Title	PERFORMANCE OF GMSK FREQUENCY DETECTION WITH SOFT DECISION DECODING OF BLOCK CODES USING CHASE'S SECOND ALGORITHM IN MOBILE RADIO CHANNEL
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Description	

cessing (Fig. 2). It can be seen that only AND, OR gates and delay lines with short delay time (four time slots and less) are required for implementation. The photonic delay line could be made compact, since applications in super high-speed environment are supposed.

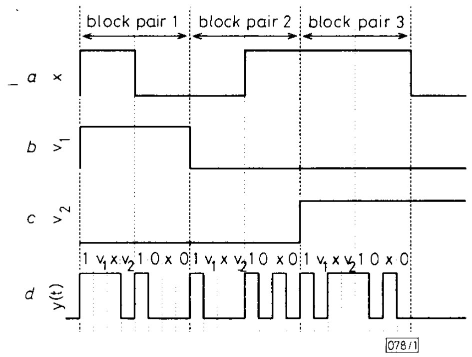

Fig. 1 *Example of k/mBnB paired block code (k = 3, m = 1 and n = 4)*

The direct use of logically recovered clock pulse should be acceptable provided that the signal to noise ratio is sufficiently large. This is due to the relatively short transmission distance, as for example intra-office applications. Otherwise, the logically recovered clock can be supplied to an optical phase locked loop, which can equivalently improve the transient response of the loop to obtain a reliable clock.

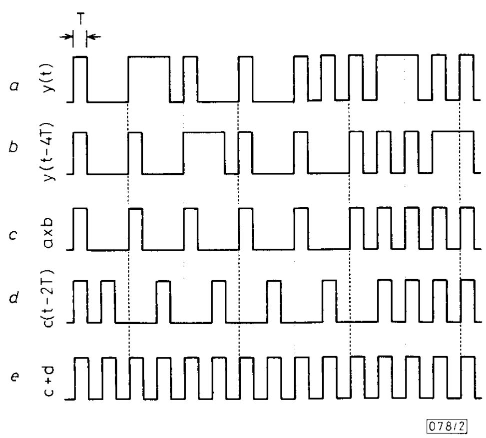

Fig. 2 *Clock recovery by logical processing applied to 3/1B4B PBC*

The efficiency of the *k/mBnB* PBC can be given by

$$\eta_{PBC} = \frac{k+m}{2n} \tag{1}$$

It is convenient to choose $k = n - 1$ and $m = n/2 - 1$ (n is even). Then,

$$\eta_{PBC} = \frac{3}{4} - \frac{1}{n} \tag{2}$$

It can be seen that the efficiency approaches 75% for a sufficiently large n (Fig. 3).

Conclusion: New line coding schemes called paired block codes (PBC) have been investigated for application in pure photonic networks. The first block of each pair utilises coding rule violations to simplify transmission frame structures, so that limited functions of optical logic can be applied for processing. The second block is provided with sufficient redundancies to attain clock recovery through logical processing.

An upper bound efficiency of this type code is 75%. However, designing at around 50% should be recommended from the practical standpoint. The efficiency is the same as that of the well-known coded mark inversion (CMI) and differential mark inversion (DMI) line codes.[5] It should be more than justifiable because of the abundant bandwidth inherent in optical processing and the advantageous features of this type of line coding scheme.

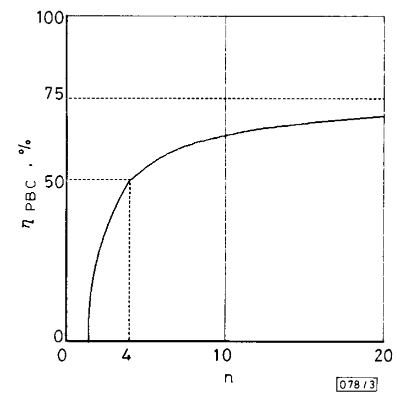

Fig. 3 *Dependence of coding efficiency on n for k/mBnB PBC (k = n − 1, m = n/2 − 1 and n is even)*

The paired block code proposed in this letter should prove efficient for alleviating the network capacity explosion anticipated in the mid to late 1990s,[1,2] by facilitating and accelerating the deployment of super broadband pure photonic technologies.

