An effective Estimation scheme based curvelet de-noising algorithm for wireless optical communications.

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Abstract: This describes detection scheme without channel state information for wireless optical communication (WOC) systems in turbulence induced fading channel. The proposed scheme can effectively diminish the additive noise caused by background radiation and photo detector, as well as the intensity scintillation caused by turbulence. In Indoor diffuse optical wireless systems with a limited or no line of-sight (LOS) path the strength of the received signal highly depends on the location of the receiver and objects within the room. Thus, the channel impulse response will vary accordingly. In addition, inter-symbol-interference (ISI) due to multipath limits the data rates compared to LOS links. The additive noise can be mitigated significantly using the modified wavelet threshold de-noising algorithm, and then, the intensity scintillation can be attenuated by exploiting the temporal correlation of the WOC channel. Moreover, to improve the performance beyond that of the maximum likelihood decision, the maximum a posteriori probability (MAP) criterion is considered. Compared with conventional blind detection algorithm, simulation results show that the proposed detection scheme can improve the signal-to-noise ratio (SNR) performance.

Keywords: Wireless optical communication (WOC) curvelet denoising Block detection Intensity-modulation/direct-detection (IM/DD) Scintillation index (SI).

I. Introduction

The earliest form of wireless optical communications (WoC) can be traced back when human beings lit up _res and smoke to alarm the invasion of intruders. Never- the less, it was not until late 19th century when Bell _led a patent on the concept of photo phone" and prototyped the apparatus able to convey the voice over 200 meters. The community remained inactive since then until the time wheel rolled into 20th century, when the theory, components and system integration technology became more mature. On the other hand, people have been seeking more efficient and effective ways of communication because the traditional radio frequency (RF) based wireless communication and other applications rendered the spectrum unprecedentedly crowded. The first achievement in the optical communications happened to based on the fiber with lower insertion loss medium which had been long envisioned by the Nobel Laureate Sir.

Charles Kao. Optical sources such as light emission diode (LED) and solid state laser (SSL) entered into mass production with smaller size and higher emitted optical power. In a word, the developments in the fields of optical channel, sources, detectors and theory of communications have propelled academia and industry to review the feasibility of wireless optical communications which may provide free-licensed, easy-to-deploy, high throughput wireless data access.

As a category of wireless systems, a WoC link shares a similar architecture as a RF system consisted of a transmitter, channel and receiver. Discussion on the physical layer performance relies on a comprehensive understanding in the characteristics of these components to abstract and formulate theoretic models. An optical transmitter stimulates the source to convert electronically modulated signal into optical _eld, which is illuminated into the atmospheric channel through the optical lens. By analogy, the optical front end with a lens acts in a similar way as the antenna to a RF system. As for the optical source, a laser diode (LD) or LED may be the candidate. Distinct as the underlying physics that determines the beam and the purity out of the source, both provide certain amount of optical power as large as hundreds of milli-watts even up to watts, while being small in size and convenient to be driven by a simple electrical circuit. On the other hand, based on the input-output characterization, LED typically maintains good linearity and has limits on the peak power while the LD is more suitable for transmitting the optical power in a fast gated fashion. Hence it is usually adopted for high speed pulse based modulation. For some LDs, the highest gating speed can reach 10Ghz and with the external modulator such as the Mach CZehnder modulator (MZM) modulator, the speed can be even higher. Overall in the context of optical communications, the optical source can provide reasonably large overall system bandwidth and the generated pulse can have arbitrarily fast transition between ON (high) and OFF (low) states (levels).

In many hundreds of papers published in journals throughout the scientific and engineering disciplines, a wide range of wavelet-based tools and ideas have been proposed and studied. Initial efforts included very simple ideas like thresholding of the orthogonal wavelet coefficients of the noisy data, followed by reconstruction. Later efforts found that substantial improvements in perceptual quality could be obtained by translation invariant methods based on thresholding of an un-decimated wavelet transform. The new ridgelet and curvelet transforms were developed

over several years in an attempt to break an inherent limit plaguing wavelet denoising of images. This limit arises from the well-known and frequently depicted fact that the two-dimensional (2-D) wavelet transform of images exhibits large wavelet coefficients even at fine scales, all along the important edges in the image, so that in a map of the large wavelet coefficients one sees the edges of the images repeated at scale after scale.

II. System design model

A. Channel model

In the WOC channel, the gamma- gamma probability density function (PDF) is usually used to describe the intensity distribution, Signal model Consider along-distance WOC system where the receiver's signal-to-noise ratio(SNR)is effectively restricted by the shot-noise caused by back ground radiation and thermal noise arising at the photo detector. In this case, the noise can usually be modeled as additive white Gaussian noise (AWGN)which is statistically independent with the transmitted data.

B. De-noising algorithm:

We present is consistent with the developing theory of curvelet denoising, which predicts that, in recovering images which are smooth away from edges, curvelets will obtain dramatically smaller asymptotic mean square error of reconstruction than wavelet methods. The images we study are small in size, so that the asymptotic theory cannot be expected to fully “kick in;” however, we do observe already, at these limited image sizes, noticeable improvements

of the new methods over wavelet denoising.

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to a relatively high mean squared error (MSE).

