Simulation results: A simplified asynchronous DS-CDMA system with BPSK spreading (ideal code, carrier and symbol synchronisation) was simulated using the SPW software. The channel model consisted of inter-user interference and AWGN. The short spreading codes corresponding to spreading ratios (processing gains) of 127 and 255 were Gold and Kasami (the large set) sequences, respectively. Gold sequences of period $2^n - 1$ were used as long codes. Relative code delays and carrier phases were selected randomly, and they were the same in the simulation of both short and long codes, i.e. just the codes were changed. Long simulation times limited the simulation of small BER and large $E_b/N_0$ values. The BER results are shown in Figs. 2 and 3. It can be seen that the system performance using long codes is ~0.5 – 1.0 dB worse, when the $E_b/N_0$ is ~10 dB (10 dB is a typical value in digital cellular telephone applications). The worse BER performance results from uncontrolled partial crosscorrelation properties.

![Fig. 3 BER of DS-CDMA system when spreading ratio is 255](image)

**Fig. 3 BER of DS-CDMA system when spreading ratio is 255**

- - - Kasami sequences (the large set) of length 255
- - - Gold sequences of length 1073741823
- - - Theoretical single user BPSK curve

Spreading ratio: 255, number of simultaneous users: 20

**Conclusion:** The loss in the BER performance is tolerable, because long codes provide several benefits that are desirable in the design of a large cellular CDMA network. The benefits are [3]: the number of available individual codes is extremely large, the flexibility with respect to multiple bit rates and variable spreading ratios is high, there is no need for inter-user or inter-cell synchronisation, and the code does not change when the mobile station crosses the cell boundary (the handover situation). Slightly worse BER performance can be improved with powerful error correction coding as in [2]..

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**Pseudo-syndrome method for supervising Viterbi decoders at any coding rate**

C. Berrou and C. Douillard

**Indexing terms:** Viterbi decoding, Codes and coding

A new technique for the supervision and synchronisation of Viterbi decoders, using the novel concept of the pseudo-syndrome, is presented. This technique is applicable with slight additional complexity, whatever the coding rate, to all decoders which contain the function of search for the maximum likelihood path. Simulation results are presented in the particular case of a $K = 7$ encoder/decoder for different rates.

**Node synchronisation:** Various ambiguities in the input symbols of a Viterbi decoder may have to be removed, for instance the relative positions of the symbols after the using and/or demultiplexing. This problem is referred to as node synchronisation; solving it generally consists in scanning all the possible cases of synchronisation by relying on a supervision algorithm, able to discriminate between the in-sync (good synchronisation) and the out-of-sync (bad synchronisation) behaviour of the decoder.

Among other techniques, node synchronisation based on the computation of a syndrome has been proposed. The syndrome is a Boolean $[1,2]$ or possibly a soft [3] value which is representative of the validity of the decoder input samples as symbols compatible with convolutional generation. The syndrome is easily identified for an $K = 1/2$ coding rate; for instance, with constraint length $K = 7$ and encoding polynomials 133 and 171, it is formed (as a Boolean) by the exclusive-OR of ten symbols considered in hard decision. For higher rates, a larger number of symbols is necessary to build the syndrome, and its reliability becomes very sensitive to the channel noise. The pseudo-syndrome method is inspired by this, but with reduced complexity and improved performance.

**Fig. 1 Convolutional code with $K = 3$, polynomials $5$ (symbol $X$) and $7$ (symbol $Y$), and associated decoding trellis**

**Pseudo-syndrome:** Consider in Fig. 1 the convolutional code with $K = 3$, polynomials $5$ (symbol $X$) and $7$ (symbol $Y$), and the decoding trellis. Suppose for instance that, at time $k$, the maximum likelihood state is associated state 00. If this state was actually the state of the encoder, at the corresponding time, then the symbols $(X_{k-1}, Y_{k-1})$ 'expected' by the decoder is not just any couple. If a hard decision is considered, it must be either (0,0) or (1,1); these couples are also compatible with state 01. For the other two states, couples (0,1) and (1,0) are relevant. It is therefore possible to build a parity relation between the maximum likelihood state at time $k$ and the symbols coming at time $k+1$.

