Contemporary Engineering Sciences, Vol. 7, 2014, no. 9, 397 - 404
HIKARI Ltd, www.m-hikari.com
http://dx.doi.org/10.12988/ces.2014.4217

Co-directional Stream Effect in Fiber Optic Cables with Regular Heterogeneities

Al-Gawagzeh Mohammed Yousef

Balqa Applied University
Faculty of Engineering, Computer Engineering Department
Jordan, Al-Salt

Al-Hadidi Mohammed Rasoul

Balqa Applied University
Faculty of Engineering, Computer Engineering Department
Jordan, Al-Salt

Abstract

In this paper it was received an expression for definition the co-directional stream in optical fiber cables which caused by reflection from heterogeneities of joints, taking into consideration the reduction of modes amplitudes that caused by reflection. Also it was calculated and analyzed the co-directional stream for equivalent cable section length depending on the number of heterogeneities. the signal security from co-directional stream effect for different lengths of cable section was calculated.

Keywords: Co-directional Stream, Signal security, Heterogeneity, Optical Fiber

1 Introduction

The major problem of increasing the efficiency of optical cables is the increasing of regeneration section length, which first of all depends on the transfer parameters optical fiber; energy losses and dispersion [1,2,3].the reduction of regeneration section length substantially caused by different types of heterogeneity which available in the building length of optical fiber and in the places of their connection[4]. The characteristic types of internal heterogeneity are the micro and macro bends which influence on the transfer parameters of optical fiber was investigated in [5] and other works.

Heterogeneity leads to formation the opposing stream and co-directional stream which influencing on the signal security and regeneration section length; to avoid this influence usually we use an optical isolator.

The influence of opposing and co-directional streams on the transfer systems was discussed in [6, 7] and other works, were the dependence of signal security on the heterogeneity size and regeneration section length has been calculated. However the influence of joint heterogeneity on the condition of signal distribution along optical fiber was investigated insufficiently. in the work [7] for example the research on signal security from the co-directional stream of receiving signal in digital optical fiber system was not consider the reducing of modes amplitude in the process of their distribution along the optical fiber which caused by reflection a part of power from heterogeneities, and this can lead to essential errors in the calculation results. Thereupon the influence research on the received signal taking into account the loss from joints heterogeneities from practical and theoretical points of view represents an important task.

The purpose of the given work is to get more exact equations for calculation the co-directional stream and to study its influence on the received signal taking into account the losses from joints of building length of optical fiber on the equivalent cable length.

2 Method And Procedure

Let's see the figure of co-directional stream formation in the equivalent cable length with m butt heterogeneities (figure.1) ,and we will try to get an expression defining the co-directional stream formed by the reflected waves from" m " heterogeneities at the joints of building length of optical fiber and also from heterogeneities at the place of connection of Transmitter-optical fiber and Receiver-optical fiber.

Generally the co-directional stream is formed as a result of two-four and more multiple (even) numbers of reflections from heterogeneities of extending waves. So let's consider only the waves of co-directional stream formed by two multiple reflections from heterogeneities, reflection of higher orders we will neglect and that is justified. The indicators of results shown that at such assumption the calculations error will make less than 0.1%.

