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THE EFFECT OF RAMAN PUMP ON SIGNAL TRANSMISSION OVER FIBER OPTICS CABLE

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ABSTRACT

Signal fading and attenuation are key issues in optical transmission over long distances (usually >100km). For example, a transmission link with a length of more than 100 kilometers on fiber optic cable will experience significant packet loss, detectable dropouts, and fluctuating attenuation. In essence, this will result in an unreliable and unusable transmission link. From the input, the optical signal passes through an Erbium Doped Fiber Amplifier (EDFA). With a Wavelength Division Multiplexer, the 1550nm signal is coupled with a 980nm pump laser. The signal and pump laser pass through a length of Erbium-doped fiber, and the EDFA uses the erbium-doped fiber as an optical amplification medium. The interaction with the doping Erbium ions amplifies the 1550nm signal. The interactions enhance the signal intensity by amplifying the weak optical signal to a higher power. The signal booster described above can only send signals for a distance of 100 kilometers. This research looked into the issues of massive packet drop and loss, as well as attenuation on the transmission path. The optical transmission signal was improved above 100km using the Dense Wavelength Division Multiplexing approach with the help of the Raman pump. This method helps to reduce transmission losses and boost signal intensity from one location to another. The optical transmission efficiency and performance were measured using BER. (Bit error rate, Optical Domain Reflectometer (OTDR), Network Monitoring System (NMS) and, signal to noise ratio (SNR) tests to confirm the optical strength of the transmission link.

KEYWORDS: Signal drop out, wavelength, Transmission path, NMS, EDFA, SNR, DWDM Raman Pump

INTRODUCTION

Telecommunication is defined as the electronic transmission of information across long distances; examples include voice, data, and video transmission. The examples given are broad terms that cover a wide range of information transmission methods and communications, including corded phones, mobile devices like cell phones, and microwave communication. Satellites, fiber optics, radio and television broadcasting, the internet, and telegraphs prior to the introduction of fiber optics cable, copper wire was widely used. (Wesley & Lazer, n.d.)

Sanjeev et al. (2016) conducted a statistical analysis on stimulated Raman scattering (SRS) crosstalk to investigate the influence of pulse walk-off in wideband WDM Raman amplification systems.

DWDM works by mixing and transmitting many signals at different wavelengths on the same cable at the same time.(Tate, 2018)

Available DWDM Channels in C and L band depending on channel spacing (Liqiang 185 et al, 2020)

The generation kinetics of optical noise in a silica single mode fiber (SMF) as a function of pump power variation in a counter pumped fiber Raman amplifier (FRA) were investigated experimentally (Georgi & Mykhailo, 2016).
A multi-objective particle swarm optimizer was used to create the configuration of pumping lasers of Raman amplifiers (Carmelo et al, 2012).

The diagram of a Raman Pump Amplifier (Miglani, 2016)

Ideally, optical transmission should deliver reliable and efficient bandwidth in transmission. However, they are bound by EDFA Amplifiers, which cover restricted distances and bring absorption, noise, and packet drop to the transmission channel, and therefore the entire system.

As a result, utilizing compact wavelength division multiplexing with a bidirectional RAMAN pump helped to reduce resistance and clear out noise, resulting in a robust optical transmission network.

METHODS

Network Monitoring System equipment (NMS) software, OTDR and power meter was used to design and simulate optical transmission.

1. Raman amplifier/pump is basically deployed to compensate for losses on fiber optic network link with longer span more than 100 – 120km (though subject EOM design)
2. The pump assists EDFA in balancing optical link power for better performance of the network.
3. Raman inject a high power (gain +dBm) into Rx leg of an optical fiber from upstream node and boost the attenuated receive power.
4. Raman pump is only compatible with installed standard SM fiber (G652D & G655).
5. For better performance of Raman Amplifier, functional AGC (automatic gain control) is require to manage appropriated gain/noise in the link.

The Raman pump and dense wavelength division multiplexing settings was set right as a result of the findings. The results are presented below.

Optical Time Domain Reflectometer

In general, losses occur in one form or another, or in all forms of communication systems. Defects and losses in optical fiber communication must be found and traced to improve the system's efficiency. Optical time domain reflectometry (OTDR) is a commonly used technique in optical fiber transmission systems for fault classification and localization. It is calculated how much of a probe pulse is dispersed back from a silica fiber. Due to the low backscatter of single-mode fiber at long wavelengths, very sensitive optical detection is necessary for optimal range performance. Testing and evaluation at many levels are required to ensure the availability and efficiency of fiber networks. Optical fiber testing methods include continuity, splice continuity, splice loss, fiber loss, fiber quality testing, splice reflectance, and connector testing, as well as loss measuring techniques such as splice loss measurement, fault location identification, and insertion loss.