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PERFORMANCE OF GMSK FREQUENCY DETECTION WITH SOFT DECISION DECODING OF BLOCK CODES USING CHASE'S SECOND ALGORITHM IN MOBILE RADIO CHANNEL

Indexing terms: Telecommunications, Codes, Mobile radio systems, Decoding

Bit error rate (BER) performance of a GMSK frequency detection system with soft decision decoding of block codes using Chase's second algorithm is investigated in mobile radio channels. The channel measurement information (CMI) for a bit in the received block is calculated from samples of the received signal envelope (R_s) and the demodulator output (eye level). The CMIs of eye level × R_s and of R_s^2 are investigated, and the decoding performances for the CMIs are compared using the Hamming (7, 4) code in nonfading (static) and fading channels in laboratory experiments.

Introduction: Recently, the need for data communication with very low bit error rates (BER) through mobile radio channels is increasing. In land mobile radio, severe degradation in the bit error rate (BER) performance due to multipath Rayleigh fading is a serious problem. Diversity reception is an effective technique for combatting fading. Another attractive technique is forward error correction (FEC). Linear block codes such as the BCH codes with hard decision decoding is one of the attractive methods because the hardware of its coder and decoder can be easily implemented. It is well-known that soft decision decoding of block codes can achieve better performance than hard decision decoding.[1-3] This is because soft decision decoding uses channel measurement information (CMI) for estimating reliability of a received bit, while hard decision decoding uses only the algebraic redundancy of the codes. Chase[2] proposed three simplified algorithms for the soft decision, and investigated the decoding performance in Rayleigh fading channels through computer simulation. It has been shown that the second algorithm results in the decoding performance only slightly inferior to that of maximum likelihood decoding, while the complexity is greatly reduced.

The BER performance of noncoherent FSK with soft decision decoding of block codes using Chase's second algorithm has been analysed in a Rayleigh fading channel in Reference 4. The received signal envelope was sampled and used for the CMI. This method achieves a great improvement in the BER performance over hard decision decoding in Rayleigh fading channels. Experimental evaluations of the BER performance of a coherent Gaussian-filtered MSK (GMSK) system with soft decision decoding using the second algorithm were presented by Stjernvall *et al.*[5] and Ekemark *et al.*[6]

This letter deals with the BER performance of a GMSK three-level eye decision system[7] with soft decision decoding using Chase's second algorithm in mobile radio channels. The CMI values for the bit in the received block are calculated from the samples of the signal envelope and the demodulator output (eye level). The performances for the methods to calculate the CMI values are compared using the Hamming (7, 4) code in nonfading (static) and fading channels in laboratory experiments.

Methods for CMIs: In Reference 8, Hagenauer has presented some methods to calculate the metric values for Viterbi decoding of convolutional codes using samples of the received signal envelope and the eye level for coherent PSK system in mobile radio channels. The method with the best performance uses both envelope sample R_s and eye level (YSAS method), in which the metric value for the bit in a received block is given by eye level $\times R_s$. Finely quantised samples of the R_s and eye level are necessary in the YSAS decoder. This increases the decoder complexity.

One of the attractive methods for implementation is YHAH, which uses hard decisions on the signal envelope and demodulator output. The metric value is calculated as $\log [(1 - P_X)/P_X]$. Here, P_X is the conditional bit error probability given by

$$P_X = \begin{cases} \displaystyle\int_0^{\gamma_{th}} p_b(\gamma_s)p(\gamma_s)\, d\gamma_s \ldots \textit{for envelope sample lower than threshold value } R_{th} \\ \displaystyle\int_{\gamma_{th}}^{\infty} p_b(\gamma_s)p(\gamma_s)\, d\gamma_s \ldots \textit{for envelope sample higher than threshold value } R_{th} \end{cases} \quad (1)$$

where $p_b(\gamma_s)$ is the bit error probability for received signal to noise power ratio (SNR) $\gamma_s = R_s^2/2N_0$, N_0 the additive white Gaussian noise power, and $p(\gamma_s)$ the probability density function of γ_s, and $\gamma_{th} = R_{th}^2/2N_0$. The receiver uses the envelope sample R_s as information that indicates the channel is in good state (received SNR is higher than the threshold value R_{th}) or in bad state (lower than the threshold). However, the value $p_b(\gamma_s)$ approximates the bit error probability more accurately than that by eqn. 1. Therefore, it is appropriate to use the value $\log [\{1 - p_b(\gamma_s)\}/p_b(\gamma_s)]$ as the metric value. Decoder complexity is reduced from that of the YSAS method.

For the FSK frequency detection system, the BER $p_b(\gamma_s)$ can be approximated by $(1/2) \exp(-a\gamma_s)$ in which parameter a is experimentally obtained. One of the practical approaches of using the value $\log [\{1 - p_b(\gamma_s)\}/p_b(\gamma_s)]$ to the Chase decoder is to apply another approximation which is $1 - p_b(\gamma_s) \approx 1$. When this approximation is applied, the metric value is proportional to the value R_s^2. Therefore, the value R_s^2 is appropriate for the CMI of the Chase decoder. The decoder finds the code word which minimises the sum of the CMI value associated with the bit positions where the received word and the code word have different symbols.