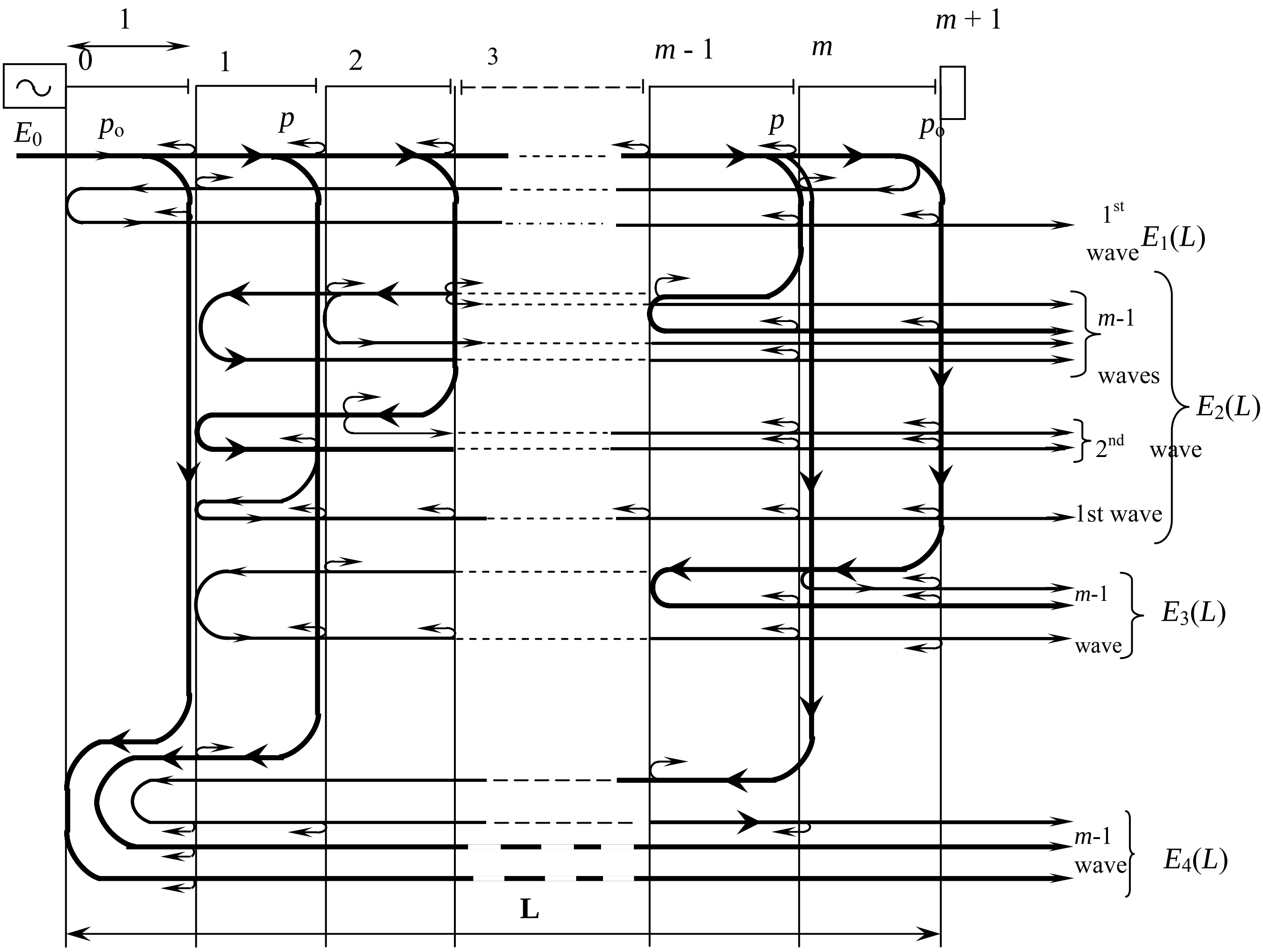

Figure.1:co-directional stream formation scheme

Suppose that all building lengths of optical cable are equals with length l, and also the reflection factors P from all 'm' heterogeneities are equals, besides, the reflection factor of Transmitter-optical fiber, and Receiver-optical fiber are also identical and equal P_0 .so at the receiving end of equivalent cable section with length L which contain m of building length, a four groups of co-directional stream will arrive, where each one consists of various number of partial waves (from 1..to m) with normalized amplitude $E(L)$.

The first group with normalized amplitude $E_1(L)$ representing one wave; primary reflected from heterogeneity (optical fiber-Receiver),and again from the (Transmitter-optical fiber).

The second group of partial waves with total amplitude of co-directional stream $E_2(L)$ as a result of primary reflection from joint heterogeneities (from m to 2nd) and secondary reflection (from m to 1st).