Wavelength

a. There are wavelength ranges where the fiber performs best. An operational window is the name given to each range. These wavelengths were chosen because they best fit the transmission properties of available light sources with optical fiber transmission

b. There are wavelength ranges where the fiber performs best. An operational window is the name given to each range. As shown in the table below, each window is centered on the normal working wavelength.

c. These wavelengths were chosen because they best match the transmission properties of available light sources with the transmission qualities of optical fiber.

Interpretation and the parameters of OTDR

a. **Range**: in OTDR parameter determine distance that the OTDR can cover.

b. **Pulse:** Set the duration of each laser pulse emitted, pulse width allows OTDR to measure accurately and pulse width maximum is1.0ns.

c. **Acquisition time:** Set the time duration of averaging the measured of reflected light, the time OTDR acquires and average date point from the fiber under test.

d. **Length:** Length of the cable installed per route or to conduct test upon.

e. **Total loss:** Total loss on fiber cable measured at all event and it can be differentiated by maker (between two marker).

f. **Average loss:** Specifications of average loss on the fiber optics cable measured which is less or equal to 0.1db.

g. **Maximum Splice loss:** All the wavelength losses has their individual maximum losses etc. splice loss in 1310wavelenght cannot be more than 0.1-1db.

h. **Splice loss:** in 1550 wavelength cannot be more than 0.1-07db. So maximum splice loss is 0.05db (average)and the maximum connector loss is 0.5db.

i. **Optical Return Loss (ORL):** OTDR is used to measure ORL of fiber span and optical continuous wave reflectometer (OCWR), it is an instrument designed to specifically measure system and component ORL reflectance.

j. **High Resolution Acquisition:** Determines the location of event on a fiber with more accuracy, OTDR takes measurement of every 8meters along fiber spans.

k. **Indexing of Refraction (IOR):** is a value to calculate distance, if IOR is not known, it is used for setting to know the distance length of a cable.

l. **Rayleigh back scatter (RBS):** During propagation in fiber, some light is scattered in all directions, part of it is coupled into fiber in the backward direction and that is what is called RBS.

m. **Helix Factor:** is an information expected from manufacturer parameter, the parameters are refractive index, backscatter coefficient. This is used to confirm specification of fiber supplied to company to determine spec requested.

n. **Splice loss Threshold:** is guideline on loss to expect when testing optical fiber.

o. **End of Fiber Threshold:** optical pulse is launched by OTDR to a fiber under test are reflected back from end of the fiber via Fresnel reflection and then the aggregate averages of pulses are calculated. OTDR is connected to one end of fiber optic within a few seconds after pressing the start button and it will measure the overall loss, overall length and distance.

