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PERFORMANCE IMPROVEMENT OF OPTICAL COMMUNICATION BY CALCULATING INSERTION LOSSES USING ARTIFICIAL INTELLIGENCE

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Abstract: *In modern optical communication system, the efficiency of system can be improved either by increasing the parameters value or by decreasing the losses. A fuzzy control system is a real time expert system, implementing a part of human operator's or process engineers expertise which does not lend itself to being easily expressed in differential equations but rather in situations / action rules. In telecommunication, insertion loss is the loss of signal power resulting from the insertion of a device in a transmission line or optical fiber and is usually expressed in decibel (dB). In this paper we are calculating the insertion loss using artificial intelligence the parameters of insertion loss is calculated using the models of fuzzy logic. MATLAB 7.0 versions is used to calculate the losses.*

Keywords: *Insertion Loss, Artificial Intelligence, Optical Communication.*

1. INTRODUCTION

Today, Optical fiber is the most common medium in a variety of applications. An optical communication system has many parts like a transmitter, which encodes a message into an optical signal, it also comprises of a channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal. The most common type of channel for optical communications is optical fiber, however, there are different types of optical waveguides used in communication systems, The transmitters in optical fiber links are generally light-emitting diodes (LEDs) or laser diodes. Infrared light, rather than visible light is used more commonly. The reason for using the same is because optical fibers transmit infrared wavelengths with less attenuation and dispersion. Information revolution implies that multimedia networks need high bandwidth for real time communication services. At present, optical fiber is the only transmission medium offering such large bandwidth with low loss communication links. One of the foundations of this information society is high capacity optical fiber communications, which has been one of the fastest growing industries since the 1980s and is the key technology to fulfill the demands for bandwidth for broadband systems. The early optical fiber had a very high attenuation up to 1000 dB/km and could not be used for commercial fiber optical communication systems. In 1970, the scientists at Corning Glass Works were successful in producing a fiber with 20 dB/km loss which opened the doors for optical fiber communications. Now a day, the optical fibers with losses up to 0.2 dB/km are commercially available.

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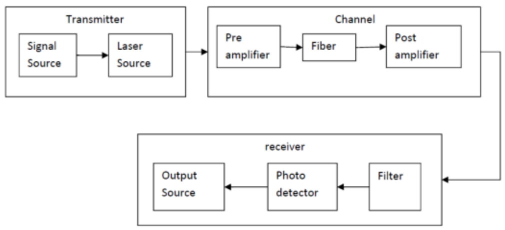

Figure 1: Block diagram of fiber optics system

1.1 Insertion Loss

An **optical fiber** (or **optical fibre**) is a flexible, transparent fiber made of high quality extruded glass (silica) or plastic, slightly thicker than a human hair. It can function as a waveguide, or "light pipe",[1] to transmit light between the two ends of the fiber.[2] The field of applied science and engineering concerned with the design and application of optical fibers is known as **fiber optics**. Optical fibers are widely used in fiber-optic communications, which permits transmission over longer distances and at higher bandwidths (data rates) than other forms of communication. Fibers are used instead of metal wires because signals travel along them with less loss and are also immune to electromagnetic interference. Fibers are also used for illumination, and are wrapped in bundles so that they may be used to carry images, thus allowing viewing in confined spaces. Specially designed fibers are used for a variety of other applications, including sensors and fiber lasers.

Optical fibers typically include a transparent core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by total internal reflection. This causes the fiber to act as a waveguide. Fibers that support many propagation paths or transverse modes are called multi-mode fibers (MMF), while those that only support a single mode are called single-mode fibers (SMF). Multi-mode fibers generally have a wider core diameter, and are used for short-distance communication links and for applications where high power must be transmitted. Single-mode fibers are used for most communication links longer than 1,000 meters (3,300 ft).

Under normal conditions, all materials absorb light rather than emit it. The absorption process can be understood where the energy levels E 1 and $E2$ correspond to the ground state and the excited state of atoms of the absorbing medium. If the photon energy $h\nu$ of the incident light of frequency ν is about the same as the energy difference $Eg = E2-E1$, the photon is absorbed by the atom, which ends up in the excited state. Incident light is attenuated as a result of many such absorption events occurring inside the medium.

