Analysis of Opposing Stream Effect on the Non-uniform Optical Fiber Communication Lines

MOHAMMED YOUSEF AL-GAWAGZEH
Department of Computer, Faculty of Engineering
Al-Balqa Applied University
JORDAN

AMJAD YOUSEF HENDI
Department of Electrical Engineering, Al-Husun College.
JORDAN

Abstract: In this paper the expression for definition the opposing stream in optical fiber lines with N heterogeneities is received. The opposing stream dependence on the values and number of heterogeneities has been carried out. It was found that, the calculation of opposing stream in optical fiber lines with N heterogeneities can be limited by four-five heterogeneities which are nearest to the transmitting end.

Key-Words: - Optical fiber, Opposing stream, Heterogeneity, Non-uniform, Wave reflection.

1 Introduction

There are an enough publications in analysis of optical signals and waves distribution conditions in optical fiber communications lines with heterogeneities [1-6]. Thus the various heterogeneities which frequently meeting in optical cables renders an essential influence on the transfer conditions in optical fiber lines. the typical representatives to such heterogeneities are the joints of lengths building of optical fiber cables where cables are connected among themselves with application of demountable or welded connections. To such constructive characteristic of heterogeneities are the distinction of diameters, numerical apertures, parameters of refraction, and also the radial, axial and angular displacement from each other of connected optical fiber[6,7].

As a result of reflection from such heterogeneities. The arising waves which forming the dispersion, serves as a reason of formation the opposing stream of energy, which essentially influences on the quality of transmitted information in the optical fiber. and this is shown from reflected waves as a result of return dispersion from each heterogeneity, these waves are summarized and going aside transmitting end of optical cable and cooperating with the active environment of laser(transmitter) and creates an additional parasitic light stream and therefore the quality of transmitted information's will be essentially worsens in the reception device.

The coherent single mode optical systems of transfer are subjected in greater degree to harmful influence [8, 9]. So the purpose of the given paper is to analysis the distribution conditions of optical waves in non-uniform optical fiber lines and to research the dependence of opposing stream on the numbers of heterogeneities taken in consideration the return dispersion.

2 Problem

There is no enough publications to show us how we can calculate the opposing stream in optical fiber cables with a great number of heterogeneities, and when we can use the optical isolators.

3 Solution

The suggested methodology to solve this problem is to give an expression for definition the opposing stream value.

we shall consider the distribution process of optical waves in optical fiber with N numbers of heterogeneities in the direction of Z axis (Z>0) fig.1.

Let's designate the normalized wave amplitude at the beginning of optical fiber line, where the sign "+" corresponds to a positive direction. The normalized wave amplitude corresponds to the square root of the wave power. The distance between non-uniforms we shall designate as l_i, and α is the wave attenuation factor. when the wave distribute along optical fiber line in both directions, a part of it's power will be reflected from heterogeneities, we shall designate these reflected waves amplitude as $E^{\pm}_{IKJ}$, where signs "+ and –" corresponds to reflected waves in both directions accordingly. i, j, k Are the numbers of reflected wave's joints sequence, $R^{\pm}_{I}$ the reflection factor from i heterogeneities.

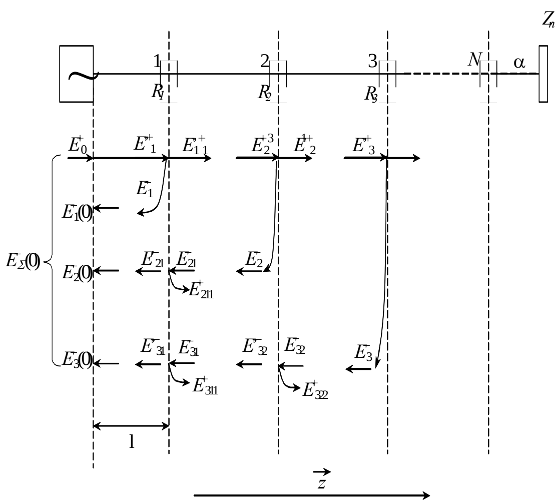

Fig.1:scheme of optical waves propagation in optical cables with heterogeneities.

The value P will describe the opposing stream and represent the relation of total wave amplitude N which reflected from all heterogeneities and acted at the beginning of optical fiber line $E^{-}_{\Sigma}(0)$, to the amplitude of falling wave E^{+}_{0}:

$$P = E^{-}_{\Sigma}(0) / E^{+}_{0}$$

We will suppose that $l_i = l$ = const, and α_i = const, and $R_i = R$ = const.

