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Reducing The Effect Of Dispersion Resulting From The Introduction Of Wave Length Division Multiplex (WDM) Due To External Pressure In Optical Network

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Abstract: - Dispersion decreases the bandwidth carrying-capacity of the reliable transmission medium of fibre optics with all its advantages over other orthodox media of copper, coaxial etc .It is inherent in the wave length method integrated into the system, to enable long haulage of modulated signal for propagation. It is a cost effective means of increasing the capacity of long haulage optical transmission system, however it limits the rate at which the intelligent signal can be received through the channel at the required bit error rate (BER). Pressure is a catalyst that facilitates the broadening of signals at the receiver. The utilisation of Guassian Minimum Shift Keying (GMSK) simulation factors are the gear system employed in resolving the problems of dispersion, attenuation bending losses etc Poor installation of optic fibre network system equally gives room for external pressure and temperature effect on the fibre.

I. INTRODUCTION

To expand the capacity of optic fibre transmission medium, two methods are available namely:
i. To provide and install a higher capacity of the fibre core there by abandoning the existing fibre core or add a core fibre that will double the existing fibre core on the route;
ii. to introduce the wave length multiplexer (WDM) technique to improve the capacity-carrying of the existing fibre core.

The first method is an economic waste and; additionally there must be a designed combiner at the receiving end to combine the two circuits before de-multiplexing. The second option is a better one, since the idea of this manner is to increase the capacity of the system [4]. This system uses transponder to adapt the signals for transmission in the system .In practice, transponders modulates individual signals, into distinct wave length around the 1550nm window .A transponder is a device that integrates a receiver (Rx),an electronic regenerator, a transmitter (Tx), beside the generation function a transponder can implement the adaptation of signal characteristics, such as wave length , optical power ,modulation format e.g. OOK, RZ, NRZ etc and transmission formats e.g. adding forward error correction code(FEC) .Once the adaptation is executed, the wavelengths are multiplexed to form a composite signal, which is amplified before being propagated through the fibre network. At the receive side, the signals are pre-amplified and de-multiplexed. The signals are being amplified by regenerative methods at intervals of about 100km, using majorly Erbium doped amplifiers or Raman amplifiers.

II. DISPERSION

Dispersion occurs when a wave interacts with a medium or passes through an inhomogeneous geometry. It causes pulses to spread (broadening),in optics fibre degrading signals over long distances [1].In fact this is a phenomenon that occurs as a result of spreading of the transmission of binary digits of 1"s and 0"s (ON and OFF) of light pulses that convey digital information Fig 1 .It is similar to the rainbows in which the white light is caused to diffract into components of different wavelengths due to spatial separation of the white light. Dispersion develops in various forms, but suffices to state that they all lead to pulse spreading in the network. Polarisation mode dispersion, (PMD), group velocity dispersion,(GVD), wave guide dispersion, Intermodal and Intermodal dispersion, material dispersion ,birefringence, and Chromatic dispersion.

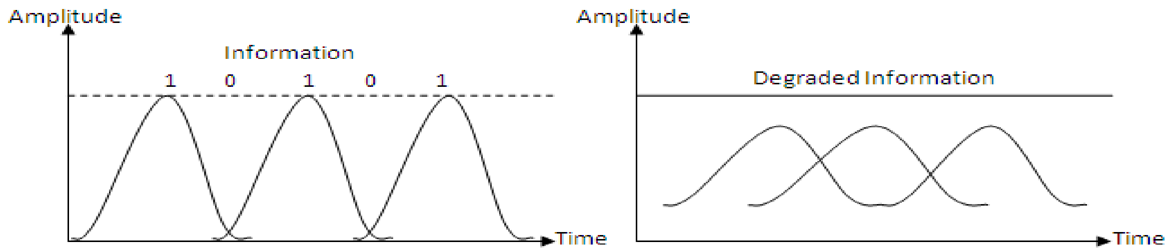
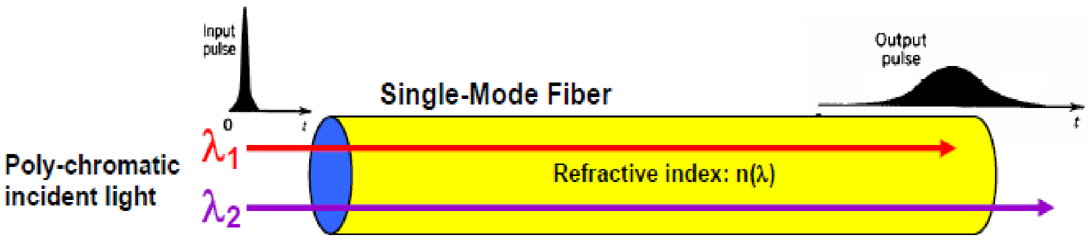


