Next-Generation Optical Fiber Network Communication

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ABSTRACT:

In all over the world, much higher order off modulation formats are further discovered to increase the efficiency or we can say spectral efficiency for making future of optical transport network. We will discuss the digital electronics equalizers and coherent receivers as the devices which will increase the spectral efficiency of WDM (wavelength division multiplexed) signals for next generation optical network. We will have a review of ongoing research on the application of higher-order modulation formats and we will also discuss the electronic distortion equalization with coherent detection.

KEYWORDS: higher-order modulation formats, electronic distortion equalization, coherent detection, spectral efficiency.

INTRODUCTION:

The advancement in technology is on the way for the 100GbE and to highest spectral efficiency are higher order optical modulation formats, which goes for the (responsible) reduction in the spectral width of a WDM channel as well as the symbol rate , which also effects the EDE (electric distortion equalization) with coherent detection. The latter permits for the next generation of optical transport system to operate close to the limits of spectral efficiency and also allow to compensate in the electrical domain for optical transmission impairments. On the other hand, the expected reduction in the cost due to the higher spectral efficiency is balanced by the higher costs of hardware's which are used for the new technology. It also increases the complexity of the receiver and transmitter. The latest technologies are still under research including higher data rates and 100GbE. In the following, we will discuss overall 7 sections. In which, section 2 will contain the discussion over coherent system technology and higher-order modulation formats. Section 3 will contain the overview on receiver as well as transmitter configurations and in section 4 to 6 we will have the discussion on transmission reach, system performance and equalization issues. Finally, section 7 will give the summary of the paper and highlights the further topics of research.

Modulation format for higher order:

In the design of optical systems of higher order modulation, the coherent detection in the beneficial thing because of the availability of all parameters of the optical field in the electrical domain where all parameters refers to the amplitude, phase and polarization. In the demodulation schemes not only the detection of phase difference for direct detection is there but also the detection of modulation constellations and arbitrary modulation formats are there. Furthermore, in the adaptive electronic compensation of transmission impairments the more effective methods are enabled by the preservation of the temporal phase like CD (chromatic dispersion) fiber nonlinearity's and PMD (polarization mode dispersion). High-selective electrical filtering are used for performing channel separation because coherent receivers provide very small channel spacing and also offers tenability when used in WDM. In the implementation of coherent receivers there are some kinds of challenges, which are electronic equalizers, carrier synchronization of real time, the implementation of high-speed ADC (analog to digital converter) in addition of low cost of fabrication of the optical frontend.

Transmitter as well as Receiver Configuration :

There are many different types of generating the optical signal of higher-order modulation but the optical complexity can be reduced by increasing the electrical complexity and vice-versa. However, to generate arbitrary modulation signals of higher-order the signal dual-drive MZM (mach-zehnder modulator) is sufficient, but the requirements of multilevel electrical driving signals are there. Another option can also be used which is optical IQ-modulator because in generation through MZM it increases the electrical efforts which becomes a big problem at high speed. In the case the necessary number of states of electrical driving signals will be in phase and quadrature phase with the number of projection of symbols. The suitable device for generating the square QAM signal is optical IQ-modulator. However, the requirement here is of generation of multilevel driving signals. Especially at high data rates, multilevel electrical driving signals are difficult to generate, therefore transmitter configurations should be attractive which require solely binary electrical driving signals. However, this will also affect the complexity and numbers of optical modulators as the number of required optical modulators increases as well as the complexity of optical transmitter will also increases. For the adaptive compensate for distortion of signals, the next generation optical transmission system is there, which consists of digital signal processing module, ADC , high-speed photodiodes as well as optical frontend. Digital signal processing is used to accomplish the compensation of transmission impairments and the arbitrary high-order modulation signals can be demodulated completely electrically. In case of polarization multiplexing the two optical 90 degree hybrids are there to interfere the light received with the local laser light, separately from each of the orthogonal polarization modes. The received data is digitally equalized after detection by ADC and BP (balanced photodiode). This signal processing consists of data recovery, phase correction, frequency offset, adaptive linear and nonlinear equalization as well as timing recovery.

