lengths and the wavelength dispersion was estimated to be about 17 ps/nm km at 1·55 μm,[11] which is small enough for practical use. It has been confirmed that the single-mode fibres at long wavelengths are promising candidates for long-distance large-capacity transmission media such as trunk lines or submarine cables. It is hoped that light sources for the 1·6 μm wavelength region will be developed.[12]

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SOFT-DECISION DECODING OF THE TELETEXT CHARACTER CODE

Indexing terms: Data communication systems, Decoding, Error-correcting codes

This letter proposes a soft-decision decoding algorithm as a means of improving the displayed-character error rate of teletext transmissions by simple modifications to the decoder only. The expected improvement is theoretically assessed, performance curves are given and implementation of the scheme is discussed.

Introduction: In a hard-decision error-control-coded binary-data-transmission system the receiver/demodulator makes a 'hard' 0/1 decision on each incoming data signal before feeding the demodulated bit to the error-correction decoder. This procedure results in a degradation of the channel decoder's performance because signal-quality information is being thrown away. A soft-decision demodulator, on the other hand, assigns a 'confidence' value to each output bit, in addition to the 'hard' binary 0 or 1 decision. In practice this means that each demodulated bit is quantised into $Q > 2$ levels, rather than $Q = 2$ levels as in the hard-decision case. This confidence information can then be used to improve the channel decoder's performance (in terms of lower output error rate) without incurring any further redundancy penalty.

Teletext transmissions in the UK[1] use the (8, 4) single-error-correcting double-error-detecting Hamming code to protect address, control, page and time codes, and the (8, 7) odd-error-detecting single-parity-check code to protect the ASCII data characters. Also, present teletext decoders[2,3] employ hard-decision decoding of these codes. Soft-decision decoding can be used to improve the performance of both these codes, but, as the Hamming code gives very good protection even under low signal/noise conditions, we restrict our attention to the single-parity-check code. In particular, we show that soft-decision decoding of this code enables some single errors to be corrected, resulting in an overall improvement in the displayed-character error rate.

In general, the increase in coding gain (over that achievable with hard decision) that can be expected by using soft-decision decoding depends on a number of factors. These include the number and spacing of the quantisation levels, the decoding algorithm used and the channel characteristics. It can be shown,[4] however, that for the Gaussian channel a performance loss of about 2 dB is incurred when hard-decision decoding is used as opposed to infinitely quantised soft-decision decoding. Also, the degradation involved in using the much more practical equal-spacing 8-level quantisation is only about 0·2 dB.[5] In general, on Gaussian-type channels, we would expect performance improvements of 1 to 2 dB.[6]

The improvement in correction power can be estimated in the following way. First, assume that the soft-decision demodulator quantises each output digit v_i to $2^J = Q$ levels, symmetrically spaced about the hard 0/1 decision boundary. The estimate of the ith received binary digit is given by the soft-decision J-bit byte:

$$[v_i] = [v_i^1 v_i^2 \cdots v_i^J]$$

where the square brackets indicate a soft-decision or quantised quantity. The first bit of $[v_i]$ is the hard-decision estimate and the remaining $J - 1$ bits give an indication of the confidence of that estimate (that is, distance in levels from the hard-decision 0/1 boundary). Alternatively, we may consider that $[v_i]$ gives an estimate of the soft-decision error digit $[e_i]$ that has been added to the transmitted digit $[u_i]$. Hence $[v_i] = [u_i] \oplus [e_i]$, where $[u_i] = [00 \cdots 0]$ or $[11 \cdots 1]$ only. The value of the soft-decision error digit in *levels* can therefore lie between 0 and $(Q - 1)$, and a value of $\geq (Q/2)$ constitutes an 'error' in the hard-decision sense. Now, given a block code with minimum distance d_h, its bounded-distance correcting power is the largest integer $t_h \leq \{(d_h - 1)/2\}$. In the soft-decision sense, code words are $\geq d_s = (Q - 1)d_h$ soft-decision *levels* apart, and the soft-decision correction power in *levels* is therefore $t_s \leq \{(d_s - 1)/2\}$. The smallest number of levels that constitutes an error in the hard-decision sense is $Q/2$, and therefore the maximum number of 'hard' errors that can be corrected is

$$t_s/(Q/2) = \frac{2}{Q}\{(d_s - 1)/2\} = \frac{1}{Q}\{(Q - 1)d_h - 1\} \approx d_h$$

for Q large. Asymptotically, at high signal/noise ratios, the correction power of the code has therefore approximately doubled from t_h to d_h. For the teletext codes, with 8-level quantisation, the above analysis implies that the (8, 4) code can be made to correct double errors and the (8, 7) code can correct single errors. It should be noted that these improvements are a maximum: for example, there is no guarantee that *all* single errors can be corrected by the (8, 7) code; the correctability of an error pattern depends on the total number of level errors in the block.

Algorithm: Following the above analysis, we can formulate a soft-decision decoding algorithm for the (8, 7) code.