Fig. 1 Pulse spreading causing information distortion as a result of Chromatic Dispersion.

III. CHROMATIC DISPERSION

It must be realised that the introduction of the wavelength division multiplex (WDM) creates room for the longer fibre length hence the introduction of dispersion, which includes the chromatic dispersion.
Fig.2 Polychromatic Incident Light in Single Mode Fibre (Source)
It is a known fact that Light within a medium travels at a slower speed than in vacuum. The speed at which light travels is determined by the medium's refractive index. In an ideal situation, the refractive index would not depend on the wavelength of the light. Since, this is not the same case, different components have different wavelengths and speeds within an optical fibre.CD in single-mode fibre Laser sources is spectrally thin, but not



monochromatic

[3]. This means that the input pulse contains several wavelength components, travelling at different speeds, causing the pulse to spread, Fig 2. The detrimental effects of chromatic dispersion results in the slower wavelengths of one pulse intermixing with the faster wavelengths of an adjacent pulse, causing inter-symbol interference.

The Chromatic Dispersion of a fibre is expressed in ps/(nm*km), representing the differential delay, or time. Due to the fact, that the effect of dispersion increases with the length of the fibre the transmission system is often characterised by its bandwidth-distance product usually expressed in MHz/km. The value of bandwidth-distance product of 500MHz, could carry a 500MHz signal for 1km or 1000MHz for 0.5km. Each fibre can carry many independent channels and each using a different wavelength of light (wavelength division multiplex WDM) The net data rate without over head byte per fibre is the pre-channel data rate reduced by the Forward Error Correction (FEC) over head multiplied by the number of channels (Usually up to 80 channels in common different Dense wave division multiplex in SONET/SDH [2]. For modern glass optical fibre, the maximum transmission distance is limited not by direct material absorption but by several types of dispersion or spreading of optical pulses as they travel along the fibre, Fig. 2.

Dispersion in optical fibre is caused by a variety of factors. Intermodal dispersion is caused by different axial speed of different transverse modes. It limits the performance of multimode fibre, because single mode fibre supports only one transverse mode, intermodal dispersion is easily eliminated. In single mode fibre performance is primarily limited by CD, also known as Group Velocity Dispersion (GVD) which occurs because the index of the glass varies slightly depending on the wavelength of the light. Also, it is important to note that light from real optical transmitter necessarily has non-zero spectral width due to modulation factors. Polarisation mode dispersion (PMD) is another source of limitation, critically related to CD. Dispersion limits the bandwidth of optic fibre because the spreading optical pulse limits the rate at which pulses can follow one another on the fibre, and still be distinguishable at the receiver .Chromatic Dispersion is the basic problem envisaged in the expansion of fibre optics in its development to improve the bandwidth and provide more services to clients. As light travels down the fibre length the pulse broadening results and this is a consequence of intra-modal dispersion and intermodal delay effect'. The group velocity of the guide mode, which relates to the speed at which energy in a particular mode travels along the fibre.
Intermodal dispersion is pulse spreading that occurs from the finite spectral emission width of an emitted optical source signal. It is equally known as Group Velocity dispersion (GVD). Similarly, because dispersion is as a

result of group velocity which in turn is a function of wavelength Chromatic Dispersion is a basic resultant of two main factors viz:

i. Material dispersion: This results as variation of core refractive index of materials used in glass fabrication. It operates similarly like the light ray crossing the prism;

ii. wave guard dispersion: The fibre is made up majorly of the core and cladding, during transmission about 80% of the power of the coupling signal is confined in the core while the remaining 20% is propagated along the cladding. This 20% on the cladding travels faster, then arrives at the receiver earlier than the 80% propagated through the core.