Tolerances of the System:

The switching to higher-order formats with more symbol per bits from traditionally used modulation formats leads to the reduction of spectral width and also of symbol rate. Therefore, per fiber capacities and higher spectral efficiencies can be achieved. This will be the main reason of using higher-order modulation formats but it also effects the performance of the system. The positive points of this change is that it improves the CD tolerances and at reduced symbol rates there will be increment in robustness against PMD. Result can be obtain through Monte Carlo simulations with the help of commercial software tools like matlab and VPI transmission maker. It can be observed that when the order of the modulation formats get increased then CD tolerance improves. For the limited noise and Kerr nonlinearities the multi-span long-haul optical fiber transmission system can be used. For higher-order modulation format these impairments will become more critical, so when these transmission effects are limited for system therefore significantly lower reach can be expected. With increase in number of bits per symbol the noise performance decreases especially for higher order PSK formats. For comparing the QAM formats gives better noise performance for same number of bits per symbol. With the increasing order of the PSK format the robustness against SPM decreases, as phase distances are getting smaller. Symbols with different intensity levels, causes the unequal mean nonlinear phase shift because of which SPM has a critical impact on QAM signals. There will be an inherent problem of optical QAM transmission as there is an latter effect that can partly be compensated.

Nonlinear Impairments Compensations:

When input power is high to the optical system then he nonlinear impairments plays a very important role. The main distorting mechanism during the time of low power input is ASE(amplified spontaneous emission) therefore, the input power is increased which will also reduce the BER(bit error ratio) and increases the SNR(signal-to-noise ratio) . When the input power is increased the nonlinear effects also gets increased and reaching to a particular moment these effects become more noisy or create more noise, therefore, there will be an favorable value of input power for BER will be minimum. In both of the two distortions (noise and nonlinear effect) noise cannot be compensate because of distortions random behavior but the nonlinear impairments can be compensate generally. KERR nonlinearities is the main origin of the nonlinear impairment in fiber optical system and this can be described by the equation known as Schrodinger equation.

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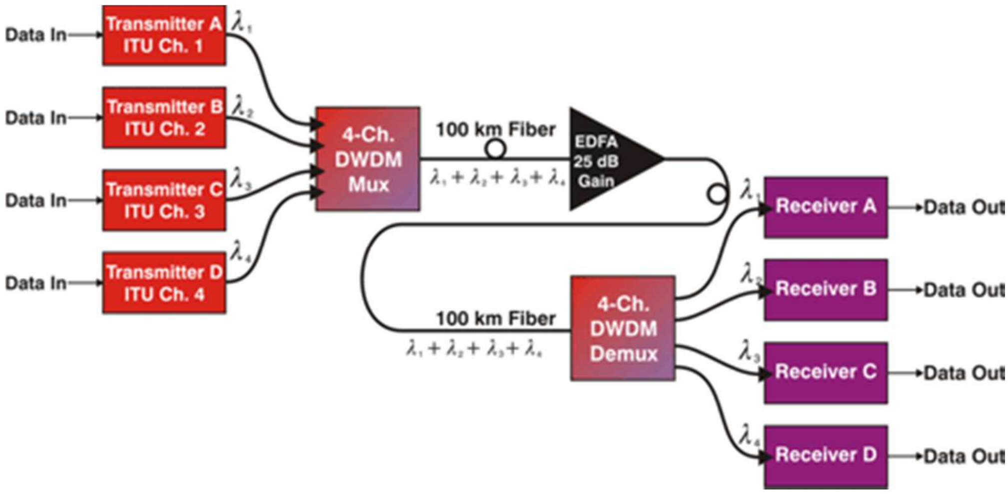
Equation:

In which A stands for electric field vector, γ is for nonlinear parameters, α is attenuation and $\beta 2$ is group velocity. In non-linear impairments, there is an self-phase modulation which leads to the high Bit error ratio(BER) at high intensities and it can also be compensated by the known method from literature. To amplify the attenuated signals the amplifiers of long-haul optical transmission systems are used as periodically. It is investigated that for QPSK transmission of 10Gbaud at 4800km distance, the amplification of signal was 60 times. It is cleared that because of periodic attenuation, nonlinear effects doesn't takes place everywhere but after that amplification they are high enough. The working scheme of the nonlinear equalizer and CD compensation is as follows: Nonlinear compensator is used after compensating CD of one span and there will be occurring of high intensity region where nonlinear effects are dominating. Nonlinear compensator can be implemented by addition of the electrified square and nonlinear coefficient is multiplied, which is impact the compensation of induced KERR nonlinearity. Results gets from the above mentioned schemes of nonlinear compensation were more than satisfactory. As can be seen above that high computation power is needed in case of nonlinear impairments which gives the law enough BER, and it also mentioned that after each of the 60 transmission spans, CD goes compensated.

