Optical fibre communication systems engineering essay

Engineering

RESEARCH METHODS AND PROJECT MANAGEMENTLITERATURE SURVEYON

OPTICAL FIBRE COMMUNICATION SYSTEMS

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ABSTRACT

This paper mainly concentrates and explains about the basics of " Fibre Optic Communications System". This report states clearly about different types of defects that can be observed in optical cables. It focuses about the parameters through which efficiency can be measured in optical fibre communication. It deals with different types of tools used to identify and eliminate the observed defects in optical fibre cables. This paper also explains about basic Losses in Optical Fibre System.

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INTRODUCTION

From the previous two decades it is observed that there is fast growth of fibre optics application in this communication world because of its marvellous benefits when compared to other emerging technologies. The main advantage of fibre optics is, it is cost effective, low attenuation, less weight and it`s performance is high. The main usage of optic fibre is lies withinTo replace the copper wire with optical fibre for high speed point to point data transmission. To interconnect computers and very fast networksFor light structure and thin coatings (Glista, A. S, 1993)The main concept on which optical fibre runs is light technology. During 60`s onwards this light source leads to completely different behaviour when compared to other sources. One such light source is LASER. After this development of diode lasers are developed for optical fibre transmitters. At the time of 70`s,

the first fibre optic glass with low attenuation for the transmission of EMW (" Electromagnetic Wave") was developed (Strobel, O.; Lubkoll, J, 2010)FIG 1. 1: Fundamental Fibre Optic System (Strobel, O.; Lubkoll, J, 2010)In order to detect the transmitted signal Photodiodes are used as detectors, and by using " optoelectric (O/E), Electro optic (E/O)" at transmitters and receiver side and by placing the fibre in the middle the systems are developed. Charles Kao is the originator for optical fibre transmission systems. Along with the above said advantages, key role of optical fibre communication is it`s realizable bandwidth.

OPTICAL FIBRE

The fibre cable is consisted with three major parts in it. They areCoreCladdingOuter coatingFIG 2. 1 Optical Fibre (Personick. S, 1983)

Core:

The light signal is transmitted from transmitting end to receiving end through the core. It is the smallest and sensitive part of the cable. It can be made either by plastic or glass, which consists of impurities such as Germanium or Phosphorous. Addition of these impurities results in rising of the refractive index of the core at unbalanced conditions. The diameter of the core varies for different applications. Range of the glass core is from 3. 5 to 200µm. when compared to glass; the core sizes of plastic fibres are greater and are in the range of 100µm.*Typical refractive index of core= 1. 48

Cladding:

Cladding is the one which protects the core and has refractive index less when compared to core. Manufacturing of core and cladding are always with the same material ie., either with the glass or plastic. Addition of impurities for core and cladding varies in the amount in order to maintain different refractive indexes. Standard cladding diameters are 125µm and 140µm.*Typical refractive index of cladding= 1. 46

Outer coating:

This is the most important and final protective layer of the cable which protects the core and cladding. It is made of either acrylate or plastic. This protects the fibre from various damages such as scrapes, shocks, temperatures etc,. This outer coating does not have the capability of carrying light and is of colourless. [1]

OPTICAL FIBRE COMMUNICATION

FIG 3. 1 Block Diagram of Optical Fibre Communication (Personick, S, 1978)The main building blocks of optical communication are transmitter, receiver, optical fibre and connectors.

Transmitter:

Electrical signal is converted to light signal. Here the signal can be generated either by a computer or a telephone or ant raw data from a sensor. This transmission can be simplex or duplex systems depending up on the application. Simplex system transmits the signal only in single way whereas duplex system transmits in both ways having transmitter and receiver in

both ends. There are again two types in duplex system. Half- duplex systemFull- duplex system

Receiver:

Light signal is converted to the electrical signal and later converts into its original form. The receiver typically consists of a photo detector to convert the received light into electricity, and circuitry to amplify and process the signal. In the receiver section there are certain specifications namelyWavelengthDynamic rangeResponsivityBit rateResponse time

Wavelength:

This can be mentioned as the range which gives the highest peak output ie., peak wavelength= 850nm

Dynamic range:

It is defined as the ratio of maximum input power to the minimum input power and is expressed in decibles (db).

Responsivity:

Responsivity results in the total output current which is obtained by the every watt of input light. That means the input light and output current is directly proportional to each other.

Bit rate:

Bit rate defines the speed of the incoming signal to its maximum and determines the response time

Response time:

Response time comes into picture because of the detector as it switches fastly and gives the maximum transmission rate.

Optical fibre:

This is used to carry the converted light signal and transmit it to the receiver. The entire signal is carried in the core part with its specified refractive index depending upon the type of application.