(*a*) If the parity check does *not* fail in a received block, display the character as normal.

(*b*) If the parity check fails, assume that this is due to a single error somewhere in the block.

(*c*) For each bit position in the block, calculate the total number of noise levels ($\sum_{i=1}^{n} [e_i]$) assuming that an error has occurred in that bit position.

(*d*) Choose as the error position the position that results in the smallest total number of level errors, provided the total is $\leq t_s$. Invert that bit and display the corrected character.

(*e*) If two positions result in the same total error-level count, or if no position gives a level count $\leq t_s$, do not perform any correction but display a blank and wait for a repeat of the character (as is done in the hard-decision case when the parity check fails).

The above algorithm can be considerably simplified as regards hardware implementation, with only a slight loss in performance, if the following modified algorithm is adopted:

(*a*) If the parity check does *not* fail, display the character as normal.

(*b*) If the check fails, identify the 'worst' bit in the block, that is, the received bit $[v_i]$ nearest the hard 0/1 boundary.

(*c*) If this bit is the 'strictly worst' bit, that is, no other bit is the same number of levels from the boundary, assume that this is the error position and correct the bit.

(*d*) If two or more bit positions are equidistant from the 0/1 boundary, do not correct but display a blank.

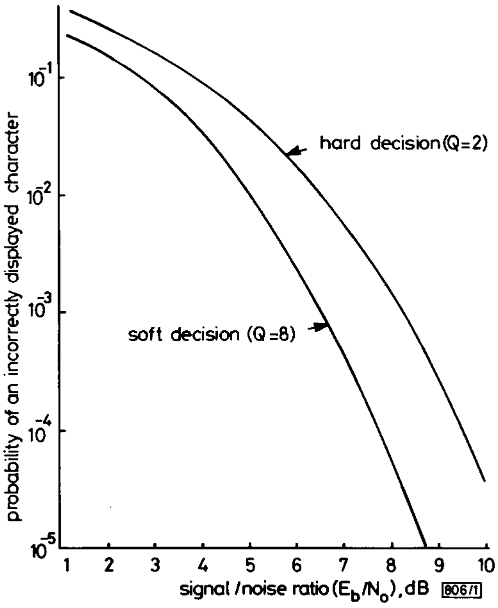

Fig. 1 *Performance in Gaussian noise*

Performance: The simulated performance of the modified algorithm is shown in Fig. 1, for transmission under conditions of Gaussian noise. Output-character error rate (that is, the proportion of characters either incorrectly displayed or displayed as blank) is plotted against normalised signal/noise ratio per bit (E_b/N_0). It can be seen that performance is improved, resulting in a coding gain of approximately 1·7 dB at the higher signal/noise ratios. This is certainly a useful improvement and conforms to the theoretically expected improvement in performance.

Implementation: Existing teletext decoders can be easily modified to implement the soft-decision algorithm, in a truly 'add-on' manner.[7] The extra circuitry required consists of a video quantising stage, a 'worst-bit' identification logic unit and a correction logic unit. A point in common with all the available teletext decoders is the presence of an 8-bit data highway operating at the slow system clock speed. The add-on soft-decision correction unit is therefore inserted across this highway at a point before the existing teletext decoder's error correction and detection circuitry. All the required voltage reference signals (for the quantising unit's comporators) and timing signals are readily available on existing teletext decoders, making implementation simple.

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GYROTROPIC WAVEGUIDE SWITCHING ELEMENTS AT OPTICAL WAVELENGTHS

Indexing terms: Magneto-optical devices, Optical waveguide components

Principles of switching elements that use the variation of propagation properties of gyrotropic waveguides caused by changes in the orientation of the applied d.c. field are outlined. It is shown that packing densities comparable with magnetic-bubble devices (25 μm per cell) are readily obtainable and that applied magnetic fields and associated d.c. currents can be quite small, giving rise to minimal heat dissipation. Switching speeds in the nanosecond range are expected.

Guided-wave logic and computation devices based on electro-optic waveguides have been discussed recently.[1] The principal advantage of such devices is their speed, since they are based on guided electromagnetic waves, but their size is expected to be of the order of a few millimetres, since the electro-optic effect requires a considerable distance to introduce a differential phase shift of π radians.

The aim of this letter is to outline analogous devices based on the magneto-optic effect as manifested in garnet waveguides. These devices are again expected to be very fast for the same reasons as their electro-optic counterparts. However, it will be shown that the gyrotropic devices are much smaller. In fact, packing densities comparable with magnetic-bubble devices can be expected.

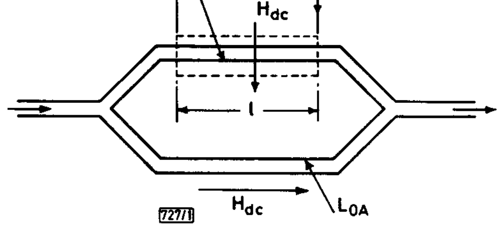

Fig. 1 *Gyrotropic-interference-switch geometry*