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A study of optical modulation and higher transmission capacity

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Abstract
In this paper the assessment of different approaches to overcome the capacity shortage in optical fiber communication. Optical transmitters, receivers and media are not preferred owing of high cost, unavailability of complex hardware setups and economic infeasibility of upgrading media. Consequently, Optical modulation is the sole and promising technique with cost effectiveness in the current scenario. By incorporating certain modulation scheme in optical transmitter and receiver only data-to-be-sent is required to modulate before sending. It will help to cater this capacity crisis quite effectively.

Keywords: optical modulation and higher transmission capacity

Introduction
The emergence of optical fibre communication technology has opened new communication possibilities which are rapidly replacing conventional means of communication for a number of reasons. The optical fibers have higher transmission capacity than metallic cables and are therefore better suited to the increase demand for high transmission capacity. The optical fibers also provide higher security to the transmitted information in terms of eaves dropping and interference. The optical fiber cables are also smaller, lighter and more robust than metallic cables. Optical fibre technology is also advantageous to developing countries, where the installed communication infrastructure is minimal.
In spite of the higher transmission potential promised by optical fibers, a number of factors have emerged as limitations to their maximal utilization. These factors include the speed of the electronics, fibre attenuation, fibre dispersion and detector noise. Except for fibre distortion, the effects of the other problems have been substantially reduced through applied research. Fiber dispersion distorts the optical pulses transmitted through them by causing them to broaden and break into multiple pulses. In conventional systems, which constitute most of the already installed systems, transmission is carried out at 1300 nm where the optical fibers have zero dispersion [1–3]. Efforts have therefore been carried out to combat the dispersion at 1500 nm and take advantage of the lower attenuation by modifying the dispersion profiles of the optical fibers. One of the promising techniques proposed for conventional optical fibres is that of shaping the electrical pulses so that the transmitted optical pulses suffer least distortion as they propagate within the fibre. The analysis is based on computer simulation, a technique which is quite cost effective. Moreover, the rate equation model of the laser is used, because results which are obtained by using this model closely approach those of practical system.

Optical Modulation
For the effective transmission of message signal, some of the parameters of carrier signals are varied relating to the message signal. This conversion process is called Modulation. The modulation of light beam with respect to optical fiber communication (OFC), or the mapping of digital information on an optical carrier is known as Optical Modulation. Direct modulation may result in loss of information and pulse spreading that is why optical modulation is preferred.
The major advantage of using digital modulation formats in fiber optics is reduced hardware complexity, interference and noise. It provides more information capacity, better communication and high data security [4]. Different optical modulation techniques are required as well to encode or extract information from the transmission medium.

The process of applying information to a light wave is called the optical modulation. Those light waves may be sent through a transparent medium as a laser beam, or contained within a fiber optic cable. The conversion from high frequency/high speed electrical signals into light can occur in two general ways--applied directly to the power source of the light wave emitter (e.g. photodiode), or indirectly, by manipulating the light beam. Simple Schemes Simple optical laboratory experiments often involve voice transmission or low rate digital information, such as Morse code. It is easy to apply the modulation for either via control of the current to a laser diode or LED. On-off keying and amplitude modulation (AM) arc accomplished in the same manner as a radio transmitter, using a series pass transistor in the DC feed to the transmitting device.
For these simple signals, indirect light beam modulation may also be accomplished, using mechanical shutters or a voice-coil driven mirror. These electro-mechanical devices are, of course, limited to low frequencies and useful only in the most simplistic applications.
Some very early light-beam communications and remote control equipment used techniques similar to those just described, mainly to demonstrate the viability of light wave technology. But soon, high frequency modulators were developed, using both direct and indirect modulation methods.