Besides, the waves reflection factors in both directions are equal each other $\left|R^{+}\right| = \left|R^{-}\right| = \left|R\right|$.thus, as a result of wave's reflection from the first and second heterogeneities at the beginning of optical fiber line; tow waves will be act, which there amplitudes $E^{-}_{1}(0)$ and $E^{-}_{2}(0)$ equal[10]:

$$E^{-}_{1}(0) = E_0.R.e^{-2.\alpha.l} \qquad (1)$$

$$E^{-}_{2} = E_0.R.(1-R)^2.e^{-4.\alpha.l} \qquad (2)$$

Then the reflected wave amplitude from i heterogeneity $E^{-}_{1}(0)$ at the cable beginning will be determined by the ratio:

$$E_i(0) = E^{+}_{0}.R.(1-R)^{2(i-1)}.e^{-2.i\alpha.l} \qquad (3)$$

The total amplitude of all reflected waves from N heterogeneities will be equal:

$$[E^{-}_{\Sigma}(0)]^2 = \sum_{i=1}^{N}[E^{-}_{i}(0)]^2 \qquad (4)$$

Then the value of opposing stream P will be defined from the ratio:

$$P = R.\sqrt{\sum_{i=1}^{N}[e^{-4.\alpha.i.l}(1-R)^{4(i-1)}]} \qquad (5)$$

After simple transformations which are not shown here, it is possible to define the finally expression of opposing stream calculation P which equal:

$$P = R.e^{-2\alpha.l}\sqrt{\frac{1-e^{-4\alpha.N.l}(1-R)^{4N}}{1-e^{-4\alpha.R}(1-R)^{4}}} \qquad (6)$$

In equation (6), first factor is the reflection factor from heterogeneity, second factor is multiplier which taking in consideration the attenuation of building length for optical cable, the third factor describe the increasing of P depending on N heterogeneities.

It's possible to enter the parameter A , and we shall name it as attenuation of opposing stream which connected with P by the ratio[10]:

$$A = 20\log\frac{1}{P} \qquad (7)$$

From analysis of equations (6) and (7). It's shown that, with growth the number N, the value P is increase. However A decreases with small number N, but at big enough number N, the values P and A cease to depend at N.

Let's carry out a research for the value P in real optical fiber line, constructed on the basis of standard single mode optical cable [OTDR].

With this purpose we shall make calculation for wave reflection factor from a joint, at which heterogeneity is an axial displacement of connected optical fibers. Such backlashes frequently arise in case of mechanical connections of optical fibers. In case of welded connections, the reflection is caused by the following factors:

- Discrepancy of modal field diameters.
- Cross-section and angular displacement.
- Discrepancy of refraction indices.

However, the arising value of opposing stream in long optical cable with heterogeneities is defined not as concrete character of heterogeneity, but as an absolute value of total reflection factor. therefore the given restriction does not influence on the character of dependence P at N.

When the backlash between faces end of connected optical fibers takes place at distance equal S , then the reflection factor R is determined from ratio [6, 7]:

$$R = \frac{(n_1^2 - n^2)\sin^2(2\pi.n.s/\lambda)}{4.n_1^2.n + (n_1^2 - n^2)} \qquad (8)$$

where n_1, n - refraction indexes of core and environments in backlash. We will suppose that the backlash is the air, so ($n = n_0 = 1$) .

S - Distance between faces end in backlash of optical fiber.

λ - Wave length,

where λ_1 =1.31 μm and λ_2 =1.55 μm ;so the values of refraction indexes at these wave lengths are equal (1.466 and 1.467).

The factors R_1 and R_2 , corresponded to wave lengths λ_1 and λ_2 have been calculated for different values S/λ which changing from 0.2 to 0.002, the results of calculation are shown in table.1.

Table.1: Coefficients of wave's reflection from heterogeneities

S/λ	0.2	0.1	0.05	0.02	0.01	0.005	0.002
$R_{1\lambda}$	0.1140	0.0470	0.0134	0.00223	0.00056	0.00014	0.00002
$R_{2\lambda}$	0.1123	0.0465	0.0133	0.0220	0.00055	0.00014	0.00002

From results of calculation we can notice that, at identical values of S/λ the sizes R_1 and R_2 which corresponds to the wave's length λ_1 and λ_2 are insignificantly defer from each other. and the deference between them decreases together with reduction of values R,which equivalent to reduction of S/λ.