Dispersion occur since the propagation constant β is a function of optical fibre diameter relative to the wavelength λ/a, where a is the core radius and the propagating wavelength is λ. Another factor affecting the pulse spreading is the intermodal delay and this is after effect of each mode passing different values of group velocity at a given frequency, This dispersion is equally aggregated by factors such as non ideal index profile ,optical power lunching conditions, i.e. different amount of optical power lunched into the various modes, non uniform mode attenuation, mode mixing in the fibre , splice and statistical variation in all the factors along the fibre length.

IV. MODELLING A CHROMATIC DISPERSION COMPENSATION

In our, model, CD being a linear phenomenon was compensated with GMSK linear filter Fig 3. The modulation linear filter can be deployed in either the transmitter side or the receiver side. In both pre and post compensation GMSK schemes, the filter applies the inverse effect of chromatic dispersion and consequently we have the desired signal without dispersion at the receiver.

i. Receiver sensitivity with attenuation/dispersion measurements

ii. Frequency and phase error of the GSMK modulation

iii. Transmitter timing errors

The model is given by

$$F(e_x) = \sum_{i=0}^{n+1}((S_n) + F_{gmskMod} + S_{Amp}) \qquad (1)$$

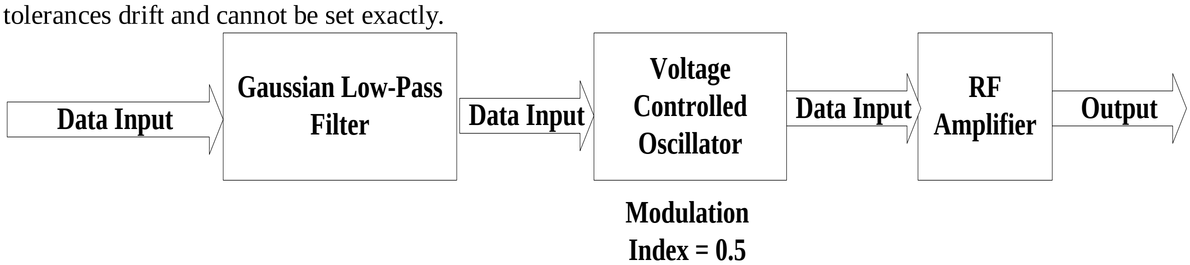
Where S_n gives the contribution of signal generation, F_{gmsk} gives the filter modulation function and S_{Amp} gives the signal amplification contributions. **GMSK Modulation in Fibre Communication Network**

Gaussian Minimum Shift Keying or Gaussian filtered Minimum Shift Keying, GMSK, as a form of modulation (F_{gmsk}) with no phase discontinuities was used to provide data transmission with efficient spectrum usage. In our model, it has advantage of being able to carry digital modulation while still using the spectrum efficiently. This addresses the major problems with other forms of phase shift keying where their sidebands extend outwards from the main carrier thereby causing interference to other radio communication systems using nearby channels.

Using GMSK modulation as a continuous phase scheme, there are no phase discontinuities because the frequency changes occur at the carrier zero crossing points. This arises as a result of the unique factor of minimum shift keying (MSK) in that the frequency difference between the logical one and logical zero states; is always equal to half the data rate. This was expressed in terms of the modulation index, which was set equal to 0.5.