Laboratory experiments: The performances for the Chase decoders with the CMI values of eye level $\times R_s$ and of R_s^2 are compared using the Hamming (7, 4) code in nonfading and fading channels in laboratory experiments. Chase's second algorithm was applied to a 16 kbit/s signal transmission using a GMSK modulation and frequency detection system. The 16 kbit/s bit stream of the coded data was bit-interleaved, differentially encoded, and fed to the GMSK modulator operating in a 900 MHz band. The differential encoding was necessary to apply the three-level eye decision method.[7] A Gaussian-shaped lowpass filter with a 3 dB bandwidth of 4 kHz was used for premodulation band limitation. The fading GMSK signal was generated by a Rayleigh fading simulator. The maximum Doppler frequency f_D of the fading simulator was set at 40 Hz, corresponding to a typical vehicle speed of 50 km/h at 900 MHz band. The bit-interleaving degree was set at 256: one bit of a code word is transmitted every 256/16000th of a second, in which the envelope samples in a received block are considered statistically independent. A limiter-discriminator type receiver and the three-level eye decision method were used.

An approximately Gaussian-shaped ceramic filter with a centre frequency of 455 kHz and a 3 dB bandwidth of 16 kHz was adopted for the predetection bandpass filter. The frequency discriminator output was lowpass-filtered by another Gaussian-shaped filter with a 3 dB bandwidth of 7 kHz for post-detection noise reduction. The post-detection filter output was sampled using an 8 bit A/D convertor at the decision instant for each bit in the received block. The logarithmically-compressed IF signal was envelope-detected. The envelope detector output was lowpass-filtered by a 2 pole Butterworth filter with a 3 dB bandwidth of 1 kHz. The filter output was sampled and, then, value-limited in the $0 \sim 20$ dB range using another 8 bit A/D convertor.

An amount of 16 bit data segments, sufficient to accurately measure BER and consisting of the samples of the signal envelope and post-detection filter output, were stored for later processing. Chase's second algorithm was carried out using the stored data. The filter output data was interpreted as the reliability information of the three-level eye decision result, as shown in Fig. 1, and multiplied by the envelope data to obtain the eye level information for the limiter-discriminator type receiver.

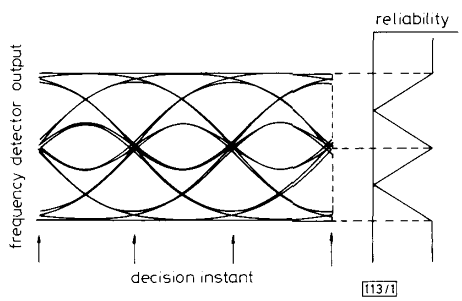

Fig. 1 *Reliability of three-level eye decision result*

The experimental BERs against the average SNR are shown in Fig. 2 for nonfading and fading channels (BER curves for coded data against average SNR per one information bit should be off-set by 2·4 dB for the Hamming (7,4) code). It is found from the Figure that the BERs for the Chase decoders are better than that of the hard decision decoder for fading channels. However, those for the decoders with the CMIs of eye level $\times R_s$ and of R_s^2 are equivalent. This implies that the effect of the variations in the limiter-discriminator output samples is negligibly small compared with that of the envelope variation which comes up to $30 \sim 40$ dB in a Rayleigh fading environment. For the nonfading channel, on the other hand, although less improvement over hard decision decoding is obtained by the Chase decoding with the CMI of R_s^2, a slight improvement is achieved when the CMI of eye level × R_s is used. An SNR reduction of about 1 dB is obtained for a BER of 10^{-3}.