Connectors:

These connectors connect the optical cable to the transmitter and receiver on both ends. Depending upon these connections the performance of the optic fibre varies and results in various connector parameters such asInsertion lossReturn lossMating durabilityOperating temperatureCable retentionRepeatabilityColour schemes

Advantages:

Small size and light weightWider bandwidthImmune to interferences (electromagnetic)Less crosstalkCompatibilityCost is lowData securityEasy installation

Disadvantages:

FragilityAffected because of chemicalsOpaqueness [3]

DEFECTS IN FIBRE OPTIC CABLES

Defects in fibre optic cables are always tested and procured before every installation in order to transform the signal efficiently and accurately. Whatever may be the type of the defect; it must be detected in its earlier

stage of installation and can avoid occurring in future. In case of fibre optic cables there are many possible defects. Out of them the most common and major defects areMiss alignment defectsScattering defectsCentre defectsMiss match defectsTension or strain defectsNetwork defectsLattice defectsMicro bending defectsVisual defectsPoint defect

Miss Alignment Defects

Alignment in fibre plays a prominent role for transmission of light through its core. This miss alignment in fibre is mainly due to connectors of low quality used to connect the fibre. i. e, especially of the fibre core diameter variations, eccentricity of the fibre, hole tolerance, ferrule concentricity etc. This may also occur due to radius of curvature because it provides the fibre to make contact exactly by polishing its surface with specific radius. There are two important key factors while considering the radius of curvature. Fibre heightApex offset

Fibre Height

For proper and good transmission of light, physical contact is very important. i. e., if the fibre height is very high, end face damage may occur. If it is too low, physical contact will never occur which results in high reflectance and attenuation. Figure 4. 1 shows Fibre height with respect to radius of curvature.

Apex Offset

Apex defines the peak of the radius. Apex offset is defined as relationship from apex to perfect centre of ferrule. There is strict limitation and is mandatory of this parameter to control distance of individual fibre from

connector surface to avoid physical contacts of various fibres.[7]Figure 4. 2 shows the Apex offset of the cable with respect to radius of curvature. [7]Basically there are three types of miss alignments. They are

Lateral miss alignment:

Figure 4. 3 shows lateral miss alignment.[7]

Longitudinal miss alignment:

Figure 4. 4 shows longitudinal miss alignment.[7]

Angular miss alignment:

Figure 4. 5 shows angular miss alignment. [7]

Scattering Defects

Scattering defects are nothing but effect of the cable due to light scattering from the end face which is called as end face defects. Because of this defect there is lot of back scattering of light. The role of this end face plays a major role in fibre cable because, the quality of this end face results in achieving high performance. A theory of " Wave- Scattering" is used to study and analyse the surface. These defects are due to surface irregularities, digs and scratches occurred while fibre cable installation. [8]Figure 4. 6 shows end face defect. (Source: Elena Avram et. al., " Quantification of Scattering From Fiber Surface Irregularities", 2002). Figure 4. 7 shows surface defect. (Source: Elena Avram et. al., " Quantification of Scattering From Fiber Surface Irregularities", 2002).

Centre Defect

It is one of the types of fibre cable defect in the centre of the core. Whenever the light is transmitted through the LED, this defect does not come into picture, whereas when the light is transmitted it is greatly affected. In order to avoid this defect while transmitting the LASER light signal, conditioning cable modes must be used. These cables are also called as patch cables which are very costly and avoid the centre defects while using laser light transmitting sources. [8]C: UsersDellPicturesofc3. jpgFigure 4. 8 shows center defect. (Source: Elena Avram et. al., " Quantification of Scattering From Fiber Surface Irregularities", 2002).

Miss Match Defects

This miss match defect occurs when the area of the source is greater than fibre core. Power is lost in such cases. The only solution to this type of the defect is to maintain the source area always less when compared to that of the core area. There are basically different types of Miss Match defects. They areNumerical aperture miss matchCore diameter miss matchCladding diameter miss matchCore and cladding concentricity miss matchCore ellipticityMiss match due to refractive indexFigure 4. 9 shows various miss match defects.

Tension or Strain Defects

These defects are caused in fibre cables due to over stress or strain by intrinsic or extrinsic elements. This results in length changes and causes various optical paths. It also leads to variations in core diameter, refractive index etc. So whenever the light is emitted from source it results in

interference patterns. Figure 4. 10 shows the tension of the cable with heavy metal or Diamond blade.

Network Defects

These defects are mainly due to aging of the cables for many years which results in determining the strength of the fibre. The fatigue parameter is used to calculate the strength of the fibre and also tests the fibre and produces the proof for evaluating its strength in its life time. Fatigue parameter: n~20There are three different types in network defects. They areIntended defectAbraded defectContaminated defectIntended defect in a cable is less when compared to that of abraded and contaminated defects.