4.0 Generating GMSK modulation

Though there are two main ways in which GMSK modulation can be generated. The first approach was to filter the modulating signal using a gaussian filter and then apply this to a frequency modulator where the modulation index is set to 0.5. This method is very simple and straightforward, but it has the drawback that the modulation index must be exactly equal to 0.5. In practice, this analogue method is not suitable because component tolerances drift and cannot be set exactly.



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ig.4 Block diagram for GSMK Generation GMSK using a Gaussian filter and VCO

The second method involving a widely accepted quadrature modulator was used. In this case, the quadrature which refers to the fact that the phase of a signal is in quadrature or 90^0 to another one. The GMSK quadrature modulator will be implemented to use one signal that is said to be in-phase and another that is in quadrature to it. In view of the in-phase and quadrature elements this type of modulator is referred to an *I-Q* modulator. Using this modulator, the modulation index was maintained at exactly 0.5 without the need for any setting or adjustment. This makes it much easier to use, and provides the required level of performance without the need for adjustments. For demodulation the technique can be used in reverse.

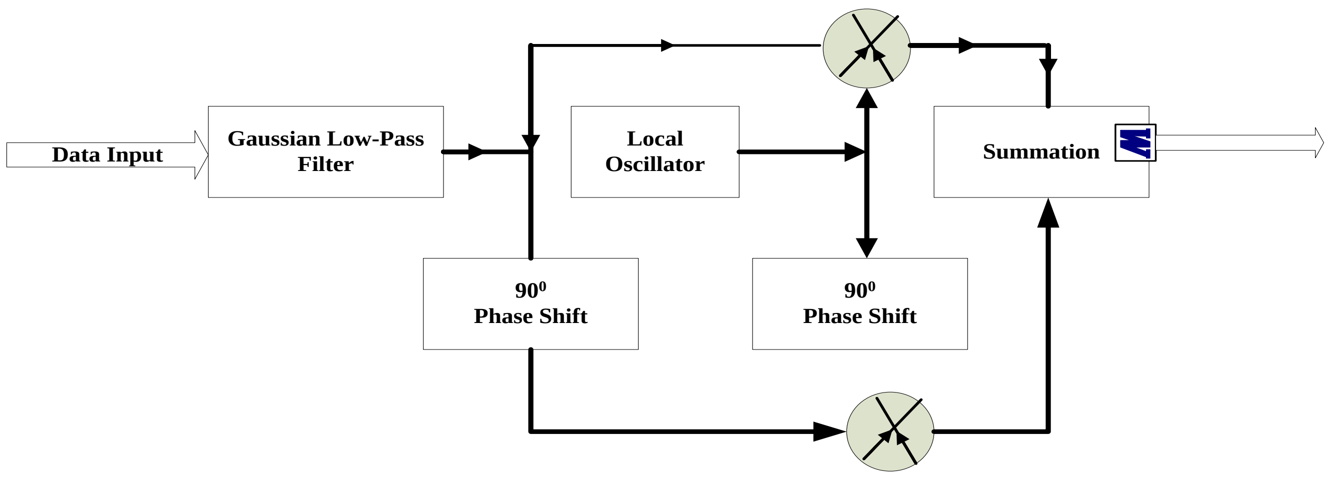

Fig.5 Block diagram of I-Q modulator used to create GMSK

The ultimate goal of a modulation technique is to transport the fibre communication signal through a wave channel with the best possible quality while occupying the least amount of wave spectrum.
Consider signal message:

$D(t) \rightarrow (t) = A\cos(wt+\theta) \rightarrow Channel.$

Where *D(t)* is the message, *Acos(wt+θ)* is the modulation. Modulation may be done by varying the amplitude (A), phase θ, or frequency *wt* of a high frequency carrier in accordance with the amplitude of the message signal.
Minimum Shift Keying (MSK) for modelling the fibre communication on the basis that GMSK is a spectrally efficient modulation scheme and could be particularly attractive for use in fibre communication systems because it possesses properties such as :

- constant envelope;
- spectral efficiency;
- good BER performance; and
- self-synchronizing capability.

