Optimization of Repeater Spacing for Undersea Fiber Optic Communication: Survey Paper

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Abstract— This paper survey shows the optimization of repeater spacing for undersea Fiber optic communication. Repeaters are used to transmit data over a long distance with high data rate transmission in undersea fiber optic communication. Repeater spacing in fiber optic communication is optimized by considering various parameters such as fiber attenuation, Stimulated Brillouin Scattering (SBS), Stimulated Raman Scattering (SRS), photodiode sensitivity and input power. This Survey concluded use of Erbium Doped Fiber Amplifiers (EDFA), solutions of threats affecting undersea Fiber optic cable and reduced the non-linearity. Also, obtained simulation results for various repeater spacing.

Key words: Optical Signal to Noise Ratio (OSNR), Erbium Doped Fiber Amplifier (EDFA), Repeater, Stimulated Brillouin Scattering (SBS), Stimulated Raman Scattering (SRS), Fiber nonlinearities

I. Introduction

Unpredictably by all people, submarine cables carry around 97% of all telecommunications around the world, whereas satellites count only 3% or lesser [1] Repeaters are generally used for Long distance undersea fiber optic communication to increase the signal capacity. Basically, when a signal travels for a long distance, its strength deteriorates and it will be inefficiently affected by noise. In order to avoid this, we deploy repeaters at regular intervals to boost the signal strength up. Survey also suggest use of use EDFA to reduce the loss due to optical - electrical conversion and vice versa [2]. So far 304 km distance of repeater has been reported [3]. One solution to this problem [To minimize the number of repeaters or to maximize the repeater spacing] is to increase the input optical power to high levels so that the signal reaches to the other end without any significant degradation in power of signal. Other complications such as Stimulated Raman Scattering (SRS), Rayleigh scattering, and Stimulated Brillion Scattering (SBS) must be taken into account .Soliton pulse is another solution to transmit data over a long distance. Soliton is a kind of pulse for which dispersion is cancelled out by its self-phase modulation, so it can maintain its shape for long distance transmission [4][5]. For a long haul communication system; after a certain distance, the Soliton pulse also gets attenuated even if it is not dispersed. So implementation of the amplifiers is needed in the transmission channel to boost up the power level of the Soliton pulse thus representing a bit of information to almost in a time interval of femto seconds and a message carrying capacity of Tb/s range can be achieved but still it has a lot of limitations [6][7]. This survey found primary reasons for increase in demand.

A preference for carrying circuit capacity on fiber rather than on satellite for major transoceanic routes. The low cost per circuit that can be achieved on cable. The high quality, reliability, and security of the service & the rapid increase in data services.

Prior to any decision for laying down a cable on the seafloor a geological and path survey must be undertaken. The work is done with the help of acoustic instruments such as echo-sounders and accurate Global Positioning System (GPS) and differential GPS. A cable route survey includes these three phases: the route study, the offshore route survey and the burial assessment survey [8]. In a submarine cable route survey, it is required to evaluate the following factors: cable safety, construction feasibility, future maintenance, operational reliability and cost.

Most of the damage is always caused by trawl nets, dredge and long anchors to the seabed [9]. Natural disaster like earthquakes and flooding can severe to submarine cables and cable station [10]. This survey suggest deployment of repeaters at regular intervals but, installation of repeaters add up the cost of communication and the spacing between them has to be increased in undersea fiber optic communication, the installation of repeater is an important concern since it is difficult to deploy underwater and the maintenance of such repeaters is a difficult and time taking task.

A. Influence of ASE

When light travels a long distances it picks up interruption called noise. In an optical amplifier if G is the gain of the amplifier the signal amplitude is multiplied with gain G times. But in case of optical fiber communication with the noise N_{in} , the signal picks up during its long travel. Which is amplified gain times with the required signal amplification the amplifier in turn insert its own additional noise. This is storyline in the real time optical fiber communication network.

