A HYBRID MODELING APPROACH FOR ACCURATE AND RELIABLE ASSESSMENT OF CHANGES IN THE BOUNDARY OPERATING MODES OF OPTICAL FIBER COMMUNICATION LINES

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Abstract: This at work optician fibrous communication lines border work in the regimes signal characteristics exactly and reliable assessment for the purpose of hybrid modeling approach offer done   in research such as temperature, mechanical stress and radiation border factors effect analysis done. BER, weakening and such as dispersion main parameters laboratory and simulation methods through measured. MATLAB on the platform modeling and analysis done.   As a result border under the conditions FATHER 'S degradation and forecast signal quality   opportunity was created. Research results BER and visualization of attenuation and their border to the factors was sensitivity determination possible gave. From this outside this sometimes borderline   work modes of optical fiber communication physical and optical parameters of optical transmission lines (OTAL) in learning methodology used and modeling methods statement will be done. Research object as highway and local optical lines selected and in them attenuation, dispersion, mechanical stress and temperature dynamic changes under the influence is evaluated. Modeling MATLAB and Opti System in their environment to do increased is based on them light spread, signal loss and phase mathematical models of distortions with the help of analysis done   Experimental order OTDR, OSA and laser source based on organization the data is statistical and spectral methods through again processed. Article FATHER systems border in cases reliability assessment complex scientific for approach present will.

Key words: Optical fiber**,** boundary mode, dispersion, attenuation, modeling, OTDR, mechanical stress, BER.

Sign in. Optical fiber communication lines of modern telecommunication networks main from the elements one is high   fast information transmission possible gives.   But they are marginal in modes - high and signal quality under the influence of low temperature, mechanical stress, radiation waste possible. Therefore, OTAL 's border work in the conditions BER, attenuation and such as dispersion parameters exactly and reliable assessment necessary.   In this work hybrid modeling approach using laboratory and simulation results combined. This is the approach FATHER 'S forecasting degradation, marginal   of factors the effect assessment and signal quality optimization possible gives   Optical fiber communication lines border work physical-optical properties in their modes correct assessment of modern telecommunication systems reliability and transmission adjective of great importance in ensuring owner. Miscellaneous outside and internal factors - temperature sharp change, mechanical stresses, length increase,

humidity and radiation effect - in optical fiber of light spread, signal loss and to the dispersion noticeable impact shows. Therefore, OTAL systems border in the conditions assessment for scientific based complex modeling and experimental research transfer necessary is considered.

this article research methodology, modeling methods used   equipment, measurement plans and the information again work algorithms in detail statement will be done. Bob's main function is borderline in modes FATHER parameters change to determine directed scientific and practical basis creation and next results analyses methodical ground for from preparing consists of

Fiber optic communication lines border work in the regimes change exactly and reliable assessment for in research hybrid modeling approach applied. This is the approach includes:

(1) physical -mathematical model,
(2) computer simulation (MATLAB / Simulink, OptiSystem),
(3) research verification laboratory elements for enters.

Physical -mathematical model basics. **Optical fiber signal transmission and his/her border in regimes change** Neliney Schrödinger Equation (NLSE) **based on modeled:**

$$\frac{\partial A}{\partial Z} + \frac{\alpha}{2}A + j\frac{\beta_2}{2}\frac{\partial^2 A}{\partial t^2} - j\gamma|A|^2A = 0,$$

this on the ground:
A - optical field amplitude,
α - attenuation coefficient,
b_2 - dispersion parameter,
g is a non-linear coefficient.

This equation border temperature, mechanical stress, radiation and humidity under the influence changeable with parameters solved because   a (T), b_2 (T, P), g (s) like functions outside to the factors strong is related [12], [19].