Let the GMSK modulation, expression for the modulated signal *x(t)* be represented by:

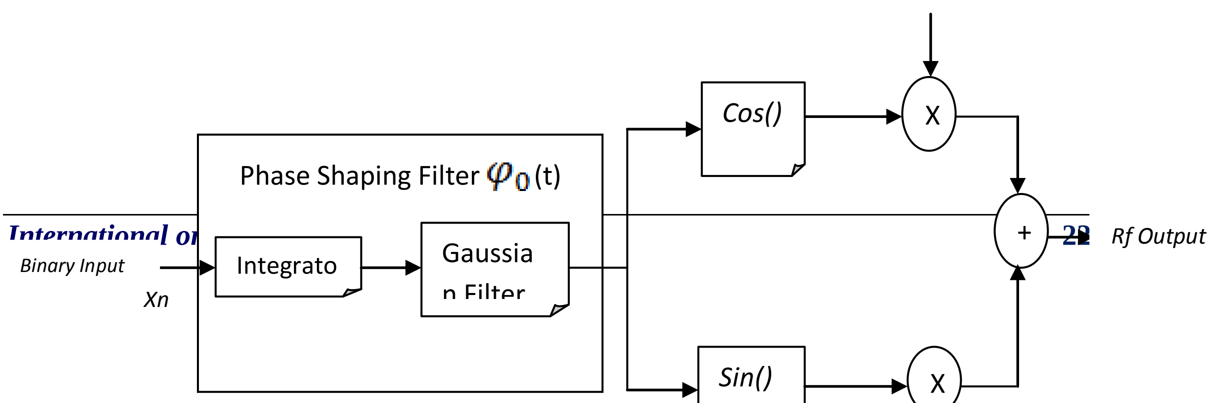

Fig 6 GSMK Modulator

Fig 6 uses the gaussian frequency shaping filter. In the model, the GMSK is a Continuous Phase Modulation (CPM) signal with modulation index *h =0.5* which is defined by the continuous phase shift function θ(t) and has the following complex baseband representation

$r_{transmit}$(t) = A exp$\left(j\pi h \sum_n x_n \varphi\ (t - nT) + \varphi_0\right)$ (3)

Where *T* is bit period, *A* is amplitude, X_n = $\pm$ is the sequence of binary alphabet symbo phase and θ(t) is the phase shift function. Constant envelop, continous-phase modulation schemes are robust against signal fading as well as interference and have good spectral efficiency. The slower and smoother the phase changes, the better the spectral efficiency.

The schematic diagram of a GMSK modulator is shown in Fig.7 where GSMK signal is generated by modulating and adding two quadrature carriers with the frequency $f_{c.}$ phase changes are smoothed by a filter having gaussian impulse response [68].

$$g(t)=\frac{1}{2T}\left[Q\left(2\pi B\,\frac{t-\frac{T}{2}}{\sqrt{\ln 2}}\right)\right]-Q\left(2\pi B\,\frac{t+\frac{T}{2}}{\sqrt{\ln 2}}\right) \quad (4)$$

Where *Q(t)* is the Q-function given by

$$Q(t)=\int_t^{\infty}\frac{1}{2\pi}\exp\left(-r^2/2\right)dr \quad (9$$

and the phase shift function *Q(t)* in (4) is given by

$$\varphi(t) = \int_{-\infty}^{t} g\,(t)\,dt$$

The key parameter in controlling both bandwidth and interference res

X bit interval product (BT) referred to as normalized bandwidth. The fibre GSMK uses BT = 0.3, which corresponds to spreading the effect of 1bit over approximately 3bits intervals. The channel separation or bandwidth at the TDMA burst rate of 271kbits/s (*T =3.69s*) is assumed to be BW = 200 kHz. The modulated spectrum must be 140 pulse length symbol intervals at both adjacent carrier frequencies.