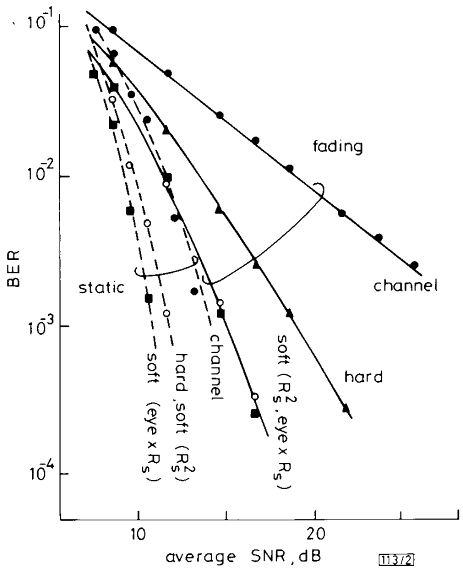

Fig. 2 *BER after decoding against SNR*

Hamming (7,4) code, f_D = 40 Hz, bit interleaving size = 256 × 7 bits

Conclusion: The BER performance of a GMSK frequency detection system with soft decision decoding of block codes using Chase's second algorithm has been investigated in mobile radio channels. The CMI for a bit in the received block is calculated from the samples of the received signal envelope (R_s) and the demodulator output (eye level). The CMIs of eye level × R_s and of R_s^2 have been investigated, and the decoding performances for the CMIs has been compared using the Hamming (7,4) code in nonfading and fading channels in laboratory experiments. It has been shown that the BER performances of the Chase decoders with both the CMIs are equivalent for fading channels. For nonfading channels, an SNR reduction of about 1 dB from that of R_s^2 is obtained for a BER of 10^{-3} when the CMI of eye level × R_s is used. From an implementation point of view, the Chase decoder with the CMI of R_s^2 is promising for mobile radio applications.

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FOUR LOGIC STATES USING TWO RESONANT TUNNELLING DIODES

Indexing terms: Semiconductor devices and materials, Tunnel diodes, Logic devices

Using a series connection of two specially designed resonant tunnelling diodes, we observed three negative differential resistance regions, resulting in four possible logic states. This behaviour can be expanded, at least in theory, to n tunnelling diodes, resulting in $2^n - 1$ times switching and 2^n logic states. These new devices can be used for analogue/digital conversion and multivalued logic or as multistate memory cells using only a minimum in device area.

Introduction: In recent years there has been considerable interest in resonant tunnelling devices with multiple negative differential resistance as functional devices for circuit applications.[1–3] These tunnelling structures are intrinsically fast at switching and offer the possibility of multilevel logic capability, thereby raising the information content per interconnection and reducing the circuit complexity. This has been achieved, in both discrete and integrated form, using two and more resonant tunnelling diodes in series.[4,5] Vertical integration of the diodes has increased the packing density and eliminated the need for interconnects between discrete diodes.

The number of logic states per device has been given by $(n + 1)$, where n is the number of stacked tunnelling structures. However, as will be discussed, the number of logic states can be dramatically increased to 2^n using specially matched tunnelling diodes. This was demonstrated in 1963 by Rabinovici and Klapper[6] using discrete Ge and GaAs tunnel diodes. We show here the results obtained using resonant tunnelling diodes. The only drawback observed in comparison to stacks of n resonant tunnelling diodes is a decrease in peak-to-valley current ratio (PTVR). However, with the currently obtained room-temperature PTVR of 3·90 on the GaAs-Al(Ga)As system on GaAs substrates[7] and 30 on InP,[8] this does not represent a severe limitation.

We present here the first results of three negative differential resistance features using only two resonant tunnelling diodes in series. The feasibility of the technique is demonstrated using discrete resonant tunnelling devices; vertical integration is straightforward.

Theory: Instead of using two diodes of equal size and PTVR, the required diodes are essentially different; the I/V characteristics of the separate diodes are shown in Fig. 1. The I/V curve of one device is shown with a reversed voltage axis, making it easy to understand how the voltage is partitioned between the different diodes of the series connection. The diode with the best PTVR will be referred to as diode 1. Diode 2 has a lower peak current than diode 1 and a higher valley current, evi-

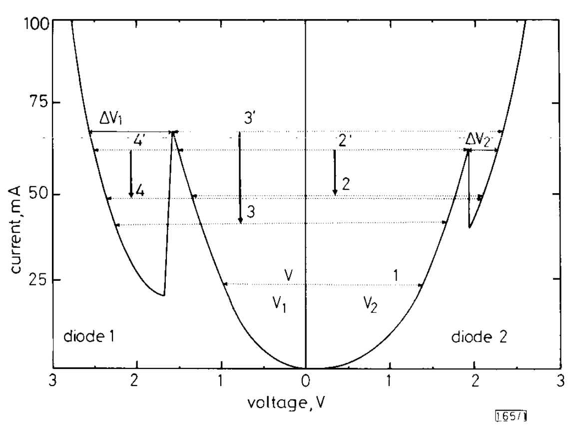

Fig. 1 *Room-temperature current/voltage characteristics of separate diodes*

I/V curve of diode 1 is shown with reversed voltage axis. Increasing applied voltage yields positions 1 to 4. Arrows indicate transient evolution from state i' to stable state i after switching