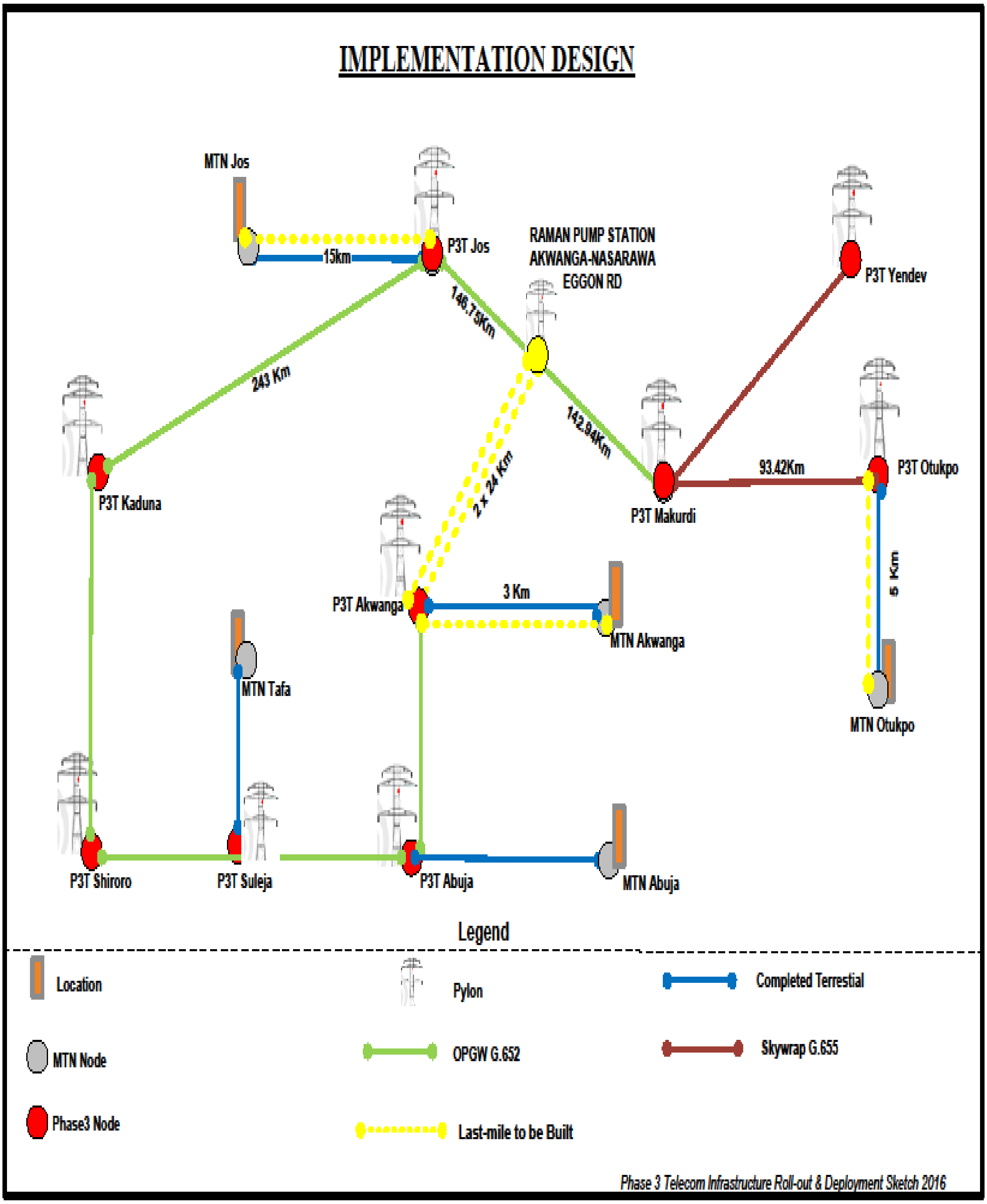


Figure: I Network implementation design

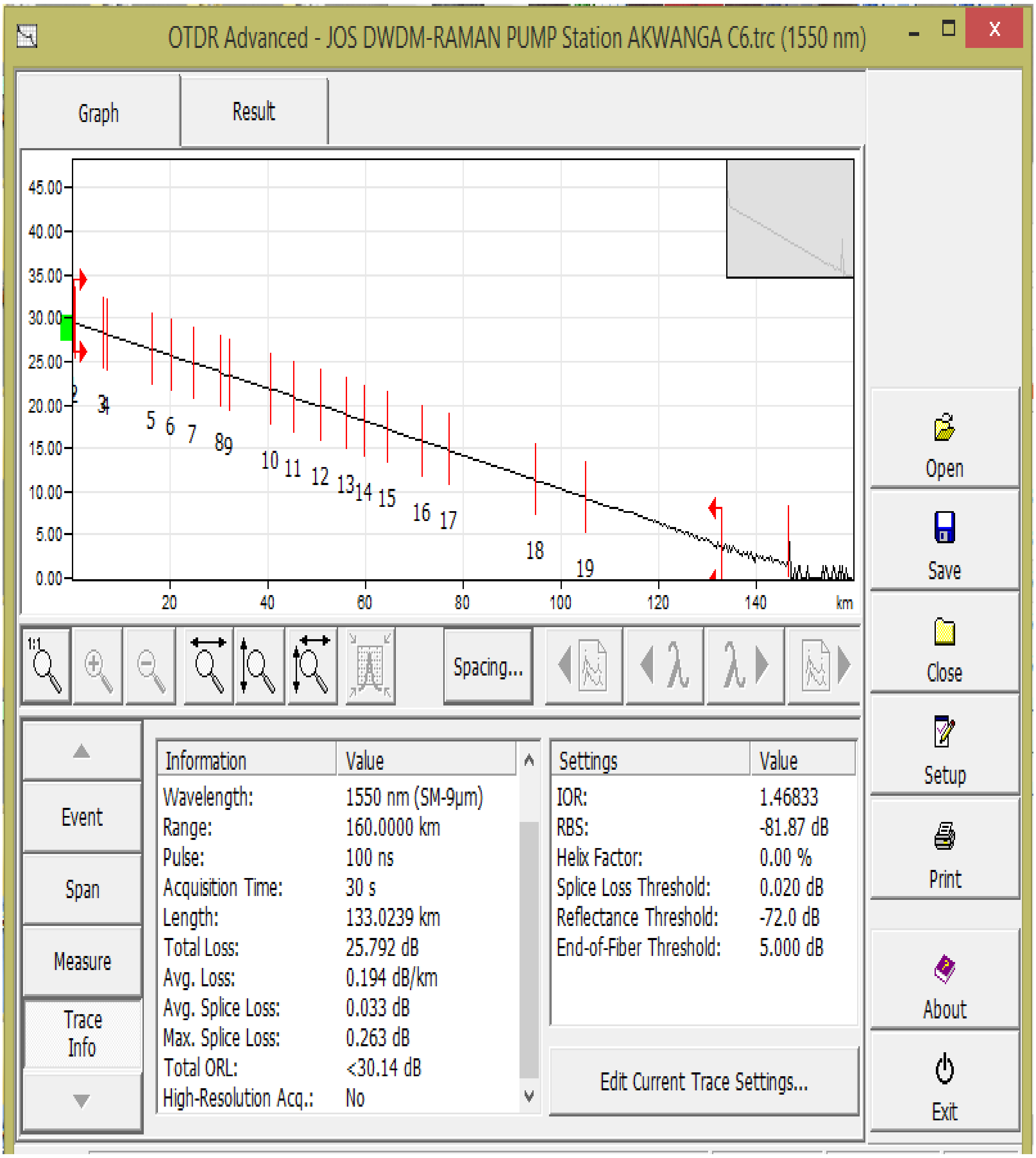


Figure: Fiber test from Jos DWDM to RAMAN PUMP Station in Akwanga using the OTDR Simulator

