Design and Simulate an Attenuator for Multi Types Optical Fiber Using Neural Networks

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ABSTRAC

The laser signals are generates in a specific power and polarity level by the sender device, and the optical fiber can't carry this signal as its. The attenuator is designed to overcome this problem by minimizing the power of the signal and tuned the optimal parameters which leads to suitable media with minimum error. In this paper; a proposed method has been designed and simulated by the MATLAB 2018a software to select the desired attenuator for the given optical fiber link using neural network NN, nntool. Four effected variables were selected as an input for the system which are: (Type of the Fiber optics, Distance, Signal power and Polarity), where only two output selected to be the goal of study which are: (Attenuator type and Attenuator parameters). The performance of the proposed method reached to 90% with error ratio 10-2 according to simulation program. The signal will be in its optimal case in the fiber media after the smart attenuator because its ability for tuning best parameter and type of device selected.

Keywords:- Optical fiber, Attenuator, Neural networks and Transmission line.

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I. INTRODUCTION

Attenuators are passive devices. It is convenient to discuss them along with decibels. Attenuators weaken or attenuate the high-level output of a signal generator, for example, to provide a lower level signal for something like the antenna input of a sensitive radio receiver. Fig. 1 below show the most famous type of attenuator, which are T and Pi [1].Optical attenuators are used in optical systems as power limiters and discriminators and are regarded as one of the most important optical components in a system network [2].

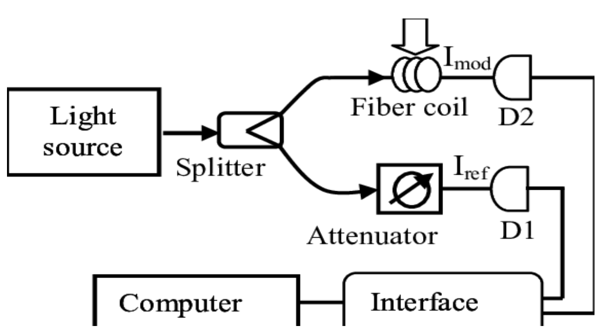

Fig. 1: The attenuator place at the optical link

The core offset and the mode-field mismatch at the two splicing points between the single-mode fiber "SMFs" and the eccentric core single-mode fiber "ECSMF" mainly cause the attenuation. Accordingly, the attenuation, α, at wavelength λ can be approximately given as [3]:

$$\propto = -20 \log \left\{ \frac{n_g(\lambda)}{n_s(\lambda)} \left| \frac{\iint E_s(\lambda) E_E^*(\lambda) dA}{\iint |E_E|^2 dA} \right| \right\} \qquad \ldots(1)$$

where $n_S(\lambda)$, $n_E(\lambda)$ are the core refractive index of the SMF and the ECSMF, and ES(λ), EE (λ) are the electric field of the fundamental-mode fields of the SMF and the ECSMF, respectively. The refractive index is the main variables which is directly effect on the attenuation ratio. The proposed method in this work will force the operator to send data in a specific range of wavelength to overcome these problems.

The use of a fiber-based variable optical attenuator ensures the output optical mode and divergence is kept near constant for all attenuation values while profiting from the known high dynamic range, e.g. exceeding 40 dB for off axis configurations [4]. The fiber is coated with an UV cured polymer which has a high absorption in the mid-infrared. The coating acts as a cladding mode stripper, slowly absorbing any power coupled to the cladding along the length of the fiber. This increases the contrast ratio measured at the output of the fiber, while avoiding a spatially localized heating [5].

The equations for the nonlinear propagation of short pulses in optical fibers are usually expressed in the time domain. When fields of different frequencies propagate through the fiber the common practice is to write a distinct equation for each field component [6].

Many researchers try to solve the attenuation problem such as; conventional Opto-mechanical variable optical attenuators VOAs provide large attenuation range (>50 dB), but their low speed (∼1 s) limits the applications. Microelectromechanical Systems (MEMS) technology has been implemented to VOAs to achieve high performance and low cost [7–8]. The main problem in the MEMS is the operation temperature, which is low. The transmission speed and operation temperature were solved by the proposed method in this work.