The third group of partial waves with total amplitude of co-directional stream $E_3(L)$ formed as a result of primary reflection of waves from the end of equivalent cable section(optical fiber-Receiver)and the secondary from m joints (started from m to 1st).
The fourth group of partial waves with total amplitude of co-directional stream $E_4(L)$ formed as a result of primary reflection from m joints (from 1st to m)and secondary from the beginning of equivalent cable section(Transmitter-optical fiber).
If we designate the normalized amplitude of electrical field intensity for optical wave at the beginning of equivalent cable section E_0,then the co-directional stream that formed by the first type wave $E_1(L)$,is defined by the expression

$$E_1(L) = P_0^2 E_0 e^{-3\alpha L}(1-P)^{3m} \qquad (1)$$

Where α - the attenuation factor of optical fiber.
The field intensity of co-directional stream that formed by the second group of partial waves $E_2(L)$,which consists from (m-1) subgroup will be defined by the next expression:

$$E_2(L) = P^2 E_0 e^{-\alpha L}(1-P)^m \left[\sum_{i=m}^{2} \sum_{k=(i-1)}^{1} e^{-4\alpha(i-k)l}(1-P)^{4\alpha(i-k-1)} \right]^{\frac{1}{2}} \qquad (2)$$

Thus the first subgroup of the second group is formed by m partial waves, the second subgroup contains(m-1) of partial waves, and the last (m-1) represents one wave of co-directional stream, formed by the reflection from 1st and 2nd heterogeneities accordingly.
The third group contains m partial waves, where the total amplitude $E_3(L)$ is defined by the expression:

$$E_3(L) = P.P_0 E_0 e^{-\alpha L}(1-P)^m \left[\sum_{i=m}^{1} e^{-4\alpha l(m-i+1)}(1-P)^{4(m-i)} \right]^{\frac{1}{2}} \qquad (3)$$

The fourth group is formed also by m partial waves, where the total amplitude $E_4(L)$ is defined by the expression:

$$E_4(L) = P.P_0 E_0 e^{-\alpha L}(1-P)^m \left[\sum_{i=m}^{1} e^{-4\alpha l(-i+1)}(1-P)^{4(m-i)} \right]^{\frac{1}{2}} \qquad (4)$$

If we analyze the (3) and (4) expressions, we see that $E_3(L)=E_4(L)$.
The intensities sum for all four groups that forming the co-directional stream will be defined then by the expression:

$$E_\Sigma(L) = \left[E_1^2(L) + E_2^2(L) + 2E_3^2(L)\right]^{\frac{1}{2}} \qquad (5)$$

After substitution (1),(2),(3),(4) in expression (5) and using some simple transformations we can get:

$$E_{\Sigma}(L)=E_0e^{-\alpha L}(1-P)^m\left[P_0^4e^{-4\alpha L}(1-P)^{4m}+e^{-4\alpha l}P^4\sum_{i=2}^{m}\frac{1-e^{-4(i-1)\alpha l}(1-P)^{4(i-1)}}{1-e^{-4\alpha l}(1-P)^4}+2P_0^2P^2e^{-4\alpha l}\frac{1-e^{-4\alpha ml}(1-P^{4m}}{1-e^{-4\alpha l}(1-P)^4}\right]^{\frac{1}{2}}$$

(6)

For the case when $P = P_0$, the expression (6) will become:

$$E_{\Sigma}(L)=E_0e^{\alpha L}P^2(1-P)^m e^{-2\alpha l}\left[e^{-4\alpha lm}(1-P)^{6m}+\sum_{i=1}^{m+1}\frac{1-e^{-4i\alpha l}(1-P)^{4m}}{1-e^{-4\alpha l}(1-P)^4}\right]^{\frac{1}{2}} \quad (7)$$

The value of co-directional stream which equal $Q=\dfrac{E_{\Sigma}(L)}{E_0e^{-\alpha L}(1-P)^m}$, will be defined from expression (6), where

$$Q=\left[P_0^4e^{-4\alpha L}(1-P)^{6m}+e^{-4\alpha l}P^4\sum_{i=2}^{m}\frac{1-e^{-4(i-1)\alpha l}(1-P)^{4(i-1)}}{1-e^{-4\alpha l}(1-P)^4}+2P_0^2P^2e^{-4\alpha l}\frac{1-e^{-4\alpha ml}(1-P^{4m}}{1-e^{-4\alpha l}(1-P)^4}\right]^{\frac{1}{2}}$$