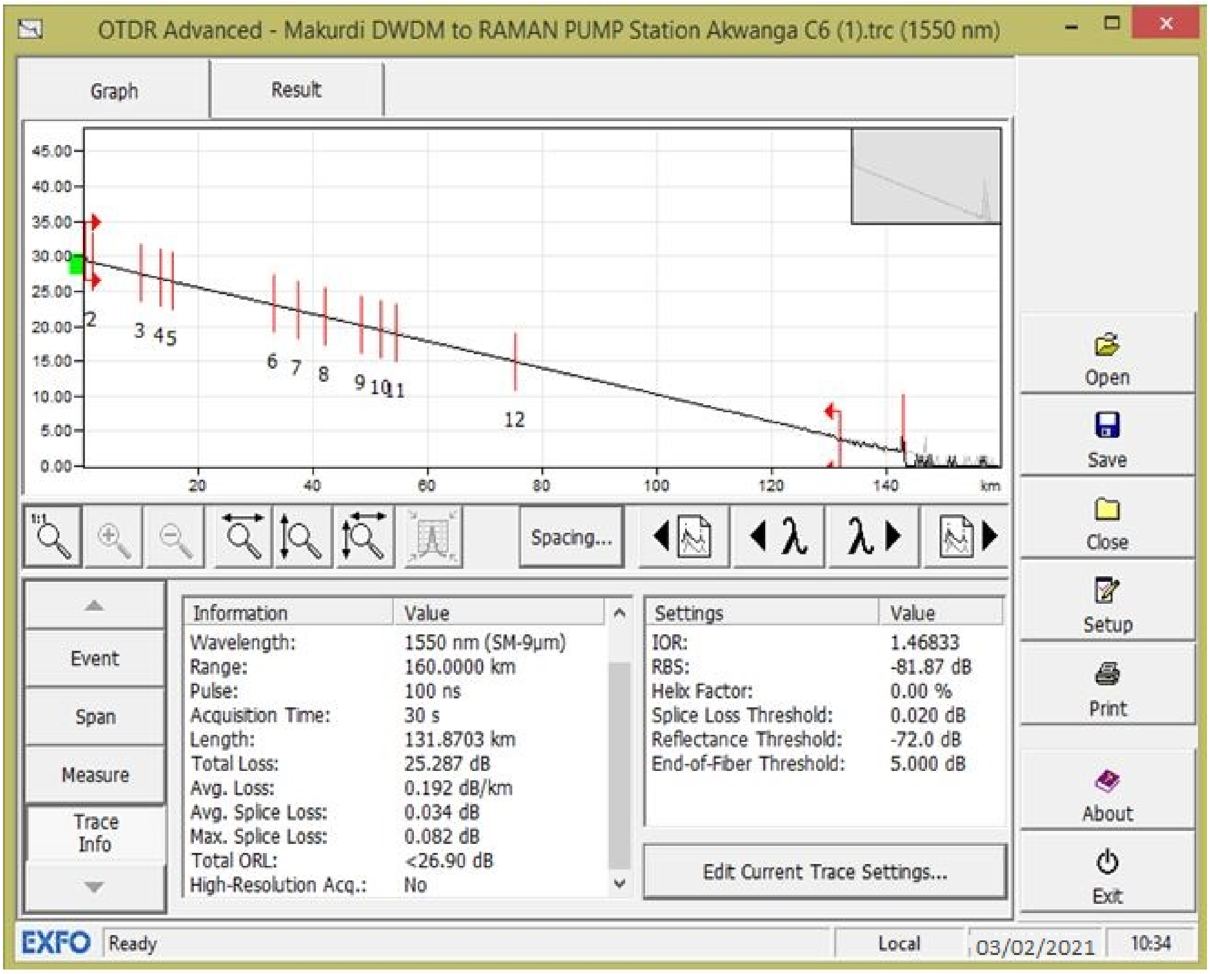


Fig 3.3: Fiber test from Makurdi DWDM to RAMAN PUMP Station Akwanga using the OTDR Simulator

RESULTS

Table 4.1: Received Power at both directions without RAMAN Pump

S/N	NAME OF ROUTE	DISTANCE (KM)	T_X A (dbm)	R_X A (dbm)	T_X B (dbm)	R_X B (dbm)	Dir A	Dir B	NOTES
1	Offa-Ilor	44	3.0298	-27.4715	2.95611	-29.431	32.4608	30.42761	Degrade Fiber but short distance, No RAMAN Required
2	Ib-Abk	68	2.49981	-17.0997	2.83979	-17.2515	19.75131	19.93949	Current results are satisfactory, No RAMAN Required
3	Ib-Abk 2	69	2.5887	-18.0052	2.85985	-17.3025	19.8912	20.86505	Current results are satisfactory, No RAMAN Required
4	Ib-Osh	108	2.53895	-542288	2.98984	-51.2185	53.75745	57.21864	Distance not too long, but degraded Fiber causing lots of frame loss, RAMAN pump required to compensate for the loss
5	Offa-Osh	52	2.73441	-12.6801	2.59976	-16.5423	19.27671	15.27986	Current results are satisfactory, No RAMAN pump Required
6	Offa-Jebba	126	2.78982	-413657	2.93186	-40.8709	43.66072	44.29756	RAMAN pump required to improve the signal quality on long distance
7	Akr- Benin	147	2.82984	-54.2288	2.98984	-54.3827	57.21254	57.21864	Long distance, received power already full of noise, RAMAN pump required to compensate for the loss
8	Akr- Benin 2	130	2.9091	-38.9568	2.84972	-37.3268	40.2287	41.80652	Long distance, received power already full of noise, RAMAN pump required to compensate for the loss
9	Offa-Osh 2	57	2.80168	-16.3846	3.11987	-16.0241	18.82578	19.50447	Current results are satisfactory, No RAMAN Required

Table 4.3: Another text conducted on different kilometers
Received Power at both directions without RAMAN Pump

Distance (Km)	T_X A (dBm)	R_X A (dBm)	T_X B (dBm)	R_X B (dBm)	COMMENT
20	30.29	7.6025	-6.000	-0.300	Degraded Signal over short distance but result still within acceptable range.
40	33.09	2.0878	-12	-0.300	Degraded Signal over short distance but result still within acceptable range
60	35.07	0.5558	-18.0001	-0.300	
80	37.02	0.5867	-18.0002	-0.02250	Degraded Signal over short distance but result still within acceptable range
100	40.03	0.04003	-30	-0.3	Degraded Signal over short distance but result still within acceptable range
120	43.11	0.0108	-30.0115	-0.3001	degraded signal over a long distance, Raman pump required to boost output signal to acceptable range
131	49.25	0.0053	-39.3134	-0.3001	Degraded Signal over a long distance, Raman pump required to boost output signal to acceptable range.
142	27.37	0.0015	-42.6118	-0.3001	Degraded Signal over a long distance, Raman pump required to boost output Signal to acceptable range.

Table 4.5: Transmission gain without Raman pump

Distance (KM	Input Power (dBm)	Output power (dBm)	Gain	Gain (dBm)
20	29.32	25.74	0.8778	-0.5660
40	29.32	21.66	0.7387	-1.3153
60	29.32	18.07	0.6163	-2.1021
80	29.32	14.16	0.4829	-3.1614
100	29.32	10.26	0.3499	-4.5606
120	29.32	6.38	0.2175	-6.6254
132	29.32	3.46	0.1180	-9.2812
146.5	29.32	0.89	0.0296	-15.2871

Table 4.6: Transmission gain without RAMAN pump

Distance (KM)	Input Power (dBm)	Output power (dBm)	Gain	Gain (dBm)
20	43.966	21.710	0.5797	-2.3680
40	43.966	17.79	0.4939	-3.0636
60	43.95	13.91	0.4047	-3.9287
80	43.95	10.29	0.3165	-4.9963