The opposing stream dependence on number of heterogeneities has been investigated also, with this purpose the calculation of P is made at $\lambda =$ 1.31 μm and three values of R corresponding to parameter S/λ equal: 0.2; 0.1; 0.05(table.1)and curves 1,2,3 on figure.2.and also at wave length $\lambda = 1.55$ μm and two values of R corresponding to parameter S/λ equal: 0.2; 0.05(table.1)and curves 4,5 on figure.2.thus the number N changed from 1 up to 6 in the first case and from 1 up to 8 in the second case.

Using simulation approach the Results of calculation are shown on fig.2.and it's clear that with increase in number of heterogeneities N the opposing stream grows in the beginning and then at subsequent increasing of N, the opposing stream practically become constant and does not depend on N.the reasons of such dependence are given above(from analysis of parities (6) and (7)).

From results of calculation and fig.1 follows, that the big value of opposing stream corresponds to the big wave’s length even at identical values R .and this is because with increasing the cable length, the waves working attenuation become smaller. thus in ratio (6), the influence of factor $(1-R)^{4N}$ on the dependence character $P(N)$ grows together with R increasing. and with reduction of R,the dependence character $P(N)$ starts to be defined in the greater degree by the factor $e^{-4\alpha.N.l}$.

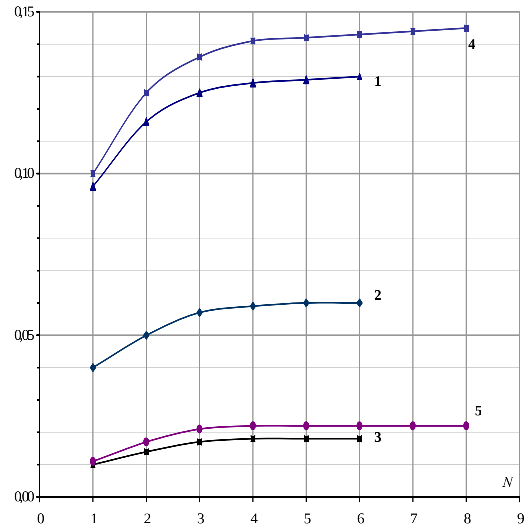

Fig.2: wave’s reflection Coefficients dependence on number of heterogeneities.

4 Conclusion

On the basis analysis of received results, it's possible to conclude that:

- The dependence character $P(N)$ and $A(N)$ in ratio (6) and (7) is defined by two factors $(1-R)^{4N}$ and $e^{-4\alpha.N.l}$.
- The calculation of opposing stream in optical fiber lines with N heterogeneities can be limited by four-five heterogeneities which are nearest to the transmitting end, or taking a cable length from 8 to 10 km, where l = 2km.
- The influence of greater number of heterogeneities N will make an amendment to the value of opposing stream, which is not exceeding more than 2%.thus; requirements by attenuation to the optical isolators can be presented to project the optical fiber communication lines proceeding from the expected values of opposing stream.

References:

[1] Yang K.,Linda P.B.,Whittker J.F.,2001.Electric Field Mapping System using an Optical-Fiber-Based Electro optic Probe, IEEE Microwave and Wireless Components Letters,Vol.11,No.4.

[2] Felsen L.B., Marcuvitz N., 1994.Radiation and Scattering of Waves, IEEE press, Piscataway, NJ.

[3] Kong J.A, 2000.Electromagnetic wave theory, EMW publishing, Cambridge, MA.

[4] Adams M, 1984.Introduction to theory of optical waveguides, pp: 512.

[5] Ploshai L.L., Smirnov V.I., Filimonov V.P.,Chertov B.G.,1980.The requirements to Optical Connectors.Electro-Communication ,No 12-pp:38-39.

[6] James J., 1991.Fiber Optic Cable// A Light Quide//ABC Faltering Inc.-Geneva.-pp: 207.

[7] Obaiedolaev P.P., 1998.Optical Fiber Networks. Radio and Communication, Moscow-pp: 267.

[8] Sheremetov A.G., 1991.Coherent Optical Fiber Communication. Radio and Communication, Moscow-pp: 192.

[9] Kimura T., 1987.Coherent Optical fiber Transmission. Journal of Light wave technology,U.S.A,V.LT5-No.4.-,pp:414-428.

[10] Grodniev I.I., Korbatov N.D., 1980.Communication Lines. Radio and Communication, Moscow-pp: 440.