By denoting $v = K-1$ (code memory), let $S = (S_0, S_1, \ldots, S_{v+1}, \ldots, S_{v+k})$, be the maximum likelihood state at time $k$. Let also, for a 1/2 rate encoder, $GX = (g_{k+1}, g_{k+2}, \ldots, g_{k+1})$ and $GY = (g_{k+1}, g_{k+2}, \ldots, g_{k+1})$ be the polynomials associated with the generation of sym-
bol X and $Y$, $g_{x} = 0$ (respectively, $g_{y} = 0$) if the the generator of $X (T)$ has no connection with the encoder register at level i, $g_{x} = 1$ ($g_{y} = -1$) otherwise. In practice, we have $g_{x} = -g_{x}$ and $g_{y} = -g_{y}$. If the decoder is in the in-sync state and if $X_{t}, \ldots, X_{t+k-1}$, $Y_{t}, \ldots, Y_{t+k-1}$ are not erroneous, the parity relation to be verified between $S_{k}, X_{t+k} = Y_{t+k} = 0$ (1)

where $\otimes$ represents the sum modulo 2 and $PS_{k}$ is the pseudo-syndrome at time $k$. Unlike the syndrome, calculating the pseudo-syndrome involves running the decoder. In the in-sync condition and in the presence of noise, $PS_{k}$ may be equal to 1 if $X_{t+k}$ or $Y_{t+k}$ is erroneous or if $S_{k}$ is not the maximum likelihood state. Because analysis of the latter case is not straightforward, the probability for $PS_{k} = 1$, lower than 0.5, will be determined by a Monte Carlo simulation. In the out-of-sync condition, because $X_{t+k}$ and $Y_{t+k}$ have not been used by the decoder to establish $S_{k}$, the probability of having $PS_{k} = 1$ is exactly 0.5. So discrimination between in-sync and out-of-sync conditions will be possible above a certain signal to noise ratio, which will be given by simulation.

Of course, the pseudo-syndrome can only be calculated if the couple $(X_{t+k}, Y_{t+k})$ is available, that is to say for a punctured code of rate $(n-1)/n$, every $n-1$ periods. Therefore the synchronisation time will be proportional to $(n-1)/n$.

The pseudo-syndrome calculation assumes that the maximum likelihood state is known, which requires some more or less complex circuitry, depending on the number of states in the decoder. In most Viterbi decoders, processing covers various rates, this circuit is already available. In particular, with turbo codes [4],[5], the number of states is low (8 or 16), and the circuit for searching for the maximum likelihood path or state is not cumbersome.

**Supervision principle:**

(i) if $X_{t+k}$ and $Y_{t+k}$ are available at the decoder input, increment a counter $C$ of periodicity $L$

(ii) if $C$ is incremented and if the pseudo-syndrome has value 1, increment a second counter $CS$

(iii) when another $C$ reaches 0 (mod L), compare the content $NS_{C}$ of CS with threshold $Th < L/2$; if $NS_{C} < Th$, the decoder is assumed to be in the in-sync state; reset $C$ and $CS$.

The choice of $L$ and $Th$ answers to a tradeoff between synchronisation time, false synchronisation and false alarm probabilities.

![Out-of-sync and in-sync conditions of decoder of $K = 7$ (133, 171) code for rates $R = 1/2, 2/3, 3/4, 5/6$ and 8/9](image)

**Fig. 2** $Pr (PS_{k} = 1)$ in out-of-sync and in-sync conditions of decoder of $K = 7$ (133, 171) code for rates $R = 1/2, 2/3, 3/4, 5/6$ and 8/9

Quantisation of 4 bits

- mean value
- mean value minus (out-of-sync) or plus (in-sync, $R = 1/2$ and 8/9) standard deviation $s$ for $L = 1024$

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**Wideband trapezoidal strip grating for elimination of specular reflection**


**Indexing terms:** Grating filters, Radar cross-sections, Electromagnetic wave-diffraction

A trapezoidal strip grating surface that eliminates specular reflections almost over the entire X-band frequency range for TM polarisation is reported. This new grating structure overcomes the bandwidth limitation of conventional rectangular strip grating surfaces.

**Introduction:** Blazed reflection gratings, capable of scattering plane electromagnetic waves to first order diffracted waves have been studied extensively [1, 2]. The most common blazed grating consists of rectangular corrugations on a conducting surface. Reflectors backed rectangular strip gratings have been reported that can be used to simulate the effects of corrugated surfaces [3]. They