100	43.95	6.9	0.2341	-6.3060
120	43.95	0.23	0.1569	-8.0438
131	43.95	3.25	0.0052	-22.8400
142.83	43.95	3.02	0.0739	-11.3136

Table 4.7: Attenuation measurement

S/N	Distance (Km)	Attenuation (dB) with Raman Amplifier	Attenuation (dB) Without Raman amplifier
1	10.0000	0.1900	0.2500
2	26.6667	0.1956	0.2578
3	43.3333	0.2011	0.2656
4	60.0000	0.2067	0.2733
5	76.6667	0.2122	0.2811
6	93.3333	0.2178	0.2889
7	110.0000	0.2233	0.2967
8	126.6667	0.2289	0.3044
9	143.3333	0.2344	0.3122
10	160.000	0.2400	0.3200

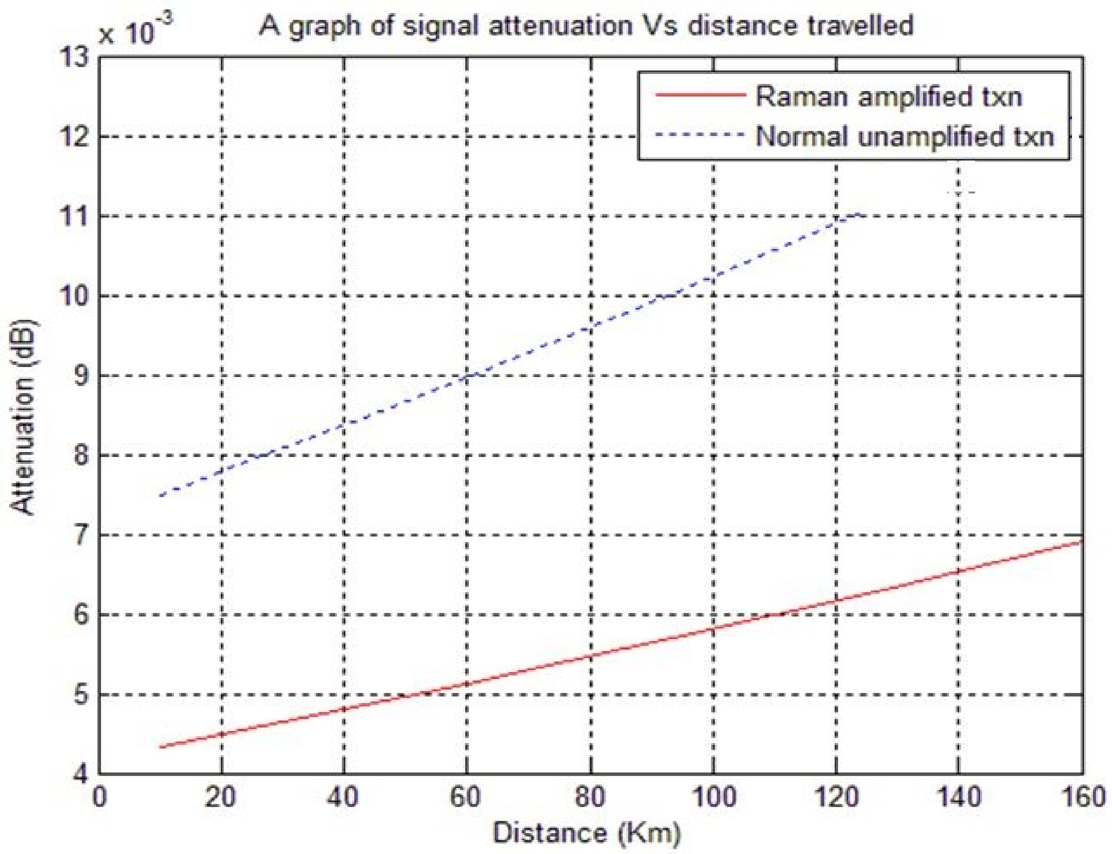


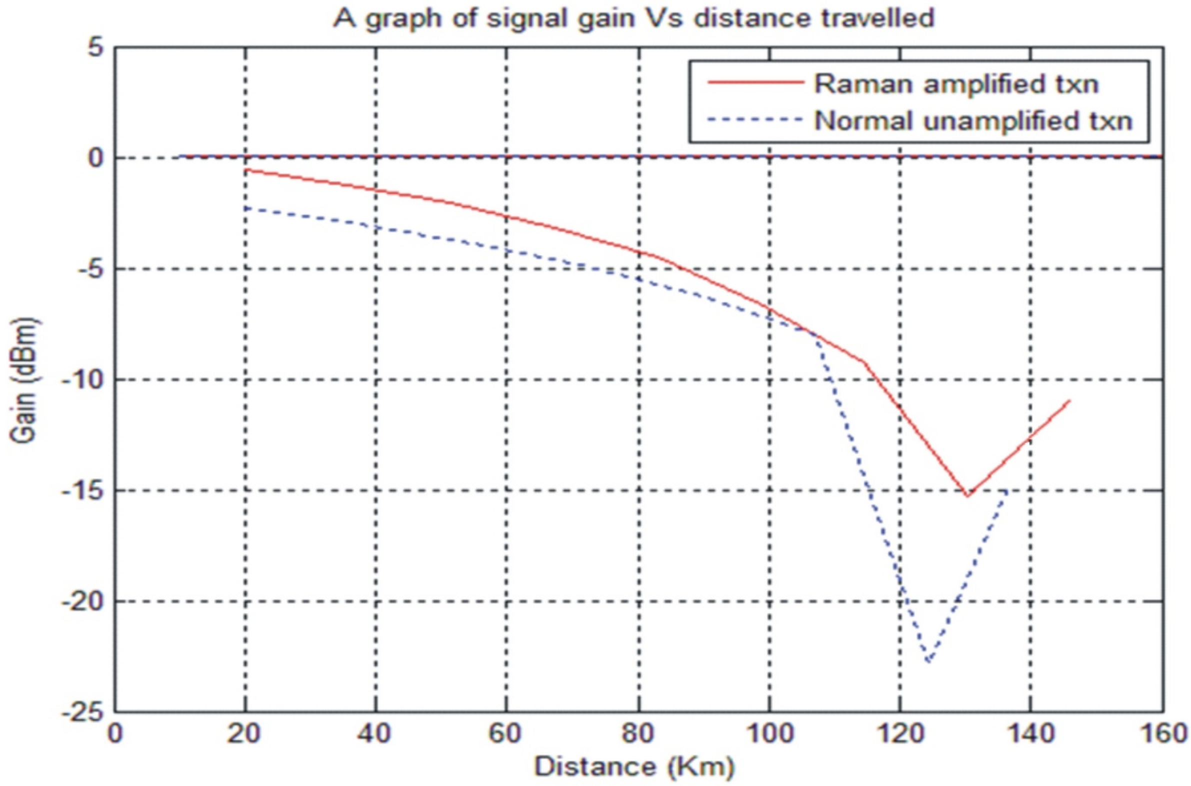
Table 4.2: Received Power at both directions (T_x& R_x) with RAMAN Pump

S/N	NAME OF ROUTE	DISTANCE (KM)	T_X A (dbm)	R_X A (dbm)	T_X B (dbm)	R_X B (dbm)	Dir A	Dir B	NOTES

1	Offa-Ilor	44	3.0298	-30.892	2.95611	-29.3554	32.3852	33.84811	Degrade Fiber but short distance, No RAMAN pump Required
2	Ib-Abk	68	2.49981	-17.09987	2.83979	-15.4806	17.98041	19.93966	Current results are satisfactory, No RAMAN pump Required
3	Ib-Abk 2	69	2.5887	-17.0983	2.85985	-17.1988	19.7875	19.95815	Current results are satisfactory, No RAMAN pump Required
4	Ib-Osh	108	2.53895	-40.9691	2.98984	-41.549	44.08795	43.95894	RAMAN introduction improved the received signal and compensate for the loss.
5	Offa-Osh	52	2.73441	-12.5477	2.62997	-14.5063	17.24071	15.17767	Current results are satisfactory, No RAMAN pump Required
6	Offa -Jebba	126	2.78982	-29.6257	2.81987	-30.4576	33.24742	32.44557	RAMAN pump introduction improved the received signal.
7	Akr-Benin	147	2.82984	-45.2288	2.98984	-36.1979	39.02774	48.21864	RAMAN pump introduction improved the received signal and compensate for the loss.
8	Akr-Benin 2	130	2.9019	-28.9963	2.84972	-26.517	29.4189	31.84602	RAMAN pump introduction improved the received signal and compensate for the loss.
9	Offa- Osh	57	2.80168	-16.4092	3.11987	-16.052	18.85368	19.52907	RAMAN pump introduction improved the received signal and compensate for the loss.