II. METHODOLOGY

In the optical communication there are laser signal generated at the sender side which carries the data from one side to other [8]. The signal subject to many types of process during the link, so; at the receiver side must simple attenuator exists to eliminate the unwanted power from passing the link. Many users and companies used a simple attenuator which has a fixed parameter to maintain the signal after a while traveling distance. The NN were proposed in this paper to design a smart attenuator that re-arrange its parameter according to the current signal and other surrounding situations. The NN learning algorithm depends on the input and hidden layer in addition to types of training methods and the activation function for each neuron [9]. The inputs are first thing to be treated in the NN and how its nature number and what is the activation function which will serve the data for this input. Four effected parameters has been selected which are: (Fiber optics Type, Distance, Signal power and Polarity), where only two output selected to be the goal of study which are: (Attenuator type and Attenuator parameters).

The data must be represented by numerical form to construct the data set for the NN that will be used in the input and hidden layers.The feed forward back-propagation FFBP NN,which is used in this study,has a specific construction as shown in table 1:

Table 1: Neural Network parameters

Network type	Activation function	No. of hidden layers	No. of neurons
FFBP	LOGSIG	2	10

The NN will predict the attenuator type when the data arrived the proposed model, immediately will be worked in the optical network for the given parameters.

The data representation for the four inputs are done arbitrary by giving a range of numbers for each one of them, for example; the fiber cable type may be a single mode, multi-mode or photonic crystal fiber PCF. The system will be assigning a number for each type of the cable fiber (250 for the single mode, 500 for the multi-mode and 750 for the PCF) in this case the NN will know the cable type by its number. The same manner is applied for the rest of the inputs, there are multi-ranges of distance, in this study only three range are involved which are (< 1km, > 1km &< 10km, > 10km), three numbers represents these three levels (1000, 1005 and 1009). The signal power is depend on the sender and receiver situation, for example; three values were selected for case study in this research which are (-30dB, -50dB and -80dB) which are represent the signal power for the transmission link with lowest and biggest values. As mentioned earlier, the signal differs in its power, for this reason the range 0-30 represent the signal in optimum case, and 31-50 acceptable case while the other needs to more process for optimization. The three range of the signal power converted into (-30, -50 and -80) as an input for the 3rd NN port. The last data type is the polarity of the signal that may be shifted either by 90, 180 or 270 degree from the original signal. Table 2 below shows the data type for the input's parameter.

Table 2: The available data for the proposed mode

	Cable type	Distance	Signal power	Polarity
Case 1	250	1000	-30	90
Case 2	500	1005	-50	180
Case 3	750	1009	-80	270

The second step is the number of hidden layers and number of neurons which are determine the performance of the network. The number of hidden layers is determine through the type of the data, while the neurons numbers are determined according to demand accuracy. In this work, two hidden layers are determined according to the data input and decision required in determining the attenuator parameters. In the other hand, 10 neurons are fixed in the hidden layers to interconnect the 4-input with its weights and the output in the next and last step.

Finally; the output of the NN will be the decision of the study and the predicted values of the attenuator parameters. Two neurons for output in the NN, one of them will be the type of the attenuator and other one is the resistance values of the attenuator. As mention in the previous section, the attenuator has a two famous type which are (T and Pi) and each of them has a three resistances. The representation of the attenuator type in the NN has done by assigning the '0' for none attenuator required, '2' for the T type and '9' for the Pi type of attenuator.

After the preparation of the proposed model, now the system is ready for training and validating according to the main parameters which will be fixed. The proposed model, as explained previously, consist of 2 layers for hidden neurons and 4 input with only 2 output as shown in fig. 2 below which is constructed using MATLAB program.