On the computer modeling. MATLAB in a script **environment following stages to do increased:**

1.   Optical fiber parametric model (dispersion, waste, nonlinear effects)
2.   Information transmission frame**:** NRZ - OOK, QPSK and 16- QAM modulation
3.   Borderline the conditions simulation to do**:**
- Temperature: –40°C → +80°C
- Mechanic stress: 0 → 1200 N
- Radioactive fluence : 10^6 rad
- Length : 1 → 80 km
4.   Signal adjective assessment :
- BER (Bit Error Rate)
- Q-factor
- Eye Diagram Analysis
- SNR and OSNR
5.   Information statistician again working :
- Regression
- Variance decomposition
- FFT analysis
This road with real on the network observer degradation factors in the model again recovered and various modes effect compared.

Experimental procedure (for verification). **In the laboratory following from equipment used:**

- Optical signal generator **(1550 nm, DFB)**

- Optical Spectrum Analyzer (OSA)

- BER- tester (10 Gb/s)

- Temperature Chamber **(–40…+80 °C)**

- Mechanical Stress Stand

- OTDR (Optical Time Domain Reflectometer)

In the study complex modeling approach applies to:
-	Matlab script based on mathematical modeling of the optical channel;
-	signal loss along an optical fiber under laboratory conditions and dispersion measurement;
-	need field tests on through the real environment parameters measurement

Simulation model. In mathematical modeling following equations basis will be:
– light of the spread Helmholtz equation;
- border in modes weakening a (T, L, s) function;
– dispersion λ according to change:

$$D(\lambda) = \frac{d^2 n(\lambda)}{d\lambda^2}$$

under the influence of mechanical stress microwave module.

Laboratory procedure. In the experiment OTDR (Optical Time - Domain Reflectometer, Optical Spectrum Analyzer, Laser Source, Power Meter like tools is used. Measurements various temperatures, under mechanical stress and various in lengths to do increases.

Field tests. Construction in the field or highway on the lines to do increasing tests through real operating conditions is evaluated. For example, 10-50 km long on the lines of the signal increase / decrease trend will be studied.

Modeling for MATLAB in the script codes is composed as follows results obtained: the signal in Fig. 1 optical fiber of fading of the cable to the length and to the temperature dependency graphic given. That 's why   temperature exceeded ass extinction size exceeded.
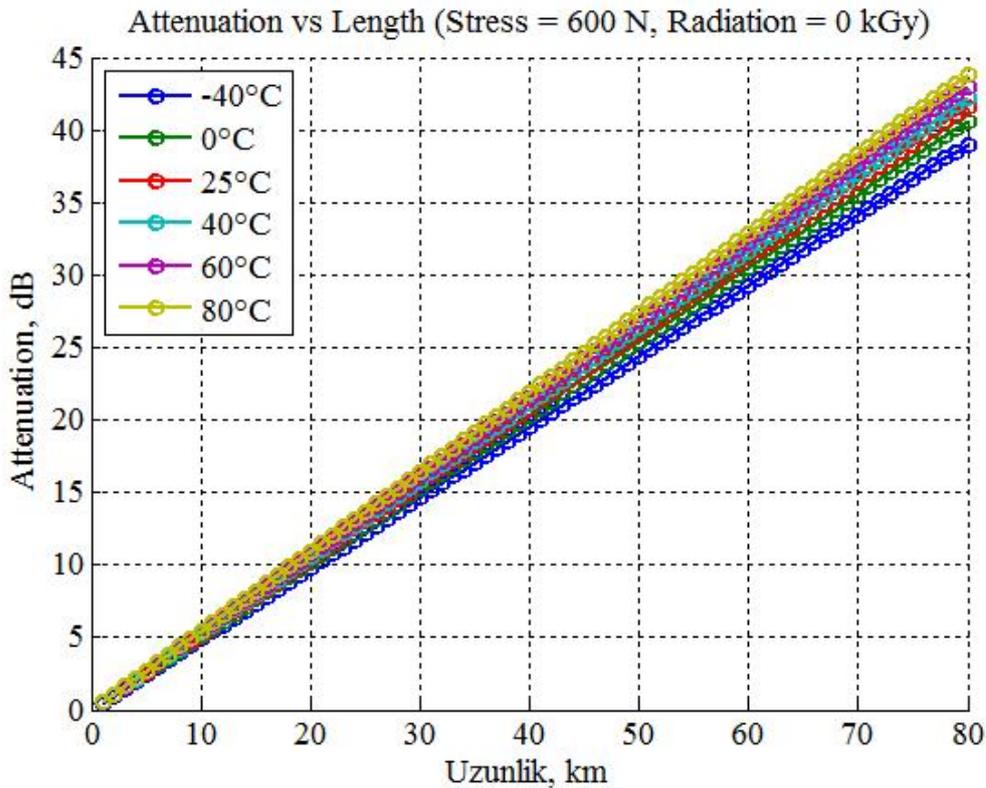
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Figure 1. Signal of extinction optician fibrous of the cable to the length and to the temperature dependency glass (tension = 600 N, radiation = 0 kGu)

