Artificial Neural Network-Based Equaliser in the Nonlinear Fourier Domain for Fibre-Optic Communication Applications

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Nonlinear Fourier transform (NFT) has shown its potential to overcome some challenges of nonlinear signal distortions in fibre-optic communications ystems [1]. However, there is yet so much unknown about fundamental properties and traits of a communication based on NFT. One of the most important aspects of an optical communication system is its robustness against the inevitable amplified spontaneous emission (ASE) noise coming from optical amplifiers. The ASE noise not only contaminates the signal as it does for all systems, but it also has a special detrimental effect on NFT-based systems; destroying the very basic concept of integrability of the nonlinear Schrodinger equation (NLSE). Moreover, this noise, undergoing a nonlinear transformation, i.e. “direct NFT” is dependent on the signal power. There are initial studies to model the noise in the nonlinear Fourier domain and some approximations for particular cases of modulation such as discrete spectrum-only or continuous spectrum-only modulations are available [2-3]. The limited extent of the mentioned studies makes it difficult to use them in order to design an optimum receiver - the primary engineering purpose of analysing the noise properties. On the other hand, machine learning-based techniques to study the noise characteristics in fibre-optic communication have been tried and promising results are already obtained [4]. Machine learning (ML) can also be used to find the impact of noise and alleviate the extent of its perturbation. In particular, in an NFT-based system, where data is mapped on the discrete spectrum (DS) of a signal, at the receiver, the calculated DS contains some spurious elements which are the result of the noise. These points are usually filtered out considered to be void of useful information about the transmitted signal. However, the correlation between these points and the main elements of the DS points that there is mutual information which can be used in order to improve the detection performance at the receiver. In this work, we use a simple Neural Network (NN) to back-propagate the received DS of a signal in a periodic NFT-based communication system. As shown in Fig1. a, drawn from a 64-QAM constellation, each symbol is mapped on the DS of a periodic signal as described in [5,6]. Performing the exact inverse transformation, a signal with the given DS is constructed and sent to a noisy link with 11 spans of 80 km length standard SMF. At the receiver, the DS is calculated and even the out-of-band components are passed to the NN-based equaliser. All data from the calculated DS is used as the input feature vector to our 2-layer (10 neurons each) NN. Raman amplification is used and assumed to provide perfect power loss compensation along the span.

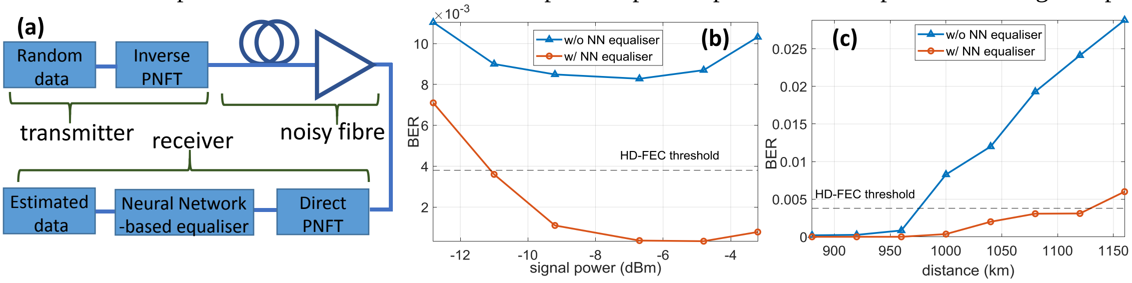

Fig. 1 **a**. system setup; **b**. BER vs signal power at 1000 km, and **c**. BER vs distance when $P = -9$ dBm for two system w/ and w/o NN equaliser.

As is common, all data is divided into three sets of training, validation and test and the overall system performance in terms of the bit error rate (BER) is depicted against signal power in Fig1. b for a 1000 km link. To compare, the achieved BER with the conventional method of phase rotation compensation is also presented which shows significant improvement resulted from applying NN equaliser. For the transmission at the optimum power obtained from Fig. 1b, the BER against transmission distance is also depicted in Fig. 1 c. To obtain each point of the BER curve, 2^{15} symbols are transmitted to achieve small deviation between transmissions.

Our simple NN equaliser delivers significant improvement in system performance for a periodic NFT-based fibre-optic communication. This improvement is partly due to making use of all points, in-band and out-of-band, in the DS of the noise-corrupted received signal.

References

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