Therefore the output noise $N_{out,}$ becomes greater than G times the input noise, Nout will be

$$N_{out} = G * N_{in} + \text{Amplifier's own Noise} \qquad (1)$$

Optical signal propagating through an optical fiber will be subjected to weakening as it travels very long distances before it reaches to the other end. Repeaters also along its path introduces its own noise. So the signal is degraded to a large value when it reaches the other end. This issue can also be expanded to WDM system [11] [12] [13]. So repeaters deployed at equal intervals to boost the signal level.

B. Fiber Nonlinearities

Fiber exhibits less attenuation at 850 nm, 1310 nm and 1550 nm based on the overtone [14] and also taking into account the non-linearity of the fiber at other wavelengths. So here, Survey suggest to optimize the repeater spacing in undersea fiber optic communication with the above parameters in mind. One possible method in this approach is to decrease the ASE and resulting increase in the optical signal to noise ratio (OSNR) [15]. Excess ASE is an unwanted parameter in any laser source [16] since it limits the maximum gain that can be achieved. Thus by considering all the above parameters tried to reduce the spacing between the repeaters.

C. SBS Threshold

One of the viable way to reduce the number of repeaters is to provide more power into the fiber but it may lead to Fiber non-linearity. Stimulated Brillouin Scattering decimate the dumping of power. So, phase control is being made to augment the threshold power [17] to be launched into the fiber. By increasing the SBS threshold and thereby feed in more power and in due course the spacing between the repeater can be large enough. Repeater spacing is most complex in the case of undersea repeaters taking into considerations the cost factor and the tediousness in installation and maintenance of the repeaters. It allows to release a reasonably high amount of power in the fiber, this helps us to attain the optical signal to noise ratio requirements and receiver sensitivity requirements based on square law detection [18] For the particular application, Since the dispersion effects are minimum at 1550nm wavelength we use the same [19]. we could set the max tolerable spectral width σ_λ in the optical source so as to maximize the power threshold.

$$P_{th} = 21 A_{eff} / g_B L_{eff} \quad (1+\sigma\lambda/\Delta V_B) \qquad (2)$$

From equation (1), concluded that it depends on the following parameters effective fiber length (Leff), Brillouin gain coefficient (gB), denotes the Brillouin gain width (ΔVB) effective cross section area (Aeff), polarization factor (b), and the source line width (Source) also, realize from the equation that Pth has to be increased so that SBS is pulled down. One aspect is to increase the effective cross sectional area of the fiber i.e., the fiber span is increased and the number of signals are increased. This leads to spectral broadening and Intersymbol interference (ISI). These are purely unwanted phenomena.

D. Major Threats affecting transmission and their correction

Major threats to a submarine cable are external impacts due to predominantly anchors and fishing gears. In order to minimize the risk of a cable tear due to a vessels' anchoring, a "Cable protection zone" or CPZ is established along the cable's path. In these areas activities that might damage or harm the cables are strictly regulated and controlled. In order to check the cable security regular surveys are envisaged. Telecoms and Governments use radar tracking systems to monitor the area around these cables. These technologies detects when a ship is getting dangerously close to a cable and can warn the vessel of its proximity. . If a cable breaks then they send repair ship and cable is lifted from seabed by special hooks (grapnel) and dragged onto the ship cable is spliced onboard joined with fresh cable sealed with watertight and anticorrosive covering. Other threats include natural hazards like earthquake/cyclone so to check cables damage periodic surveys are conducted for their maintenance.

II. OBJECTIVES

1) To maximize the distance between the repeater of undersea fiber optical network.
2) Studied Solutions of threats affecting undersea Fiber cable.

III. METHODOLOGIES

The methods that will be used it accomplished the objectives listed above can be divided into two distinct steps.

The steps are:

1) Analysis
2) Simulation

The first step will be to study existing literature available and also analysis the collected data. Select the suitable data and use in a concrete for improving their properties.

The second step is to simulate the results in Matlab to attain above results in an efficient manner.