(8)

Thus, the value of co-directional stream show a proportional of fourth degree of reflection factors and represents the sum of co-directional stream caused by reflection from transmitter and receiver. Where the first composed in expression (8),consider the first wave reflected from"transmitter-reciever"and waves reflected from joint. The second composed in expression (8), consider the reflection from "optical fiber-optical fiber". and the third composed in expression (8),consider the reflection from "transmitter-optical fiber; optical fiber-receiver".

thus ,as a rule ,the first composed in expression (8) is essential less than the second composed.

Now we will calculate the co-directional stream (Q) and signal security A_s from co-directional stream for different lengths of equivalent cable sections (from 40 to 100 km).thus the building length of optical cable L=5km, and the attenuation coefficient of optical fiber α=0.2 dB/km, and reflection coefficients are accepted to be P=0.034(0.023) and p_0=0.0032(0.056).

The calculation results are given in the table.1,and based on these calculations the relation between the length(L) and signal security A_s was constructed in figure.2.where the curve 2 correspond to reflection coefficients $P = 0.023$ and $P_0 = 0.056$,curve 4 correspond to $P = 0.034$ and $P_0 = 0.0032$ .curves 1 and 3 on figure.2 are calculated and constructed for comparison to show the dependence of $A_s(L)$ for the same values of P and P_0 ,but here we don't take in consideration the reduction of wave field intensity which caused by reflection from heterogeneities.

Table.1: Calculations for co-directional stream and signal security

Q A_s	L, km P / P_0	40	50	60	70	100
Q	P =0.034	3.01	3.58	4.07	4.5	5.6
A_s (dB)	P_0 =0.0032	5.05	49.0	47.8	47	45
Q	P =0.023	2.61	2.77	2.92	3.06	3.44
A_s (dB)	P_0 =0.056	51.7	51.2	50.7	50.3	49.3

From figure.2 follows that the difference between signal security from co-directional stream with losses on the joints and without losses on the joints is in the limits from 0.8dB when L=40 km up to 0.5 dB for L= 100 km, that makes a calculation errors of 1.5%, 1% accordingly.

Thus if we will not consider the losses caused by reflections from joints, the results of signal security calculations from co-directional stream are underestimated in comparison with the real in the range of 1….2%.while the errors calculation will increase of cable length.

Besides, the signal security from co-directional stream calculation results in this paper are better than the results in the work [7] in the limits from 15% up to 30% for L=40 km and L=100 km.