Direct Modulation
Digital signals consist of logical is and Os, which readily corresponds to electrical ON and OFF states, or to two discrete voltage (or current) levels. The typical optical communications light source is a laser diode, which is easily modulated by controlling its current.
Several factors limit the upper frequency at which a laser diode can be modulated. These include the time constants (frequency response) of the driving circuitry, the physics or the diode itself, and the characteristics of the transmission medium, which is typically an optical fiber.
Ultimately, direct modulation is limited by the characteristics of the diode itself. A full turn-on/turn-off cycle represents a significant electrical and thermal stress, which can result in a frequency shift (chirp), transients (ringing), as well as reduced operational lifetime of the laser diode. One method of dealing with these effects is to apply a modulated “radio signal” to the diode. The current swing is reduced, which improves reliability, and the bandwidth is greatly increased because the diode's drift and transient responses are reduced. But this technique also greatly reduces the signal-to-noise ratio, which reduces the range, and it requires more complex driver and detector circuitry.

Indirect Modulation
Modulation of a continuous light beam removes the laser diode-related problems at the cost of greater complexity. It also eliminates the signal-to-noise problems of applying a modulated sub–carrier. The stable light source allows maximum transmission for a given amount of dispersion in the fiber.
Established methods include delivering the data to electrically modulated crystalline materials such as lithium niobate. These devices can rapidly switch the light beam between a direct signal path, or split the beam into two paths with 180-degree phase shift, which cancel when recombined. This provides electrically controlled on-off transitions that do not affect the light source.
The other common method uses electro-absorption (EA) modulators, usually a semiconductor material that can be switched between trans missive and opaque states to provide the on-off transitions. Materials used in these modulators can be conveniently integrated with the laser diode. As with direct modulation, the driving circuitry uses microwave design and layout to couple high speed data streams to the modulating devices.

Modulation Formats
When the data rate of 40 G b/s started to enter optical networking, line coding and modulation formats became the center of interest along with the achievement of high spectral efficiencies. These formats combat militate against linear and non-linear impairments from OFC. Due to current data rate limitation, it is of utmost importance to consider practical aspects of modulation and modulator technology while designing optical modulation format for a specific system. Three basic widely used modulators are electro absorption modulator, directly modulated laser and Mach Zehnder modulators (MZMs) [5]. MZM works on the interference principle and is managed by optical phase modulation. Due to their good modulation performance and the independent possibility of modulating intensity, many of the advanced optical modulation formats are based on using it [6]. Modulation techniques promises to eliminate capacity limitation but their implementation in fiber optic system invokes these challenges.

Binary Amplitude Shift Keying (ASK)
Amplitude shift keying (ASK) or On-Off Keying (00K) in its various flavors has been used widely in OFC with its simplicity and cheapest digital coding schemes, where ASK and OOK represent digital signals. In this technique, the baseband signal is multiplied by a carrier frequency; the binary 0 is represented by no pulse ("0" W) and binary 1 is represented by a positive pulse ("A" W) [7]. Figure l illustrate a ASK modulated signal.

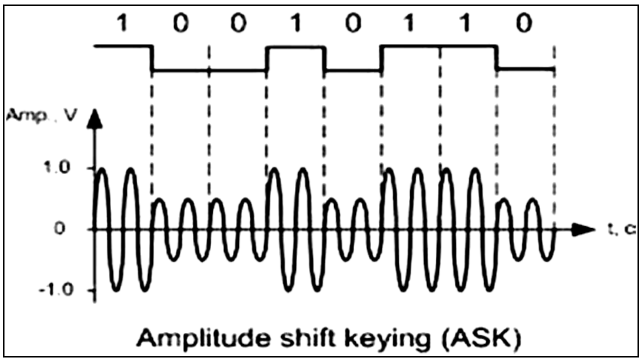

Fig l: Illustrate a ASK modulated signal

In advanced communication systems, multilevel signaling is a technique that utilizes more number of bits per symbol to achieve high transmission capacity. In ASK, 4-ary digital modulation. M=4 symbolize 4-ary format and therefore increases the transmission capacity to double up while the spectral width is maintained [8]. It also shows good performance in integration and hardware implementation. It has its application in very low speed telemetry circuits. The 8-ary ASK is also deployed in OFC to three-fold increase the transmission capacity. Channel capacity is improved despite the drawbacks of receiver sensitivity and OSNR degradation. It is no longer an optimal format for next generation high capacity optical networking systems.