IV. SIMULATION RESULTS

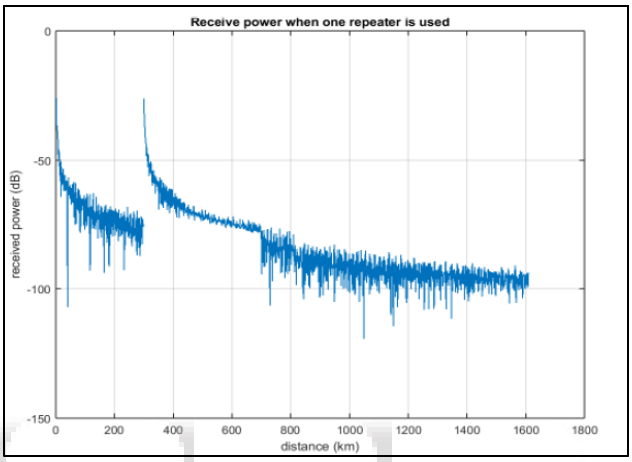

Fig. 1: Received power when one Repeater is used

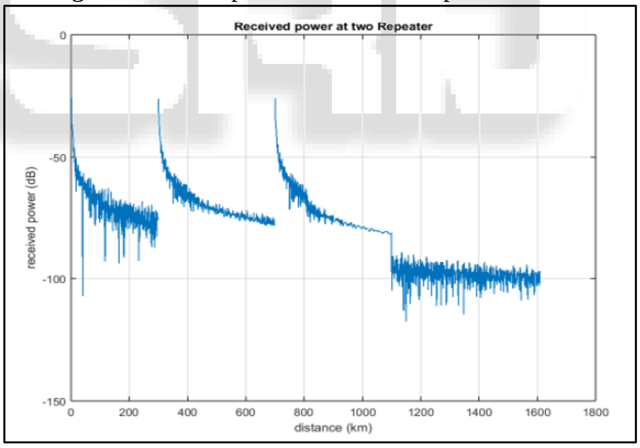

Fig. 2: Received power when two repeaters are used

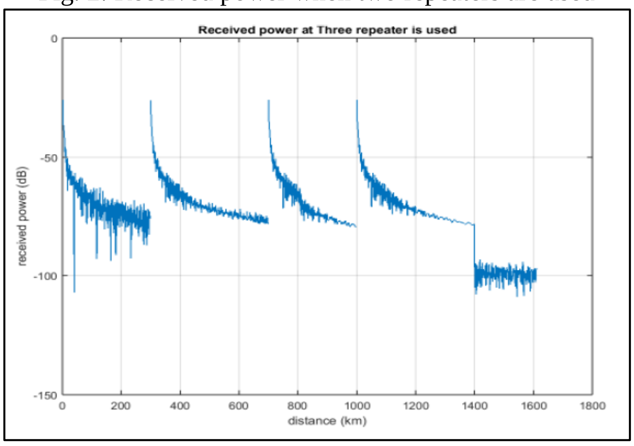

Fig. 3: Received power when three repeaters are used

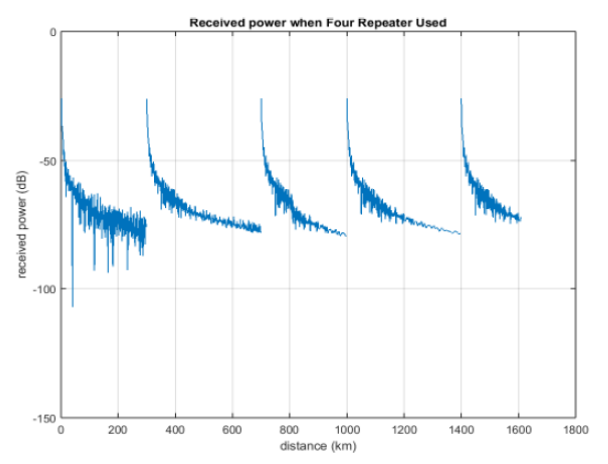

Fig. 4: Received power when four repeaters are used

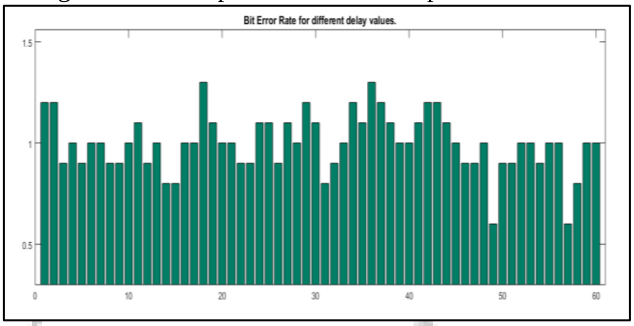

Fig. 5: Bit Error Rate For different delay times

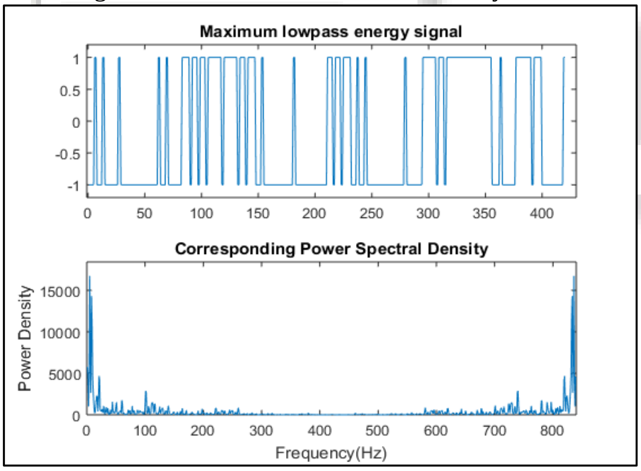

Fig. 6: Maximum low pass energy signal and its corresponding power spectral density

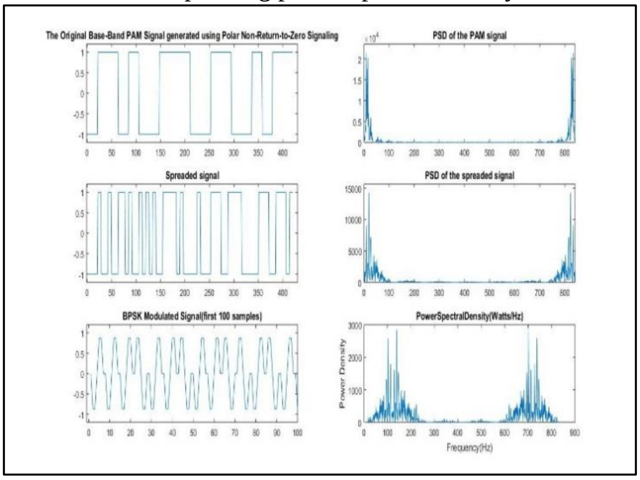

Fig. 7: Signals and their Power spectral density

V. RESULTS ATTAINED

No. of Repeaters	Distance between Repeaters (Km)
1	300
2	400
3	300
4	400

Table 1:

VI. CONCLUSION

This survey have been investigated to maximize the capacity of undersea fiber optic cable network by optimizing the spacing between the repeaters, we have tried to maximize the power threshold of SBS considering all the influencing factors and thereby backscattering is avoided. As all the parameters are interrelated so by taking one fiber nonlinearity i.e., SBS and its tradeoff with the input power, correspondingly increasing the input power to increase the Brillouin threshold. Thus results using simulation have proved that we succeed to optimize the repeater spacing in undersea more than 304 km. Fiber nonlinearities proves to be a major constraint in the optimization of distance between the repeaters. Also DWDM technology provides undersea fiber optic networks with two fundamental enhancements: increased capacity and greater network flexibility. Threats affecting fiber optic cable can be avoided if solutions mentioned above followed properly. Optimizing the distance between the repeaters leads to less maintenance and reduction in cost.

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