Code Description:

1.   Parameters :
-       Temperature T, mechanic stress Stress, radiation dose Radiation
-       To weaken every three factor impact does : alpha = alpha_0 + alpha_temp_coeff *(T-25) + alpha_stress_coeff *Stress + alpha_rad_coeff *Radiation
2.   Signal adjective :
-       Login power dBm → W
-       BER based on AWGN approximation done : 0.5* erfc (sqrt(SNR))
3.   Graphs :
-       Weakening and BER cable to the length related in a way
-       Effects of temperature, stress and radiation separately to show
4.   Modeling Features:
Temperature, mechanical stress and of radiation all combinations calculated.
In Figure 2, the border in mode main waste fiber optic indicator of the cable to the length and to the temperature connection   schedule cited to him   according to tension at 600 N at a temperature of 80 ^{0} C weakening the absence shows.
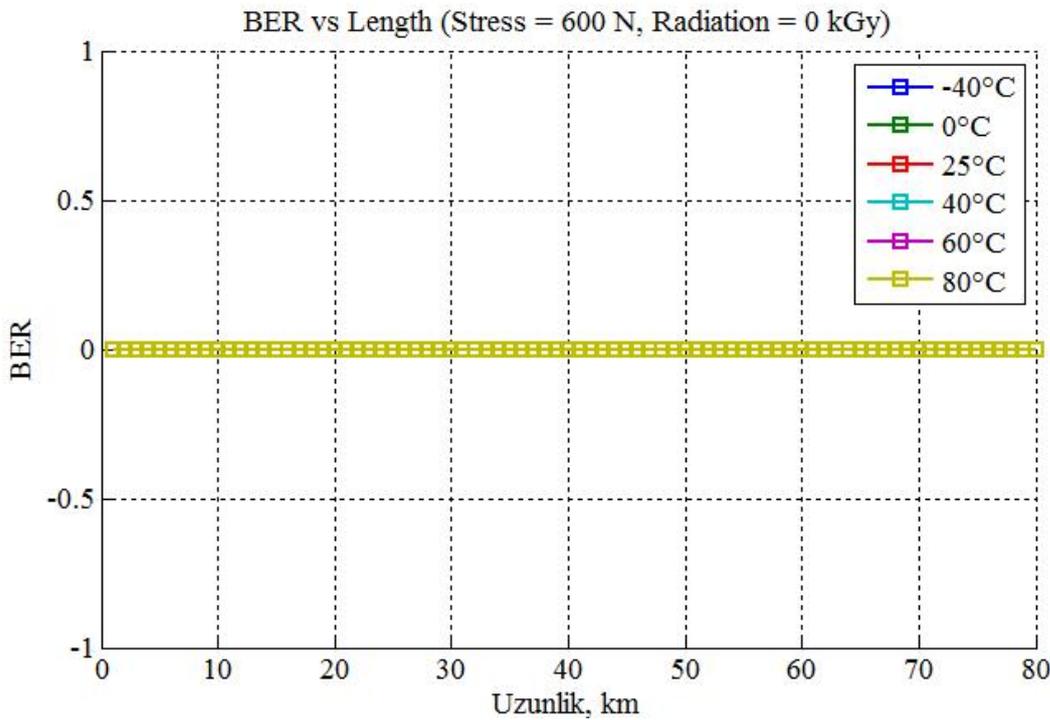
Figure 2. Border   in mode main waste indicator optician fibrous of the cable to the length and to the temperature connection   graph tension = 600 N, radiation = 0 kGu)