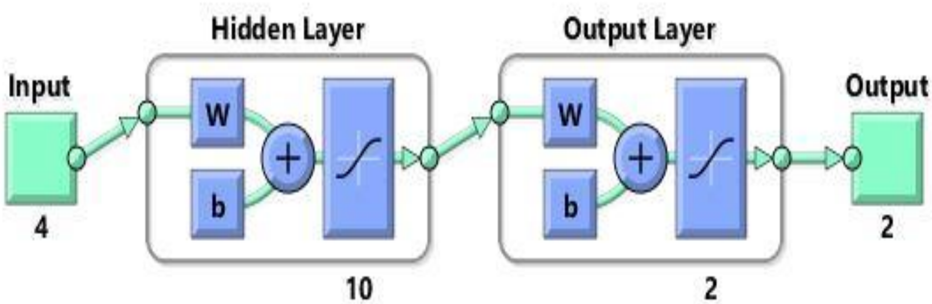

Fig. 2: The proposed network of the attenuator selector.

The data set were loaded for the model during construction process using the Microsoft excel and data array creator in MATLAB. Table 3 below shows some of the data set examples.

Table 3: Sample of proposed data set

Cable Type	Distance	Power	Polarity
250	1000	-30	90
250	1000	-30	180
250	1005	-30	90
250	1005	-80	180
250	1005	-80	90

250	1009	-80	270
250	1009	-50	180
250	1009	-50	270
500	1000	-30	90
500	1005	-30	90
500	1009	-50	90
500	1000	-80	90
500	1005	-30	180
500	1009	-50	180
500	1000	-80	180
500	1005	-30	270
500	1009	-50	270
500	1000	-80	270
750	1005	-50	90
750	1009	-50	90

The overall data set which can be involved in the system is reach to 1000, but for a case study about 30 sample used as a training pattern.

The target for the two outputs are selected depending on the instantaneous case of the input pattern, so; when the given values for the link requires the corresponding attenuator then system directly construct the model. Table 4 below shows selected target for the proposed system.

Table 4: Selected target for the system

Target 1	Target 2
0	0
0	0
0	0
2	10,10,10
2	15,10,10
2	15,15,10
2	15,20,20
2	15,20,15
9	11,10,10
9	12,11,15
9	20,11,11
9	20,10,13
9	30,10,15
9	31,10,16
9	16,16,20
9	16,17,12
9	15,15,08
9	14,13,12
9	14,14,15
2	10,18,12

III. RESULTS

The response of the NN can measured either using data logger or by using error rate and validation curves. in this paper, both of them are recorded for compare and simple to follow by the reader. Fig. 3 and 4 shows the response representing by the three important signs "Training, Test and Validation", and how the validation curves records an optimum value at different point with different epoch number.

Fig. 3 and 4 reflect the function of the artificial intelligent to optimize the performance of the system. The validation has been reduced from 168.93 in the first training to become 34.14 in the next one.

Table 5 below shows the output at a given stage during the training process, the values of the cable type and resistance values of the attenuator are closely with small error rate nearly 10^{-2}. The error rate can be calculated using tables 4 and 5 by subtracting one from other for each cell to find the corresponding error for the instant inputs.

For more details, graphical results were recorded and how the NN, which is proposed in this study, has a very low error ratio, as shown in fig. 5.

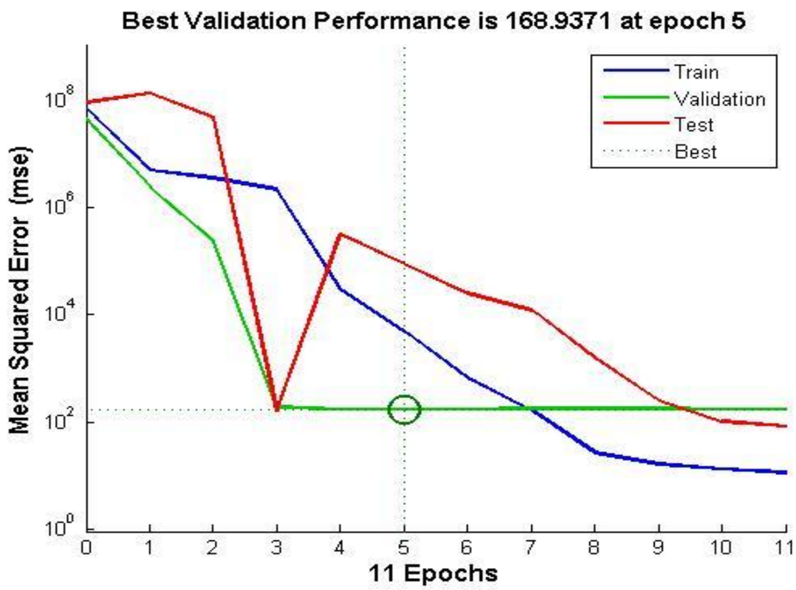

Fig. 3: System response with the validation and test curves, epoch 5.

