論 文 内 容 の 要 旨

The exponential growth of global Internet Protocol (IP) traffic has triggered the demand for spectrally efficient high speed and high capacity optical network. After the maximum use of Time Division Multiplexing (TDM), Wavelength Division Multiplexing (WDM), Polarization Division Multiplexing (PDM) and multilevel modulation formats, a single strand of optical fiber have reached its transmission capacity limit. The only physical dimension of an optical fiber which is not fully utilized is the space. Mode division multiplexing (MDM) in a Multi-Mode Fiber (MMF) is a popular approach to exploit the space dimension of the fiber.

In an MMF there exist a non-linear multi-mode propagation due to random mode coupling. In a long-haul transmission, these fibers possess a challenge to compensate coupling between signals in different modes and to minimize the differential mode group delays. The crosstalk between the modes of MMFs limits the performance of the overall system, so Multiple-Input-Multiple-Output (MIMO) processing must be done to separate the received signals. The non-linearity effect is compensated using Deep learning technique. Deep learning neural networks are highly non-linear and capable of forming arbitrarily non-linear decision boundaries.

MIMO processing at the receiver-end is not suitable if all the end-users are located at a separate location. In this scenario, we need to design an optical transmission network that doesn't use MIMO processing at the receiver end. In existing Passive Optical Network (PON) each optical network unit receives not only the data that belongs to its user but also the data of other users. This makes the network vulnerable to sniffing even though encryption has been done. To solve this problem, we have proposed and demonstrated a mode forming technique in an optical network of Multi-Mode Fiber (MMF) using fused fiber coupler so that optical channels from an optical line terminal are switched directly to different user locations in such a way that the optical network unit receives only the data that belongs to its user. The use of pre-MIMO in the transmitter eliminates the need of a MIMO processor in the receiver side. We have successfully implemented a 2×2 mode forming network by transmitting two 100Mbps channels over a 1 km long Graded-Index Multi-Mode Fiber (GI-MMF).This technique can be used to realize any $N\times N$ channel optical mode forming network to deliver them only to their destination.

Even if we assume MIMO processing is suitable to implement in the receiver side of MIMO-MDM system,

none of the available MIMO detectors is an optimum detector. Optimum MIMO detector has always been a challenge in MIMO communication systems. We have designed a novel MIMO detector using a supervised Deep Learning Neural Network (DLNN) and has been implemented successfully in an MDM optical transmission system. A conventional GI-MMF is used to design an MDM optical transmission system. We have used a DLNN for MIMO detection in MDM optical transmission system and have compared its performance with Zero Forcing (ZF) detector and Semi-Definite Relaxation Row-by-Row (SDR-RBR). The results confirm that our DLNN outruns the performance of traditional MIMO detectors by compensating the non-linearity effect of multi-mode propagation.

The performance of mode forming network depends on the feedback network. The use of pre-MIMO to eliminate the need of MIMO processor in the receiver raises questions about how accurately the channel matrix coefficients are transmitted back to the transmitter side. We have proposed and demonstrated a technique of signal extraction in the remote user location without the use of any kind of MIMO in the transmitter or receiver. We have successfully demonstrated the use of DLNN in MIMO-MDM optical transmission system for extracting the desired signal using only one composite signal. Two 1Gbps channels with sub-carrier multiplexing (SCM) has been successfully transmitted over a 1km long conventional GI-MMF and the desired signals are extracted in each remote user location using only one composite signal.

This work underlines the potential of Deep Learning technique for MIMO optical communication systems. It will inform future planned work to use Deep learning in order to enhance the BER performance of MIMO-MDM transmission system through joint system optimization.