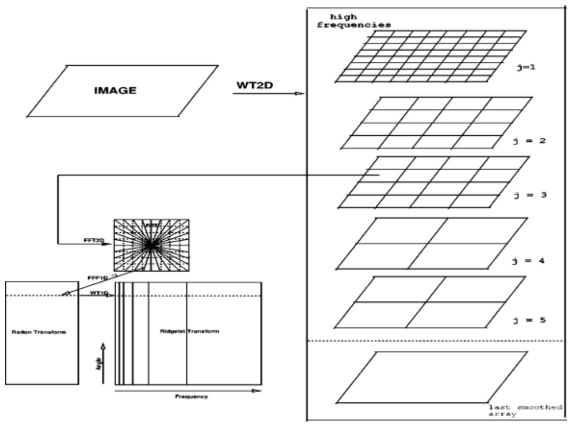
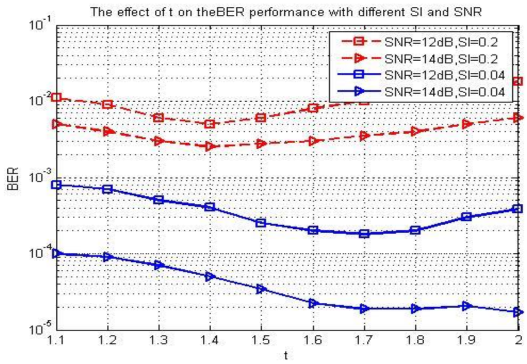


Fig. 1. Curvelet transform flowgraph. The figure illustrates the decomposition of the original image into subbands followed by the spatial partitioning of each subband. The ridgelet transform is then applied to each block

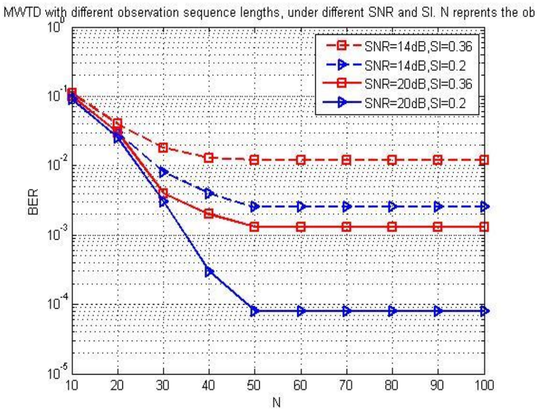
To study the dependency of the curvelet denoising procedure on the noise level, we generated a set of noisy images (the noise standard deviation varies from five to 100) from both Lenna and Barbara. We then compared the three different filtering procedures based, respectively, on the curvelet transform and on the undecimated/decimated wavelet transforms.

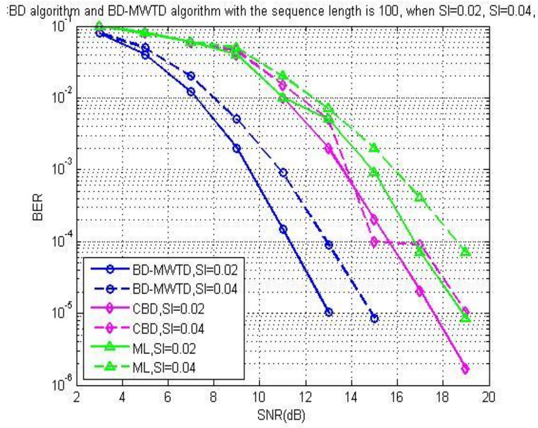
III. Simulation results

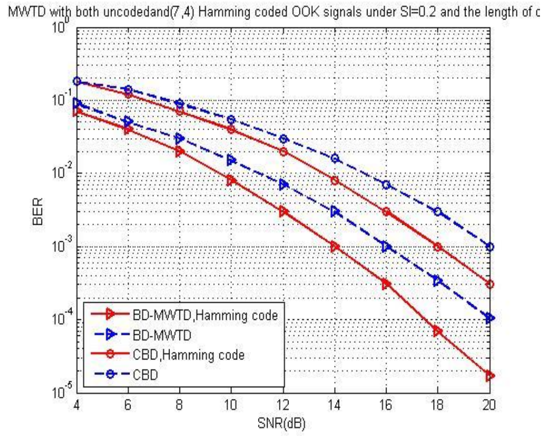
The performance of the de-noising with different observation sequence lengths is investigated when t¼1.4.As it is clearly depicted in figure, the BER performance of the curvelet de-noising is limited by the observation sequence length. The performance increases with a longer observation sequence. It can achieve the lower bound of the BD-MWTD when the length of observation sequenceisbiggerthan50.



The curvelet reconstruction of the non-0vertical lines is obviously sharper than that obtained using wavelets. The curvelet transform also seems to go one step further as far as the reconstruction of the vertical lines is concerned. Roughly speaking, for those templates, the wavelet transforms stops detecting signal at a SNR equal to one (we defined here the SNR as the intensity level of the pixels on the line, divided by the noise standard deviation of the noise) while the cut-off value equals 0.5 for the curvelet approach. It is important to note that the horizontal and vertical lines correspond to privileged directions for the wavelet transform, because the underlying basis functions are direct products of functions varying solely in the horizontal and vertical directions.







IV. Conclusion

We presented a strategy for digitally implementing both the ridgelet and the curvelet transforms.

The resulting implementations have the exact reconstruction property, give stable reconstruction under perturbations of the coefficients, and as deployed in practice, partial reconstructions seem not to suffer from visual artifacts. The optimal t has been obtained by using numerical method under different turbulence conditions. Simulation results have shown that the BER performance of the BD-MWTD is limited by the observation sequence length because the observation sequence length N determines the accuracy of the estimated I and w 2 σ . It can achieve the lower bound of the BD-MWTD when the length of observation sequence is bigger than 50. The performance is always much better than that of the CBD and ML symbol by symbol detection under the different SNR and SI.

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