with $l_1 = 0$ and $l_2 = l_3 = l_4 = \infty$, $l_1 = l_2 = 0$ and $l_3 = l_4 = \infty$, $l_1 = l_2 = l_3 = 0$ and $l_4 = \infty$, and $l_1 = l_2 = l_3 = l_4 = 0$ to approximate the upper bound of BPSK, QPSK, 16 Point QAM and 64 Point QAM, respectively, in a Rayleigh fading channel. The performance of the same PSAM schemes was then determined by simulation in a Rayleigh channel with perfect coherent detection. Switching levels of $l_1 = 0$, $l_2 = 8$dB, $l_3 = 14$dB and $l_4 = 20$dB instantaneous SNR were selected for the adaptive modulation scheme on the basis that 8, 14 and 20dB are the values at which the mean BER of QPSK, 16 and 64 level QAM are ~1% in a Gaussian channel.

An upper bound for the BER was calculated for fixed and adaptive modulation schemes. As both schemes were characterised under identical assumptions, a realistic comparison can be made. The BER against average channel SNR simulation results for the fixed and adaptive modulation schemes show a close agreement with the numerical results as seen in Fig. 1.

The BER upper bound performance of the adaptive modulation scheme is better than that of QPSK for all average channel SNRs and is better than BPSK between 0 and 20dB. BER performance better than BPSK may at first appear infeasible. However, in the average SNR range from 0 to 20dB, with the switching regime that has been implemented, the result of instantaneous SNR increase and consequential increase in BPS is an average reduction in BER when compared with BPSK. Fig. 1 also shows that in terms of BPS the adaptive modulation offers a benefit of almost a factor of 6 in throughput at high average channel SNRs when compared with BPSK. However, this figure would be eroded in a practical system by the overhead control information, sub-optimum phase and signal level estimation and instances of fast fading. This numerical evidence identifies benefits in adaptive level modulation compared with fixed level modulation schemes.

The adaptive modulation does not converge with the 64 point square QAM in the average channel SNR range shown because we found that even at 45dB average channel SNR 0.4% of the symbols are being transmitted as 16 point square QAM symbols, and a total of 0.1% of the symbols are being transmitted as BPSK and QPSK symbols. Numerical evaluation of the BER and BPS performance is significantly quicker than simulation. This is particularly true here, because the very slow fading nature of the channels that lend themselves to adaptive modulation require extremely long simulation length to obtain accurate results.

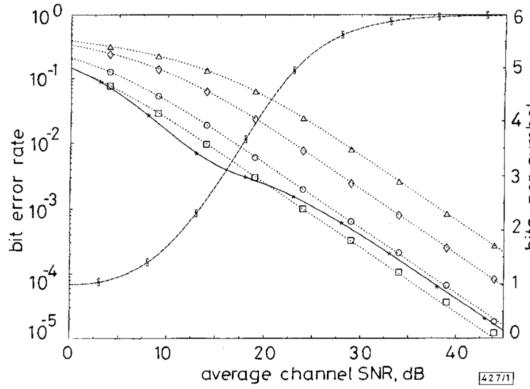

Fig. 1 *BER performance of BPSK, QPSK, square 16 point QAM, square 64 point QAM and adaptive modulation*

Switching levels –∞, 8, 14 and 20dB
BPS performance of adaptive scheme
□ simulated BER: BPSK
○ simulated BER: QPSK
◇ simulated BER: square 16 point QAM
△ simulated BER: square 64 point QAM
✳ simulated BER: adaptive
§ simulated BPS: adaptive
·········· numerical BER: fixed modulation
——— numerical BER: adaptive
– – – – numerical BPS: adaptive

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Wavelet transform-based analogue speech scrambling scheme

Fulong Ma, Jun Cheng and Yumin Wang

Indexing terms: Wavelet transforms, Speech analysis and processing

A wavelet transform based analogue speech scrambling scheme is presented. The proposed scheme offers 2-D scrambling. Related analyses and simulation results indicate that scrambled speech is highly secure in both the time and frequency domains.