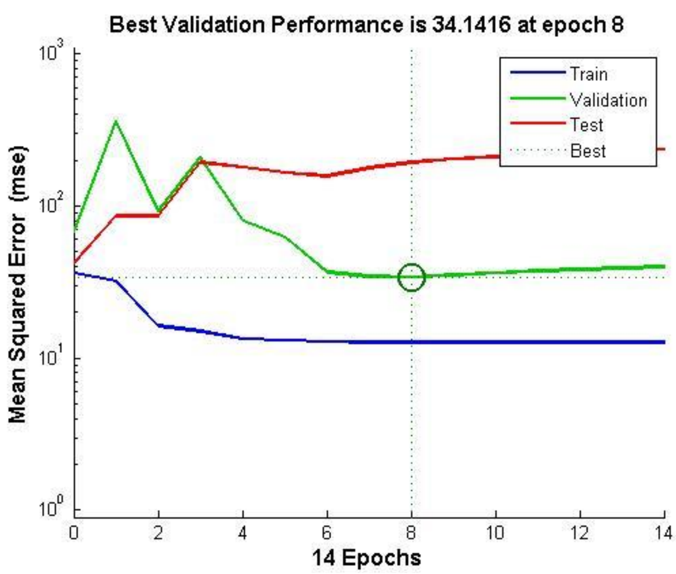

Fig. 4: System response with the validation and test curves, epoch 8.

Table 5: Output of the system with the real values of the attenuator type and resistor values

Cable type	Parameters
-0.21423	-1950.5587
-0.17962	-3812.9487
-0.07674	-15699.5894
1.9085	-5160.1562
1.8893	807.0439
1.9529	-519.6871
1.9823	-471.2307
1.9537	5216.5933
8.8979	6098.5323
8.8191	-52567.2051
8.7932	5971.329
8.7628	604.7733
8.9641	67289.1142
8.9681	60247.3224
8.905	-10627.9884
8.9664	-50820.8042
8.9797	-97219.8299
8.8744	11804.2479
8.8711	3839.4502
1.7834	-53227.936

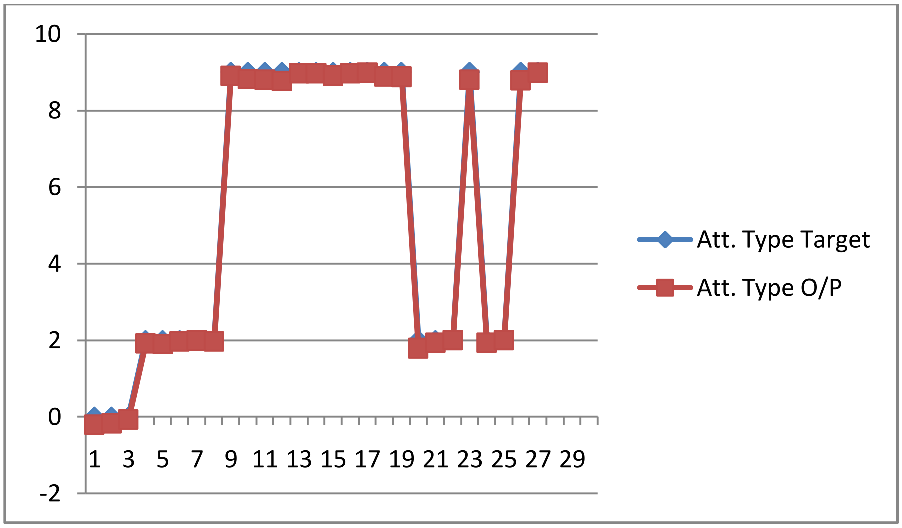

Fig. 5 Relation between attenuator type target and its real output.