Visual Defect

These are also called as surface defects (under video magnification of 1200 x). These defects include cracks, breaks, external damages etc. These defects are the main reasons for latent failures in the fibre optic cables. They occur mainly due to high temperature variations. It affects the performance of the cable while transmitting the light signal. These defects in turn lead in high dust deposits, contaminants and other moisture. [11]

Point Defect

These defects are caused by connectors, breaks in fibre cable length, splices etc., there are two types of point defects, may be reflective or non reflective. This defect results in lot of loss in optical power. These also occur due to fibre splices, bends during their installation or cable constructions. [10]

REQUIRED PARAMETERS TO DETECT THE CABLE DEFECTS

There are many parameters which are required to be measure the defects of the fibre cables. They areAttenuationDiameterTensile strengthRefractive index profileDip angleRadius of curvatureNumerical apertureTemperaturePressureHumidityTable 1 shows some of the standard values for the parameters

TESTING EQUIPMENTS

In any transmission technique the entire equipment which is required in the process is supposed to be tested. Similarly the fibre cable must be properly tested before it is installed or constructed so that the defects can be detected in the earlier stages of the cable procurements. [6]There are many detectors for testing different types of possible defects in optic fibre cables:

Fusion Detectors

Fusion defects in optic fibre cables cannot be easily detected. This is only possible through ultrasonic detection. The ultrasonic signals which are totally time varying. Because of this nature, better spectrum cannot be gained, so the defect cannot be found in time domain. So a new technique called Wave packet technique is used to detect these fusion defects by studying the echo’s of ultrasonic signals. Figure 6. 1 shows fusion defect detector. (Source: ZHANG Zhen, et. al.," Defect Recognition of Optical Fibre Fusion Based on Wavelet Packet Technique", 2010). The wavelet packet techniques have some frequency bands. The given table shows the different ranges of frequency bands. [4]Table 2 Frequency bands for wavelet packet technique.

Optical Time Domain Reflecto-Meter (Otdr)

This is one of the detectors which are efficiently used in detecting the scattering defects. Whatever the reflected light is there, it is useful in calculating the attenuation. C: UsersDellPicturesotdr1. jpgFigure 6. 2 shows the OTDR equipment. It always detects the light flow fluidity. There are certain key parameters in this OTDR technique which play a key role in detecting the defect the cable. Examples of these parameters are attenuation, length, etc., which in turn depends upon SNR ratio. The SNR in this system is defined as ration Backscatter signal and level of noise which depends upon pulse width. [1]C: UsersDellPicturesotdr. jpgFigure 6. 3 shows Optical Time Domain reflectometer(OTDR).

Video micro scope detector:

This is one among the detectors which are used particularly to detect end-face defects. It uses LED’s to identify the end face of the cable. There are several variables to detect these defects. Here the end face of the cable is placed in an index matching gel to view the light in the core. Here the refractive index of the core and gel are same. By doing this process, the amount of light which is reflected back is observed through which end face defect can be detected. [1]Figure 6. 4 show video microscopic detector.

Optical Sensor Detector For Miss Alignments

In case of misalignments, the cables are displaced to certain extinct. So whenever the light is transmitted, losses may occur which results in poor performance of the fibres. In such cases this optical displacement sensors

are used to detect these defects. There are two different types in these detectors. [5]. They are

Reflective or fotonic detector:

Figure 6. 5 shows Reflective or fotonic detector. (Source: John. Senior, 1992, pp-502).

Morie fringe modulation detector:

Figure 6. 6 shows Morie fringe detector. (Source: John. Senior, 1992, pp-502).

LOSSESS IN OPTICAL FIBRE

Light travelling from the fibre causes certain losses. The amount of light lost between input and output in the fibre is measured by using attenuation . Attenuation is the sum of all losses occurred in the optical fibre.

Losses mostly depends on :

plastic fibre have losses of several hundred dB/km . Graded index multimode glass fibre have losses about 2-4 dB/km . single mode fibre has losses about 0. 4dB/kmGenerally losses in fibre optic are measured in decibels per kilometre (dB/km)Diffent type of losses in optical fibre areBending lossa. Macro bending lossb. Micro bending lossAbsorption lossScattering loss

BENDING LOSS

When the bends of fibre cable are tighter than minimum cable's radius then bending losses are occured . Proper installation guidelines must be used to avoid the loss of light energy in cladding . Higher order modes are more affected by bending loss compared to lower order . Bending losses mainly occur on mode factor likepoor installationSharp curves of fiber

cableImperfections caused in JacketThere are basically 2 types of Bending losses they are Macro and Micro:

Macro Bending Loss

The fibre which is bent larger than the radius of curvature to the diameter of fibre then macro bending loss are obtained.

Micro Bending Loss

These are caused due to small bends in core-cladding interface . Micro bending loss also occur in fibre manufacturing process.

ABSORPTION LOSS

Fibre optics contains impurities like moisture , metal particles , where it blocks and absorb some part of light and remaining light will be removed in the form of heat energy which causes absorption loss.

SCATTERING LOSS

Light wave travelling in a fibre interacts with a particle, where the energy is removed from the propagating wave and it is sent to other direction in which scattering losses are occurred.

CONCLUSION

This paper gives the basic introduction to the fibre optic communication system, different types of fibre cable defects possible parameters which are required by the fibre cables to detect defects of the cables. There are various testing and detecting equipment’s which are been studied and mentioned in this paper briefly and the working modes of these detectors. This paper gives a brief idea about different types of losses.