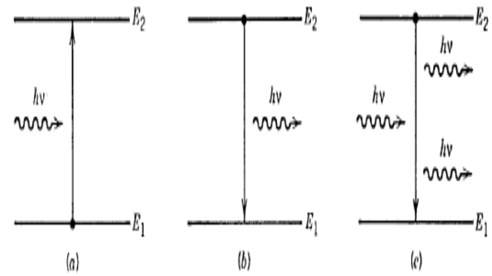

Fig 2. Three fundamental processes occurring between the two energy states of an atom: (a) absorption; (b) spontaneous emission; and (c) stimulated emission

The excited atoms eventually return to their normal "ground" state and emit light in the process. Light emission can occur through two fundamental processes known as *spontaneous emission* and *stimulated emission*. In the case of spontaneous emission, photons are emitted in random directions with no phase relationship among them. Stimulated emission, by contrast, is initiated by an existing photon. The remarkable feature of stimulated emission is that the emitted photon matches the original photon not only in energy (or in frequency), but also in its other characteristics, such as the direction of propagation. All lasers, including semiconductor lasers, emit light through the process of stimulated emission and are said to emit coherent light. In contrast, LEDs emit light through the incoherent process of spontaneous emission.

2. FUZZY INFERENCE SYSTEM

Basically a fuzzy inference system is composed of five functional blocks.

- A rule base containing a number of fuzzy if-then rules
- A database which defines the membership
- functions of fuzzy sets used in fuzzy rules
- A decision-making unit which performs the inference operations on the rules
- A fuzzification interface which transforms the crisp inputs into degrees of match with linguistic values
- A defuzzification interface which transform the fuzzy results of inference into a crisp output. referred to as the knowledge base. The steps of fuzzy reasoning (inference operations upon fuzzy.if-then rules) performed by fuzzy inference systems are :

1. Compare the input variables with the membership functions on the premise part to obtain the membership

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values (or compatibility measures) of each linguistic label. (This step is often called fuzzification).
2. Combine (through a specific T-norm operator, usually multiplication or min.) the membership values on the premise or vague, noisy, imprecise, or missing input information. Fuzzy logic's approach to control problems simply mimics how a person will make efficient decisions much faster.
Fuzzy logic was first invented as a representation scheme. It acts as calculus for uncertain or vague notions. It allows more human-like interpretations. Fuzzy logic has put reasoning in machines by resolving intermediate categories between notations like true/false, hot/cold etc. Fuzzy logic is a problem-solving control system methodology. It lends itself to implementation in systems ranging from small, simple, embedded micro-controllers to large, multi-channel, networked PC or workstation-based data acquisition control systems etc[3]. It can be implemented in software, hardware, or a combination of both. Fuzzy logic provides a simple way to arrive at a definite conclusion. Conclusion is based upon ambiguous or vague, noisy, imprecise, or missing input information. Fuzzy logic's approach to control problems simply mimics how a person will make efficient decisions much faster.
FL incorporates a simple, rule-based IF X AND Y THEN Z approach to a solving control problem rather than attempting to model a system mathematically. The FL model is empirically-based, relying on an operator's experience rather than their technical understanding of the system.

2.1 HOW DOES FUZZY LOGIC WORKS

Fuzzy Logic (FL) requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change-of-error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them. For example, a simple temperature control system could use a single temperature feedback sensor whose data is subtracted from the command signal to compute "error" and then time-differentiated to yield the error slope or rate-of-change-of-error, hereafter called "error-dot". Error might have units of degrees F and a small error considered to be 2F while a large error is 5F. The "error-dot" might then have units of degrees/min with a small error-dot being 5F/min and a large one being 15F/min. These values don't have to be symmetrical and can be "tweaked" once the system is operating in order to optimize performance. Generally, FL is so forgiving that the system will probably work the first time without any tweaking.

Once the power of an optical pulse is reduced to a point where the receiver is unable to detect the pulse, an error occurs. Attenuation is mainly a result of light absorption, scattering and bending losses. Dispersion spreads the optical pulse as it

2.2 Fuzzy Logic Toolbox

The Fuzzy Logic Toolbox extends the MATLAB® technical computing environment with tools for designing systems based on fuzzy logic. Graphical user interfaces (GUIs) guide you through the steps of fuzzy inference system design. Functions are provided for many common fuzzy logic methods, including fuzzy clustering and adaptive neuro fuzzy learning. The toolbox lets you model complex system behaviors using simple logic rules and then implements these rules in a fuzzy inference system. You can use the toolbox as a standalone fuzzy inference engine. Alternatively, you can use fuzzy inference blocks in Simulink® and simulate the fuzzy systems within a comprehensive model of the entire dynamic system.