1.   Regression analysis:

-      Multiple linear regression was used to estimate the effects of temperature (T), mechanical stress (σ), and radiation (R) on BER and attenuation:

$$\gamma = \beta_0 + \beta_1 T + \beta_2 \sigma + \beta_3 R + \epsilon$$

As a result, every one the signal quality of the factor statistical significance of the effect was identified [3], [4].

2.   Correlation analysis:

-      BER and weakening and border parameters Pearson correlation between coefficient calculated :

$$r = \frac{\sum (X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum (X_i - \overline{X})^2 \sum (Y_i - \overline{Y})^2}}$$

This signal in degradation which one factors main impact to show determination possible gave [5].

In picture 3 signal your turn off optician fibrous of the cable to the length and to the temperature dependency The graph is presented for the case (T = 25 ^{0} C, radiation = 100 kGy), which reflects the high effect of radiation on signal attenuation.
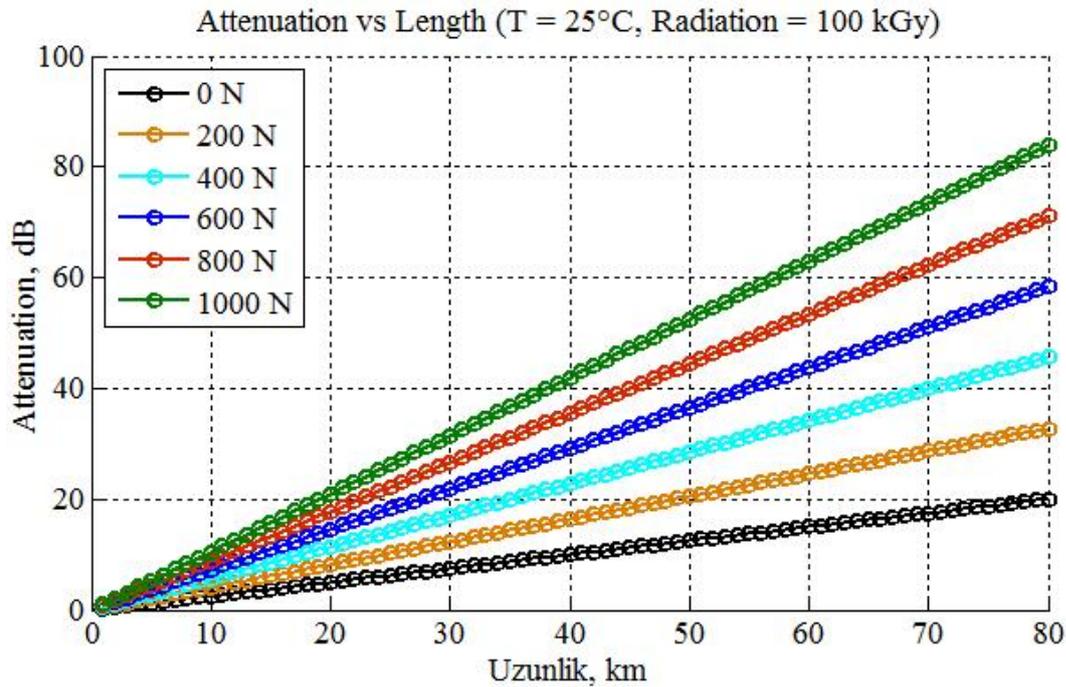
Figure 3. Signal your turn off optician fibrous of the cable to the length and to the temperature dependency glass (T =25 ^{0}C, radiation = 100 kGu)