The selected four inputs has a significant relation and they have different response with respect to iteration numbers, see Fig.6 below.Finally; the system state for the training and gradient response is recorded to shows how the validation crosses the x-axis satisfying the full optimization schemas, see Fig. 7 below.

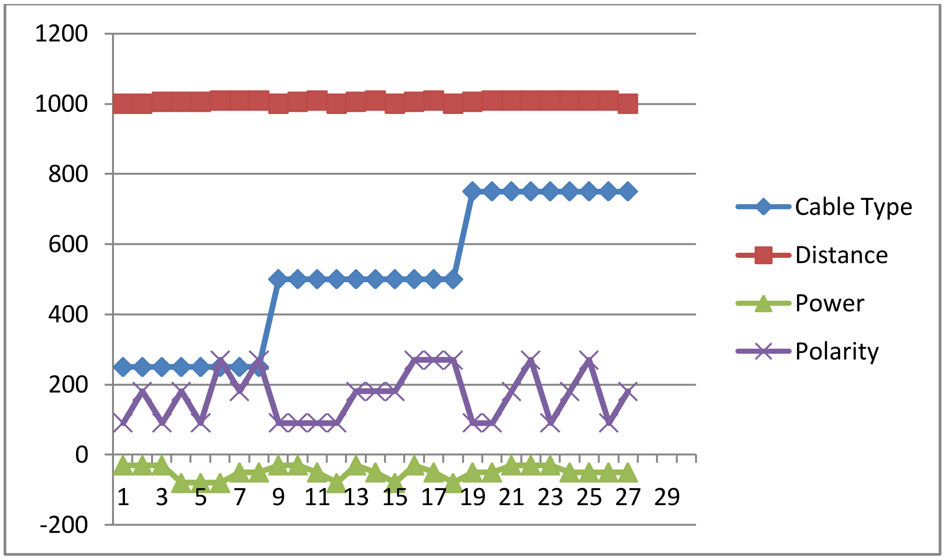

Fig. 6: Different shape of data input for the proposed system.

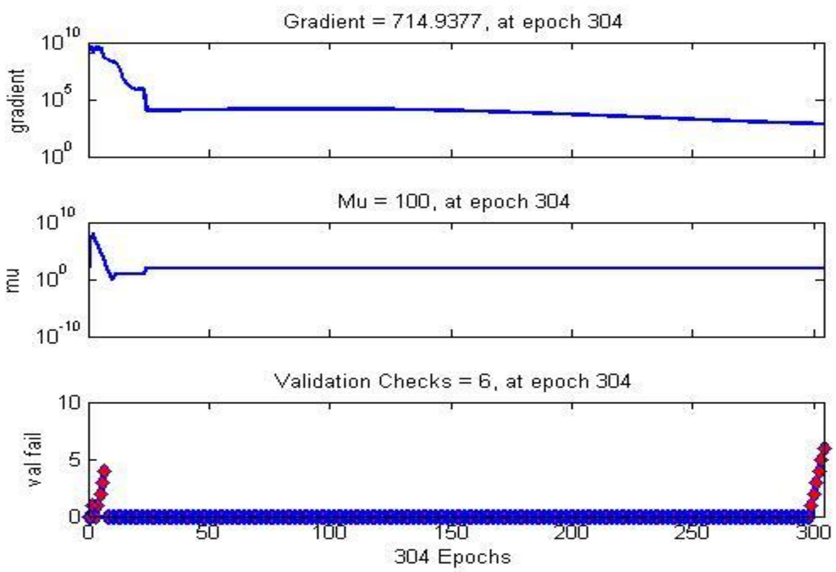

Fig. 7: system state and validation response

By reviewing the fig. 8, clear to see that the validation is satisfying the zero ratio which prolonged to all input data set till last one.

CONCLUSION

The proposed model is flexible and can be used and modified for the optical fiber communication with all its types and for any distance allocated. The NN satisfy the selection and optimization issue during the attenuator selector and re-arranged parameters according to the incoming signals. The performance of the proposed method reached to 90% with error ratio 10-2 according to nntool model in the simulation program. The signal will be in optimal case in the fiber media after passing the smart attenuator because its ability for tuning best attenuator parameter and its type.

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