Non-Return-to-Zero (NRZ-00K)
The non-return-to-zero (NRZ) is the simplest and most dominant modulation format in optical fiber communication (OFC) systems based on direct detection method. NRZ is used in the early days as it requires low electrical bandwidth as compared to RZ and other simplest formats. The narrow spectrum width of NRZ improves the dispersion tolerance but is severely affected by inter symbol interference (ISI) [9]. In this simplest modulation scheme, logic 0 is represented by a dark period and logic 1 by a flash of light. As shown in figure 2, logic 1 is transmitted as an electric pulse with amplitude (A) in volts and the duration τ. (tau) in nano seconds. Similarly logic 0 is represented as 0 V during tau ns. The maximum data rate is up to 100 Gb/s.

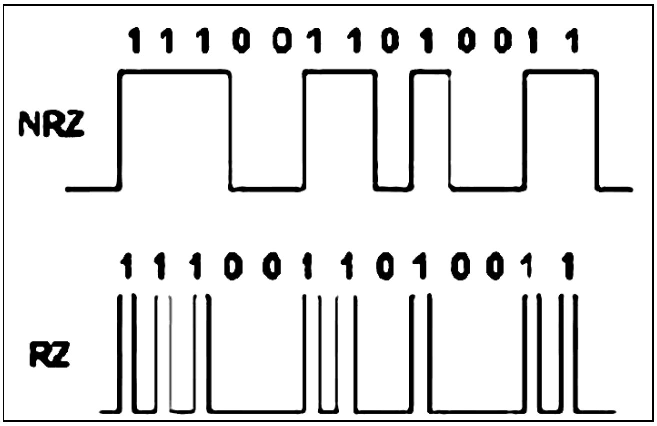

Fig 2: Comparison of NRZ and RZ wave form [10]

Return-to-zero (RZ-00K):
The RZ pulse width occupies half bit slot but utilizes twice the B.W as compared to NRZ. The RZ pulse shape has high robustness to fiber nonlinear effects. It has reduce spectral efficiency and dispersion tolerance owing to its broad spectrum. It represents logic 1 as a pulse with amplitude (A) and the duration (τ in ns), while logic 0 is represented by a zero signal shown in figure 2. The upper limit of RZ data rate is 50G b/s. NRZ modulation format is preferred by commercial systems; however, it is merely used now a days and trend is increasing to switch to alternate formats like RZ.

Carrier-Suppressed Return-to-Zero (CSRZ)
In CS-RZ pulse, there is a suppressed carrier with a p phase shift between adjacent bits. Therefore, the average optical field in it is zero [11]. It is also a sub form of RZ pulse. Two electro-optical modules are required by CSRZ for its generation. CS-RZ is a better tolerant to chromatic dispersion (CD) and fiber nonlinearity. It also provides robustness against transmission impairments [12]. It is compatible for long distances due to low BER.

Conclusion
The analysis of an optical fibre-communication system up to the fibre output stage has been undertaken using the rate equation model of the laser and practical values of the fiber parameters. The pulse shapes at the output of the fibre showed improvements as the input pulse shapes depart from the square to the less square ones. Among the pulse types used, the trapezoidal pulse with a pedestal on the leading edge gave the best shape at the fibre output. This pulse shape however, can not be claimed to be the best among all the possible shapes. In practical systems, special design techniques need to be applied to the laser drive circuits so that they produce trapezoidal shaped pulses. Such pulses are also smoothened to remove the sharp edges, and this lead to correct signal detection at the fiber outputs.

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