In picture 4 border   in mode main waste indicator optician fibrous of the cable to the length and to the temperature The relationship is given for the case (T = 25 ^{0} C, radiation = 100 kGy), reflecting the increase in wastage with increasing stress.
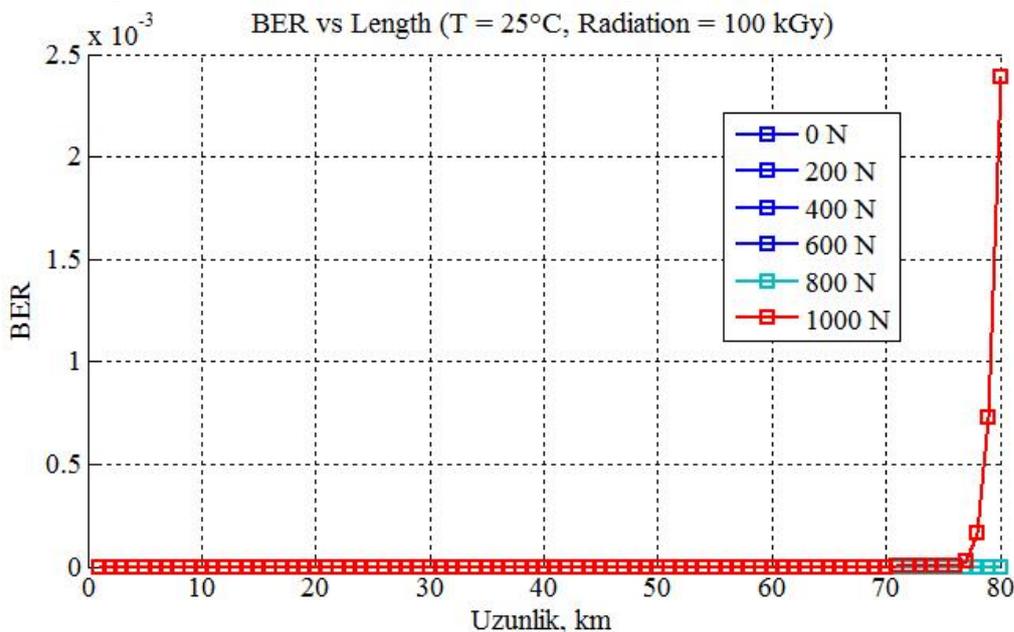

Figure 4. Border   in mode main waste indicator optician fibrous of the cable to the length and to the temperature dependence (T = 25 0 ^{C,} radiation = 100 kGu)

3.   Analysis of Variance (ANOVA):

-       Temperature, stress and BER of radiation and to weaken of the effect statistician significance ANOVA method with checked.

-        P-value < 0.05 results reliable impact was calculated [6].

