State of polarisation bias in aerial fibres

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The state of polarisation was measured for 7 days in an aerial fibre during the wintertime. A biased probability density was found. This is contrary to the generally accepted uniform probability density. A Maxwellian probability density function for differential group delay at a fixed wavelength will thus not occur when measured on this fibre for a median time period.

Introduction: Maxwellian probability density functions (PDFs) of polarisation mode dispersion (PMD) and differential group delay (DGD) are the generally accepted function when modelling, emulating, link budgeting, and comparing experimental results in fibres. PMD is the mean of DGD over wavelength. The DGD Maxwellian PDF results from the assumption that many randomly combined birefringent fibre sections can describe a highly-mode coupled fibre. The rotational angles of the fibre sections are allowed to vary randomly, and then by using the DGD recursion relation [1], a Maxwellian PDF can be produced. If the fibre sections are, however, not allowed to have a random rotation (and are thus biased in some manner) one can be certain that a Maxwellian DGD PDF will not be generated. System outage probability calculations assume a Maxwellian PDF.

Experiment: The experimental setup consisted of a laser at 1550 nm wavelength launched into a 34 km aerial fibre. The fibre had 7.45 ps of PMD. The output of the fibre was measured with a polarimeter. The polarimeter measures the state of polarisation (SOP) of the light in Stokes space. Stokes vectors were collected at 10 ms intervals to allow sampling of fast SOP changes [2]. The experiment was carried out for a period of one week in the winter of 2001 at Woodstock, NB, Canada.

As the Stokes vectors were collected the Poincaré sphere was observed to have full coverage after only several minutes of data collection. An autocorrelation was performed on the collected Stokes vectors. The autocorrelation enables one to see if the fibre is biased in a manner where the light returns to the same phase space at certain time intervals. It was found that there is no correlation for any significant length of time and at any fixed times thereafter. These results would seem to indicate that this fibre would produce a good Maxwellian PDF of the DGD.

The collected Stokes vectors were then analysed by using a Poincaré density sphere. This is similar to a standard Poincaré sphere, but the colour of the sphere surface corresponds to the probability density of how often that particular region was visited. One can think of this as a 3-D histogram of the SOP. A region is defined as an area in spherical coordinates where $\theta$ and $\phi$ span $1^\circ$ each. Fig. 1 is a Poincaré density sphere for the aerial fibre. A bias can be seen on the bottom of the sphere. This fibre will not have a Maxwellian PDF over the measured time since the sphere does not have uniform coverage. Fig. 2 shows a contour plot with the bias visible on the left side. Every region on the sphere and contour plot was visited an average of ~1200 times. This would indicate that enough data was collected to obtain a good statistical picture.

Our group has investigated other aerial fibres with similar results being observed. Aerial fibre statistics are heavily dependent on weather [3]. The commonly held view that if the light passes through all polarisation states then good statistics will be observed would seem to be a fallacy for aerial fibres. Full SOP coverage of the Poincaré sphere does not mean that it is evenly distributed, which is equivalent to a Maxwellian DGD PDF. It is plausible, that since the climate of the earth is biased (depending on the location) that the statistics of an aerial fibre will always be biased.

Conclusion: It is very difficult to measure long-term statistics on a buried fibre. To our knowledge no one has carried out a long-term study (greater than 6 months) of PMD or SOP measurements on a buried fibre. We estimate that it would be of the order of months to cover the Poincaré sphere once. Biases over time have been observed in buried fibres [4], but it usually happens when the fibre passes through a bridge or comes above ground at a telecom network office and thus is exposed to the environment. It is unlikely that any fibre exposed to the environment truly produces a Maxwellian PDF for DGD at a single wavelength. Maxwellian PDF based system outage probability calculations will thus be incorrect.