Table 4.4: Received Power at both directions with RAMAN Pump

Distance (Km)	TX A (dBm)	RX A (dBm)	TX B (dBm)	RX B (dBm)	COMMENTS
20	30.29	17.6085	-2.3558	-0.1178	Results are satisfactory given the distance.
40	33.09	12.0878	-4.3735	-0.1093	Output is better and satisfactory.
60	35.07	10.5558	-5.2144	-0.0369	Results are OK.
80	37.07	10.5867	-5.4426	-0.0080	Results are satisfactory given the distance
100	40.03	10.0400	-6.0065	-0.0601	Degraded Signal over a long range but Raman pump adequately compensated for losses bringing it to acceptable range.
120	43.11	10.0108	-6.3411	-0.0529	Raman pump amplifier helped compensate the loss over the long distance and bring output to acceptable range
131	45.25	10.0053	-6.5539	-0.0500	The introduction of the Raman pump amplifier boosted the output.
142	27.37	10.0015	-4.3721	-0.0308	The Raman pump amplifier was able to compensate for losses thus giving a good output.



DISCUSSION OF RESULTS

Without raman pump

The above result in table 4.1 was conducted without Raman pump and the result proves that from 100km, Raman pump is required due to signal degrade, loss of frame and Noise on the link that is above 100km.Though we have link on table 4.1 that is lower than 100km and it's having signal degrade but from my finding it was discovered that the fiber optics cable core is having high attenuation. The solution to this particular link is to check the temperature of the equipment and the equipment room and ensure the equipment room temperature is cool or to clean the fiber optics connectors from dust.

With Raman pump

Table 4.2 result was received Power at both directions with RAMAN pump, the test was conducted and the result proves that from 100km, Raman pump was introduced due to signal degrade, loss of frame and Noise to the link. The improved received signal compensated for the losses and the distance.

Analysis

The attenuation varied over the 160km monitored during the simulation and was measured as shown in table 4.5. At several points along the transmission network, measurements of the signal's attenuation were taken.

Signal power loss was reduced by adding a distribution Raman amplifier to a fiber span with EDFAs. A counter-propagating Raman amplifier is made up of one or more Raman pump lasers and a wavelength combiner that sends the Raman pump wavelengths into the fiber in the opposite direction of the signal. The signal will be attenuated as it travels up the fiber, but as it gets closer to the fiber end, where the Raman pump is positioned, it will begin to gain from the Raman pump wavelength, as illustrated in figure 4.2. As a result of the higher signal strength, the OSDR increases, allowing for a longer fiber span, higher capacity

and spectral efficiency, and a longer link distance.
Figure 4.1 depicts the signal levels from the receiver end with and without Raman pumping, as well as the Raman gain dispersed along the 160-kilometer fiber connection span. The exact distribution of gain in systems employing a single fiber type is mainly independent of the fiber effective area and is related to the fiber loss at the pump wavelength in systems using a single fiber type.

When a signal is transmitted across an optic fiber link without the Raman amplifier, the gain is significantly reduced. At a distance of roughly 125 kilometers, the signal strength begins to deteriorate to the point where it is too weak to travel farther without amplification. The Raman pump was introduced at this time, which increased the signal strength as shown in figure 4.1.

The main advantage of a Distributed Raman Amplifier (DRA) over a discrete amplifier like an erbium doped fiber amplifier (EDFA) is that the amplification takes place away from the fiber end, where the signal power is larger. As a result, the signal power drops to a lower level in the span, increasing the total optical signal-to-noise ratio and thereby improving the system bit error rate (BER).

By incorporating Raman amplifier into DWDM networks, the link becomes more robust

CONCLUSIONS

Finally, the creation and present application of distributed RAMAN amplifiers in dense wavelength division multiplexing techniques has ushered in a new era of optical transmission medium improvement.

The Raman amplifier appears to be a vital technology that is constantly being developed for widespread use in optical communication networks. Raman amplifiers, which are commonly used in long-haul networks, are projected to expand their reach in dense wavelength-division multiplexing (DWDM) networks. As a result, the tremendous bandwidth demand that network operators are always confronting is fueling this rising adoption.
In the optical transport network of long-distance optical communication, the dense wavelength division multiplexing (DWDM) approach has become the favored transmission technology. The invention of an efficient and powerful Raman optical amplifier has aided improvements in optical communication by eliminating the need for expensive regenerators, multiple EDFAs, and converters over long distances.

The above-mentioned experiment is an evidenced of the effect in the results. A research on increasing optical signal in the RAMAN station utilizing the DWDM technology was proven and achieved, including system modeling of critical parameters using **network Monitoring system (NMS) software equipment, power meter source and optical time domain reflectometer (OTDR) simulator**.

The optical signal can be improved utilizing RAMAN pump amplifier in DWDM technology, according to the optical time domain reflectometer simulator, NMS and power meter source

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