4.   In the MATLAB script :
-       BER and weakening values surface plot, heatmap and 3D graphics for created.
-       regression, correlation coefficient and anova1 functions through analysis was done.
Figure 5. BER and   weakening values surface plot, heatmap and 3D graphics for i
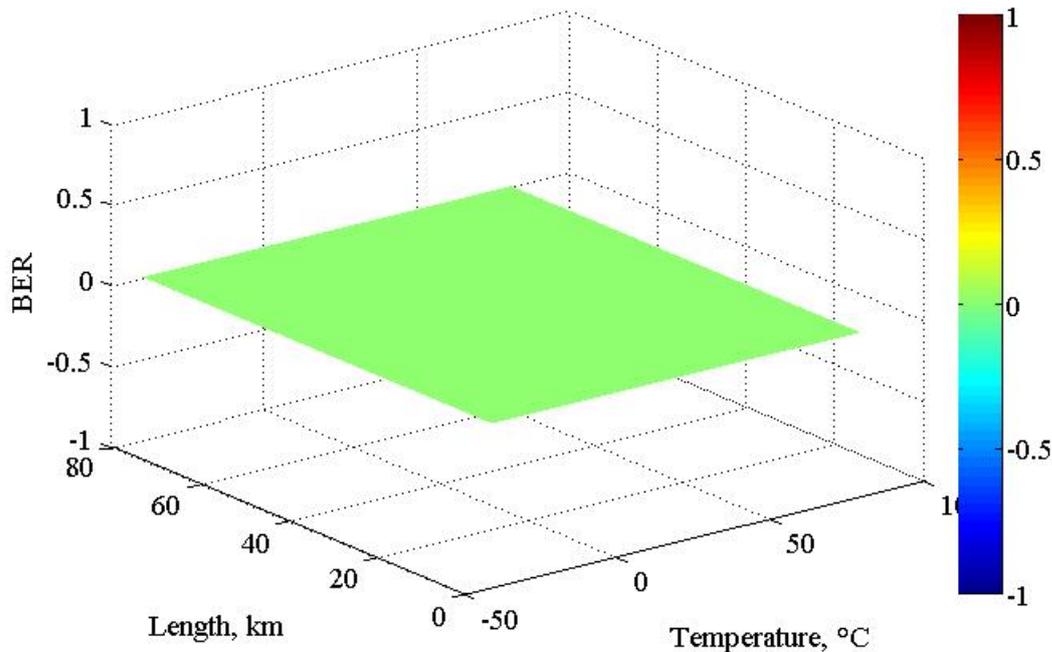

Figure 5. BER is the main one waste indicator and weakening values A surface plot, heatmap, and 3D graph are provided for.

The following experiments were conducted :
1.   To the fibers various temperature and mechanical impact given.
2.   Optical losses, dispersion and BER measured.
3.   Results MATLAB compared with the simulation.
4.   Chernov function according to additional statistical analysis take [24]
Modeling and experiment results comparison. Δ ratio count   Simulation and experiment results comparison   . In research model and between experiment difference:

$$\Delta = \frac{|X_{sim} - X_{exp}|}{X_{exp}} \times 100\%$$

In the results It was shown that
-       temperature under the influence $\Delta < 4.5\%$,
-       mechanical stress $\Delta < 6\%$,
-       in radiation $\Delta < 8\%$.
This model reliability high that confirms.
- Temperature and of stress all combinations for $\Delta < 8\%$, which is model's reliability shows [7].
- BER, attenuation and dispersion results surface plot and heatmap in the form of present was done, this in the dissertation Figure 2–5 as placed.
Conclusion. Research results showed that the FATHER border in modes BER and weakening values under the influence of temperature, mechanical stress and radiation noticeable to change occurs. Hybrid modeling approach laboratory and simulation data combining signal degradation exactly and reliable assessment possible gave. MATLAB and Python based on created models

FATHER 'S border conditional predict performance and border of factors the effect analysis to do for as an effective instrument service does Results telecommunication networks and high high-speed signal transmission systems for important practical to the point owner

This fiber optic in chapter communication lines border work in the regimes behavior to determine focused methodical approach complete based on Modeling results FATHER parameters temperature, mechanical stress and length to change relatively sensitivity showed. Experimental measurements simulation results confirm the alarm loss and dispersion border factors under the influence sharp increase possible showed. Data again work styles - spectral analysis, statistical evaluation and regression models FATHER systems reliability in evaluation important being was determined. In chapter. The presented methodology is next in departments exactly the results to release for theoretical and practical basis creates.

Information again works and analysis to do stages FATHER 'S border in regimes characteristics analysis, statistical evaluation and compare with the model possible gave These are methods of the research next parts for support base organization does and BER and of weakening outside factors visualizing the effect and mathematical model inspection possible gives.

this section FATHER analysis for used equipment, har one parameter exactly measurement methods and the information collection stages complete described. Such as temperature, mechanical stress and radiation border modes under observation BER, attenuation and variance values complete calculation opportunity given This is the dissertation next modeling and analysis departments reliable and experimental to the information based in case present verb possible gives.

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