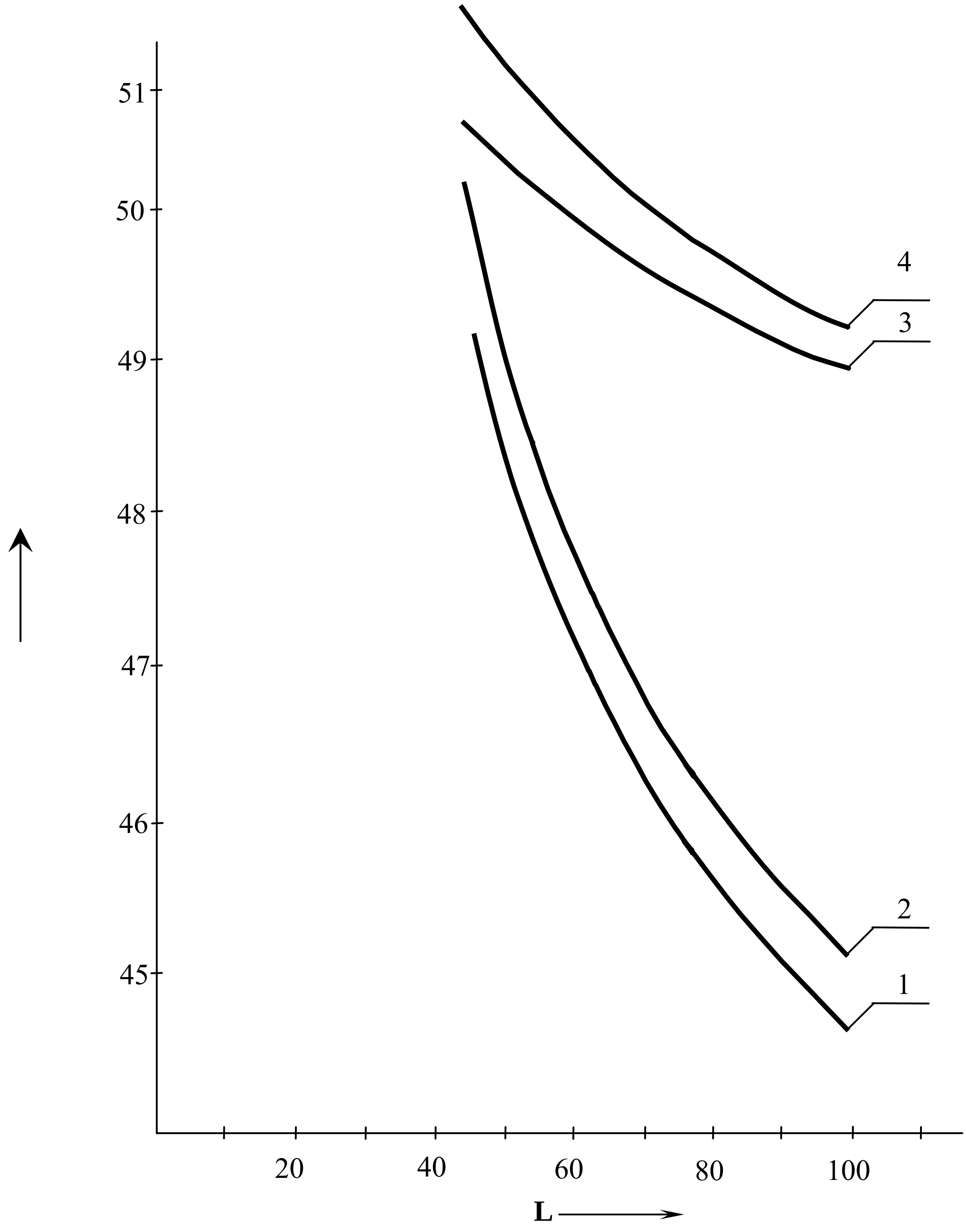

Figure.2: Dependence of Signal Security on the length of Equivalent cable section

3 Results and Conclusion

The received above expressions for calculation the co-directional stream and signal security could be used for designing the fiber optics system of transfer and definitions the numbers of optical isolators. And we can conclude that:

- To calculate the co-directional stream, it is expedient to consider the losses caused by reflections from heterogeneities.
- In spent and subsequent researches it will be shown that placing the valves at the end of equivalent cable section can lead to rather appreciable security reduction from co-directional stream, however this case need a separated study .
- Security from co-directional stream which caused by waves transformation in Anisotropic fiber optic system of transfer could be a subject for further research

References

[1] G. Keiser, *Optical Fiber Communications*, 4th edition, Mc Graw-Hill, 2008.

[2] O.V. Iiorgach, A.P. Zayats, Losses on the Non-uniform Optical Fiber Cables, Foto- Electron, 11 (2009), 61 - 64.

[3] C.E. Peter, Effect of Production Process on the Optical Fiber Properties, Electrical communication Journal, 2 (2008), 27 - 32.

[4] L.L. Ploshai, V.P. Felemonov, The Requirement to Optical Connectors, Electrical communication Journal, 12(1998), 33-39.

[5] V.B. Katec, I.E. Ruden, Analysis the Installation Process Fiber Optic Cables, Telecommunication Journal, 2(1997), 58-64.

[6] M.Y.AL-Gawagzeh, A.Y. Hendi, Analysis of Opposing Stream Effect on the Non-Uniform Optical Fiber Communication Lines, WSEAS Transactions on Communications, 7(2008), 490-494.

[7] V.O. Chernov, Protection from Passing Stream in fiber optic System of Transfer, Electrical Communication Journal, 2(2004), 112-119.

Received: February 15, 2014