2.3 Working with the Fuzzy Logic Toolbox

The Fuzzy Logic Toolbox provides GUIs to let you perform classical fuzzy system development and pattern recognition. Using the toolbox, you can develop and analyze fuzzy inference systems, develop adaptive neurofuzzy inference systems, and perform fuzzy clustering. In addition, the toolbox provides a fuzzy controller block that you can use in Simulink to model and simulate a fuzzy logic control system. From Simulink, you can generate C code for use in embedded applications that include fuzzy logic.

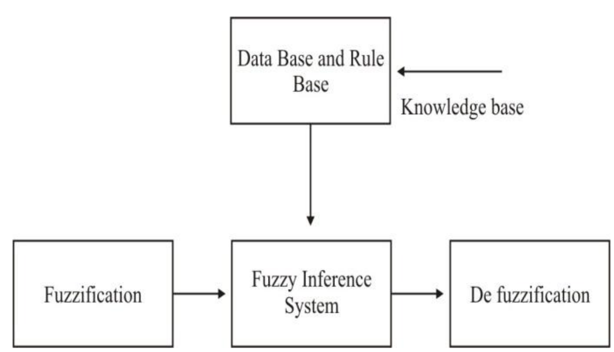

Figure 3: Block diagram of fuzzy logic System

Fuzzy systems (FS) are rule-based systems. It is based on fuzzy set theory and fuzzy logic. FS are mappings from an input space to an output space. FS allows constructing structures which are used to generate responses (outputs) for certain stimulations (inputs). Response of FIS is based on stored knowledge (relationships between responses and stimulations).

Knowledge is stored in the form of a rule base. Rule base is a set of rules. Rule base expresses relations between inputs of system and its expected outputs.

2.4 Building a Fuzzy Inference System

Fuzzy inference is a method that interprets the values in the input vector and, based on user defined rules, assigns values to the output vector [11]. Using the GUI editors and viewers in the Fuzzy Logic Toolbox, you can build the rules set, define the membership functions, and analyze the behavior of a fuzzy inference system (FIS). The following editors and viewers are provided.

FIS Editor: Displays general information about a fuzzy inference system. Key features of FIS Editor are :-

- Specialized GUIs for building fuzzy inference systems and viewing and analyzing results
- Membership functions for creating fuzzy inference systems
- Support for AND, OR, and NOT logic in user-defined rules
- Standard Mamdani and Sugeno-type fuzzy inference systems
- Automated membership function shaping through neuro adaptive and fuzzy clustering learning techniques
- Ability to embed a fuzzy inference system in a Simulink model
- Ability to generate embeddable C code or stand-alone executable fuzzy inference engines.

Membership Function Editor: Lets you display and edit the membership function associated with the input and output variables of the FIS.

Rule Editor: Lets you view and edit fuzzy rules using one of three formats: full English like syntax, concise symbolic notation, or an indexed notation.

Rule Viewer: Lets you view detailed behavior of an FIS to help diagnose the behavior of specific rules or study the effect of changing input variables.

Surface Viewer: Generates a 3-D surface from two input variables and the output of an FIS.

3. PROBLEM FORMULATION

Insertion Loss, expressed in dB is defined as

$$10*\log (Po/Pi)$$

where Po= Power Out and Pi=Power In.

There are 3 main causes of Insertion Loss: Reflected losses, Dielectric losses and Copper losses.

Reflected losses are those losses caused by the VSWR of the connector [10]. Dielectric losses are those losses caused by the power dissipated in the dielectric materials (Teflon, rexolite, delrin, etc.).Copper losses are those losses caused by the power dissipated due to the conducting surfaces of the connector. It is a function of the material and plating used.

4. SIMULATION

The two parameters of insertion loss is output power and input power. These are taken as two input : input 1 and input 2. Mamdani model is used for the evaluation of two parameters.