References
Introduction: Joint source/channel coding is an efficient approach for coding and transmitting images over noisy channels. It is envisioned that better performance with less complexity and reduced delay can be achieved by coding the source and channel jointly rather than separately. Yet, for images transmitted over binary symmetric channels (BSC), one of the best known results is obtained with a tandem framework, that is, compression of large size blocks followed by efficient forward error correction [1]. Such schemes are however subject to an inherent probability of incomplete decoding. They are, in addition, designed for a fixed channel and perform poorly under channel mismatch conditions. To date no joint source/channel scheme with good performance has been found and it remains unclear whether it is possible to obtain similar performance to traditional techniques with the joint source/channel approach.

Several schemes have been proposed to tackle the problem of transmitting compressed images over noisy channels [1,4-7]. In [6] a scheme that uses subband transforms achieves good performance by scrambling the DFT phase of the subband coefficients in such a manner that the Laplacian-like coefficients are transformed into near-Gaussian coefficients prior to channel-optimised scalar quantisation (COSQ). Note that the source distribution reshaping increases quantisation performance since, as pointed out in [6], COSQ, for generalised Gaussian distributions, performs better for larger shape parameters. Also phase scrambling spreads the impulsive noise thus drastically reducing the perceptual effect. An extension of [6] to channel-optimised trellis-coded quantisers provided further performance improvement at the expense of the extra complexity brought by the TCQ [7].

Following the same approach of [6] we propose some modifications seeking to improve the overall performance of joint source channel coding methods. To begin with we replaced wavelet decomposition by the lapped transform (LT). The block-based nature of LT allows for the use of efficient block classification strategies coupled with a steepest descent bit allocation method. It was in fact shown that significant gains can be obtained over the traditional scheme in [6] without increasing complexity.

Algorithm: Fig. 1 shows the proposed scheme building blocks. The image is first segmented into $8 \times 8$ blocks, each to be lapped transformed. Let $G_i(k,\ell) \leq k \leq 1, 0 \leq \ell \leq 7$ be the set of coefficients corresponding to the $i$th image block. The $i$th set of 64 coefficients so obtained are classified according to their block classification gain $g_i$, (AC energy squared) expressed as

$$g_i^2 = \sum_{k=1}^{M-1} \sum_{\ell=0}^{7} G_i(k,\ell) - G_i(0,0).$$

Classification uses the equal mean-normalised standard deviation (EMNSD) criterion presented in [8]. Guided by the indication in [5], that two classes provide a good classification gain versus overhead tradeoff, we have chosen to use two classes only in this work.

![Proposed scheme building blocks](image)

Results: The proposed scheme has been analysed by simulating the transmission of Lena and Goldhill $512 \times 512$ pixel images over a BSC. Several of the LTs discussed in [10] have been investigated—the results presented were obtained with the $8 \times 16$ generalised lapped bi-orthogonal transform (GBLT), selected for its good reconstruction performance. All the results presented are averages taken over 10 simulation runs. Fig. 2 shows the performance of the proposed scheme, at a rate of 1 bpp, for several channel cross probabilities. To highlight the effectiveness of variant I of the novel scheme (i.e. the one with classification) its performance is displayed against the results obtained for variant II (without classification) as well as that of the A-RQ scheme of [6] and of the robust CO-TCQ (Lena image only) of [7]. As can be seen, a performance better than that in [6], and equivalent to that of the CO-TCQ method of [7], has been achieved with the lapped transforms together with the bit allocation strategy (variant I scheme). If in addition classification under the EMNSD criterion is incorporated (variant II), gains up to 2.2 dB can be

Source/channel coding of still images using lapped transforms and block classification


A novel scheme for joint source/channel coding of still images is proposed. By using efficient lapped transforms, channel-optimised quantisers and classification methods it is shown that significant improvements over traditional source/channel coding of images can be obtained while keeping the complexity low.

1. Set $k = 7N$; let $n = 0, 1, \ldots, N$
2. Set $k = k - 1$; find $i_k$ satisfying $A_k(r_{i_k}) = \max_{i_k \in \{0, \ldots, 79\}} A_k(r_{i_k})$
3. Set $n = n - 1$. If $k = 0$ stop; else go to step 2

$A_k(r_{i_k})$ is the distortion produced by the transmission of the quantised coefficients (assumed Gaussian) over the BSC. The algorithm is fast and yields near-optimal allocation.