Performance of Transmission:

Recirculating fiber loop-testbed are usually used to determine distances of transparent optical transmission system by using high-order of modulation formats. The testbed consists of the following: transmission section, transmitter, receiver and transmission section can be arbitrary configured. The external cavity laser emits the light with in the transmitter with approximately 100KHZ line width. The RZ (return to zero) pulses are carried by the MZM (mach-zehmder modulator). Afterword's the optical QPSK signals are generated by the optical IQ-modulator and for constitution of the 8PSK constellation Л/4 phase modulation is accomplished by consecutive phase modulator. At the modulator input, a $(2)^{11}$ de brujin sequence is used as data signal with different delays. For the investigation, corresponds to a data rate of 30Gbit/sec in the case of 8PSK a symbol rate of 10Gbaud was chosen. At receiver side, in a LiNbo3 2x4 90 degree hybrid the RZ-8PSK signal is interfered with the local oscillator light. For experimental simplicity, to avoid an automatic frequency control loop the local oscillator (CO) light is taken from the transmitter laser. In this experiment, in front of the inputs of the2x4 90degree hybrid the polarization is manually controlled. The detection of the hybrid output signal is done by balanced photo detectors and using a digital storage oscilloscope of 40GSa/s their photocurrents are digitized. Finally, by applying an appropriate data recovery algorithm and with digital phase estimation the transmitted data is recovered off-line. As an example, for QPSK and 8PSK, two different system configurations were investigated. Firstly, with the help of optical in-line dispersion compensation with DCF (dispersion compensating fiber) the achievable transmission distances were determined. In this case, inside the re-circulative fiber loop the transmission link consisted of approximately 13 Km DCF which is fully compensated for the chromatic dispersion of the SSMF of 80 Km. controlling the launch power and to compensate for the fiber loss into the SSMF and DCF, the EDFAS (erbium doped fiber amplifiers) is used. Secondly, using CD compensation with complex FIR filtering the DCF modules were removed from transmission link and compensation of chromatic dispersion for electrical means after homodyne detection takes place. For the design of future optical WDM systems, latter link configuration is discussed intensively because link architecture is drastically simplified by it.



Results of experiment are depicted in figures and illustrate the EDE and the huge potential of coherent detection with respect to the achievable transparent OTD (optical transmission distance), but the distance from migration to higher-order modulation formats is decreased confirmedly, as example: from QPSK to 8PSK. On comparing the CD compensation (with and without in-line) with 8PSK results, we can see the increase in transmission distance (in case of without in-line CD compensation). On applying more enhanced signal processing such as nonlinear equalization there will be the possibility in further improvement in transmission distance.

CONCLUSION & FUTURE WORK:

To build the optical transport networks of next generation, higher-order modulation formats are intensively investigated to have a further increase in spectral efficiency. In optical transport networks, for the required transmission distance the high spectral efficiency can be attained by digital electronics equalizers and coherent receivers. We can have a review on currently research on the application of higher-order modulation formats with electronic distortion equalization and coherent detection. Further investigation and research on achievable spectral efficiency and system design as well as on transmission distance are not be avoided, in particular for higher bit-rates per wavelength and for WDM systems. With respect to dispersion maps and optical fiber input power there will be the optimization of the link configuration for every format, so that the transmission reach for system with in-line CD compensation will be maximized. In WDM based optical networks the spectral efficiencies can be evaluated by the system penalty induced by narrow optical filtering and for the various higher-order modulation formats, the inter-channel crosstalk of linear and nonlinear on system performance must be determined. At transmitter side, for practical system implementation the high speed DAS's (digital to analog converters) for the multilevel electrical driving signals of high-quality and integrated novel optical modulator structures have to be developed. Generally, for high-order modulation formats commercial implementation of optical transmitters and receivers are facilitates by the applications of the high-speed DSP (digital signal processing) technologies.

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