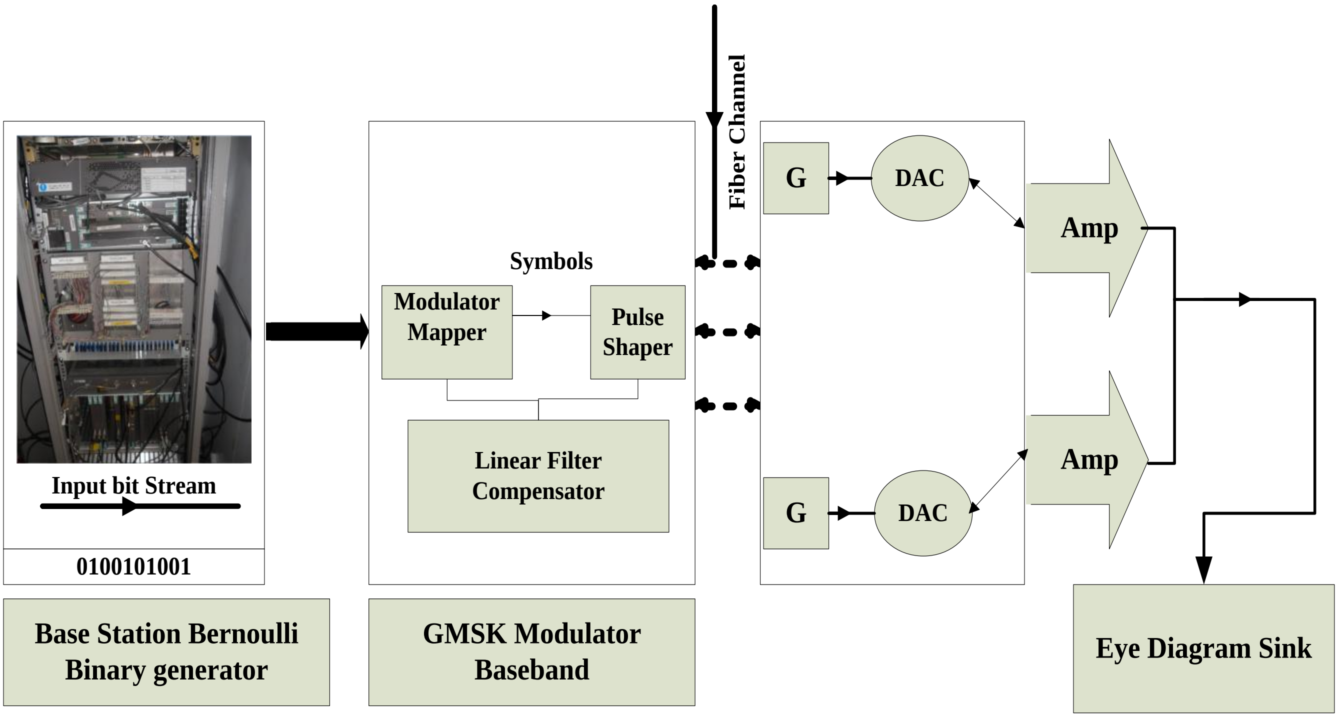

Fig. 7 System Model of the Fibre Communication Interface System

From Fig.7, the model started with the SMS binary source (Bernoulli block) into the transmission block which comprises the convolutional encoding, data framing, interleaving, data burst and CRC. The block also has the differential encoder and the GMSK modulation. afterwards, the channel block was implemented with the addition white guassian noise (AWGN) at the receiver demodulation block which is comprise of the decoder with the separation matched filter, mapping, CRC, decoder, the demodulation GMSK, differential decoder and the reshape optimizer. The model ends the receiver interface with a gain amplifier and its sink. However, most these blocks were not represented.

V. CONCLUSION AND RECOMMENDATION

From the analysis, it is clear that the GMSK modulation in optical fibre communication can conveniently control dispersion of wave transmission. It is recommended that optical sensors be integrated into the GMSK modulation for ease of monitoring.

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