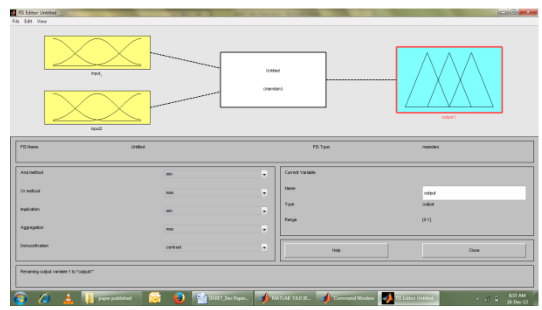

Figure 4: MAMDANI based fuzzy inference system

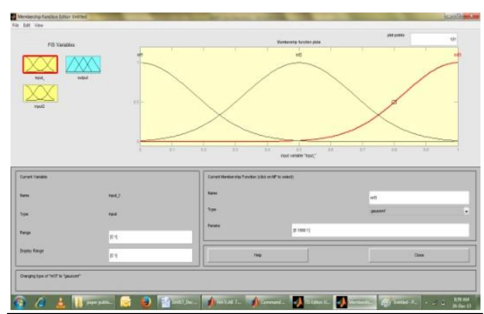

Figure 5: Non linear membership function for input1

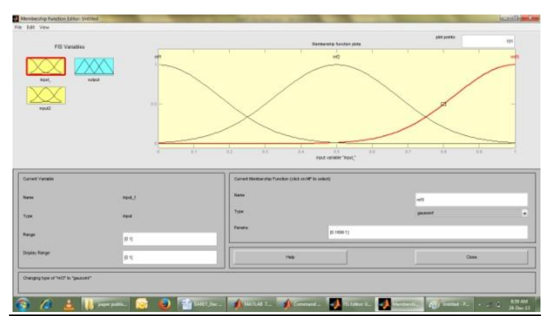

Figure 6: Nonlinear membership function for input-2

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A fuzzy set A $\in$X is characterized by membership function $\mu_A(x)$ represents the degree of membership, Degree of membership maps each element between 0 and 1. Figure 3. shows the membership functions of three fuzzy sets viz. "small", "medium" and "large" for a fuzzy variable input1& input2. The universe of discourse is all possible values of inputs.

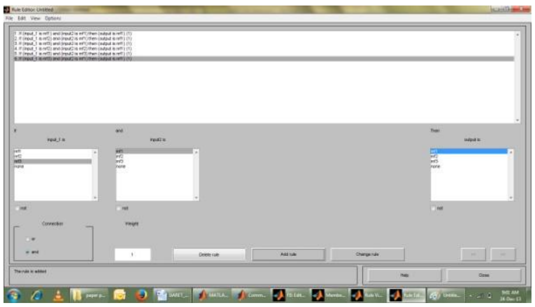

Figure 7: Non-Linear membership for output 1

Membership functions contain the membership values of elements in fuzzy set. Membership values can lie between 0 and 1.figure 1 and 2 shows the Gaussian function.

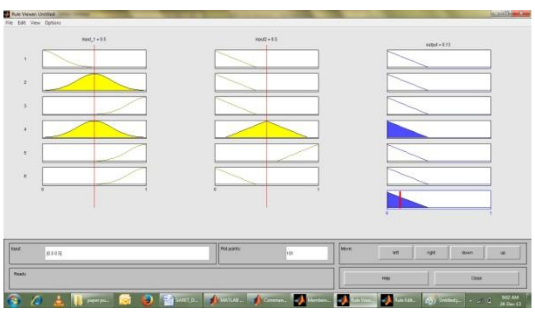

Figure 8: Rule Viewer

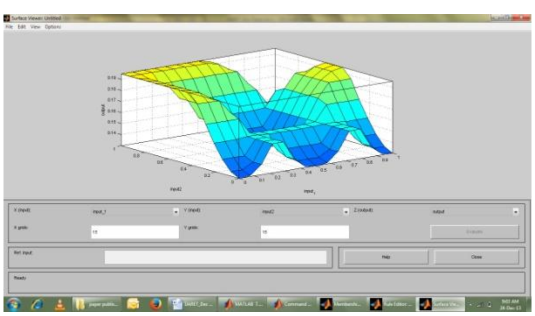

Figure 9: Surface Viewer

Figure 8 shows the rule based functions. In this we can add the rule according to AND and OR rules figure 9 shows the 3 dimensional view of the rule implementation.

5. CONCLUSION

In this paper we are trying to improve the performance of optical communication system by decreasing the losses. For MCU implementations, fuzzy TECH offers assembly code generation to ensure maximum computational performance using as little memory resources as possible. The fuzzy logic instructions use existing CPU logic to perform computations including addition, subtraction, multiplication, multiply-and-accumulate, and comparisons, so the speed and efficiency of fuzzy logic programs is greatly improved without increasing the cost of the MCU.

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