BIT ERROR RATE MEASUREMENTS OF FIBER OPTIC NETWORK THROUGH ETHERNET ANALYSERS

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Abstract—This paper describes the end-to-end performance of single mode Fiber Optic Network (FON), implemented for Unmanned Surveillance System (USS) application for the detection and tracking of land and sea based moving targets. Optical fibers are widely in fiber optic communications which permits transmission over longer distances and at higher bandwidths (data rates) than other forms of communication. Bit Error Rate (BER) is the ultimate key index parameter in assessing the FON for transmission of digital data from one location to another location. In this paper, in addition to BER, throughput and RFC 2544 testing were also performed over the FON using dual port VeEX ethernet analyzers. Both the fiber and copper ports of ethernet analyzers were exercised for obtaining the performance metric parameters of FON. Apart from BER measurements using ethernet analyzers, Optical Time Domain Reflectometer (OTDR) has also been used for checking the optical signal loss over FON. The performance analysis of BER at different data rates and the factors affecting BER are also discussed in this paper.

Keywords—Fiber Optic Cable (FOC), BER, throughput, bandwidth and latency, RFC 2544.

I. INTRODUCTION

DRDO has been actively involved in the design and development of various types of UGVs for different applications. The first Indian tracked unmanned ground vehicle, named as MUNTRA (Mission Unmanned TRAcked) with the state-of-art technologies was designed and developed by the Combat Vehicles Research & Development Establishment (CVRDE), Avadi, Chennai.

CVRDE has developed the teleoperated MUNTRA series of tracked UGVs on the BMP II class of armoured, amphibious vehicles for specific operational missions of unmanned surveillance, NBC reconnaissance and mine detection.

For one of the surveillance requirements of possible threats, CVRDE had established a fiber optic based communication link for a standalone, unmanned surveillance system (USS). Various land and sea based threats can be detected, tracked and classified using the sensor suite of the USS. Visual confirmation of the threats can also be achieved by the synchronous slaving of the electro-optic sight to the radar.

This paper describes the performance analysis of fiber optic network in terms of BER, throughput, latency, jitter using Ethernet analyzers. BER is defined as the rate at which errors occur in a transmission system. This can be directly translated into the number of errors that occur in a string of a stated number of bits. The definition of bit error rate can be defined as:

BER = Number of errors / Total number of bits sent.

If the medium between the transmitter and receiver is good and the signal to noise ratio is high, then the bit error rate will be very small, possibly insignificant, and having no noticeable effect on the overall system. However if noise is present, then there is a chance that the BER will need to be considered. When data is transmitted over a data link, there is a possibility of errors being introduced into the system and the integrity of the system may be compromised. As a result, it is necessary to assess the performance of the system. Unlike many other forms of assessment, bit error rate, BER assesses the full end to end performance of a system including the transmitter, receiver and the medium between the two. In this way, BER enables the actual performance of a system in operation to be tested.

For fiber optic systems, bit errors mainly result from imperfections in the components of the link. These include the optical driver, receiver, connectors, splices, bends, cracks and the intrinsic properties of the fiber itself. Bit errors may also be introduced as a result of optical dispersion and attenuation that may be present. Noise may also be introduced in the optical receiver itself. Typically these may be photodiodes and amplifiers which need to respond to very small changes and as a result there may be high noise levels present. Another contributory factor for bit errors is any phase jitter that may be present in the system as this can alter the sampling of the data.

II. FACTORS AFFECTING BIT ERROR RATE

BER can be affected by a number of factors. By manipulating the variables that can be controlled it is possible to optimize a system to provide the performance levels that are required. This is normally undertaken in the design stages of a data transmission system so that the performance parameters can be adjusted at the initial design concept stages. The interference levels present in a system are generally set by external factors and cannot be changed by the system design. However it is possible to set the bandwidth of the system. By reducing the bandwidth the level of interference can be reduced. However reducing the bandwidth limits the data throughput that can be achieved. It is also possible to increase the power level of the system so that the power per bit is increased. This in turn reflects the impact of increasing the power output on the size of the power amplifier and overall power consumption and battery life, etc. It is necessary to balance all the available factors to achieve a satisfactory bit error rate. Normally it is not possible to achieve all the requirements and some trade-offs are required. However, even with a bit error rate below what is ideally required, further trade-offs can be made in terms of the levels of error correction that are introduced into the data being transmitted.

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Although more redundant data has to be sent with higher levels of error correction, this can help mask the effects of any bit errors that occur, thereby improving the overall bit error rate.

III. SYSTEM DESCRIPTION

The BER of fiber optic network can be measured using the special equipment called ethernet analyzers. Here the BER is tested with the help of VeEX ethernet analyzer. The test setup consists of two ethernet analyzers, one at the transmitter end and other at receiver end. The BER can be measured at any one of the two ends making one instrument as a loopback.

The generic block diagram of performance testing of fiber optic network using VeEX ethernet analyzers and the application tools supported are shown in fig.1 below.

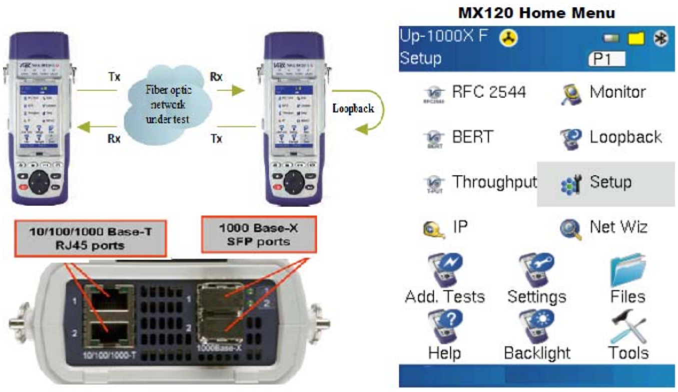

Fig. 1. Perrformance testing of fiber optic network using ethernet tesers

A. Ethernet Analyzer

The Ethernet analyzers are light weight, rugged and weather resistant with advanced triple play verification capabilities. The various performance metrics of the network can be measured using the ethernet analyzers. The instrument is equipped with the two interfaces like electrical ethernet Interfaces Dual 10/100/1000 Base –T ports (RJ 45 connector, IEEE 802.3 compliant) and an Optical Electrical Ethernet Interfaces Dual 1000Base-X SFP Ports (LC connector1000Base-SX (850nm), 1000Base-LX(1300nm), 1000Base-ZX(1550nm), 1000Base-FX).

Dual port handheld ethernet analyzer used for fiber optic network comprises of the following features :.

a) 1000-T Ethernet BERT, Throughput, RFC2544 test software.
b) 100-FX, 1000-X Ethernet BERT, Throughput, RFC2544 test software.
c) Multi Stream Test software&
d) 1310nm SFP - 1GE

B. Single mode Fiber Optic Cable

A 6 core, 10 GB bandwidth single mode FOC of span length 1 km operating at a wavelength of 1310 nm was laid down between the transmitting end of the system to the receiving end of the system. The FOC was inserted in PVC pipe throughout the length of the cable for safety purposes. Media converters were integrated onto the fiber optic network for electrical ethernet interface to carry digital data over fiber media.

C. Light Interface Unit (LIU)

The FSM – 60S fiber splicing instrument was used to splice the 6 cores of single mode fibers at both the ends of the fiber optic link. The patch cords and the couplers are used to connect the media converter and ethernet analyzer to the LIU. During BER testing, two cores were used in which one of the core is used for transmit data and other core for receive data. The layout of the fiber optic network accessories is shown in below fig.2.

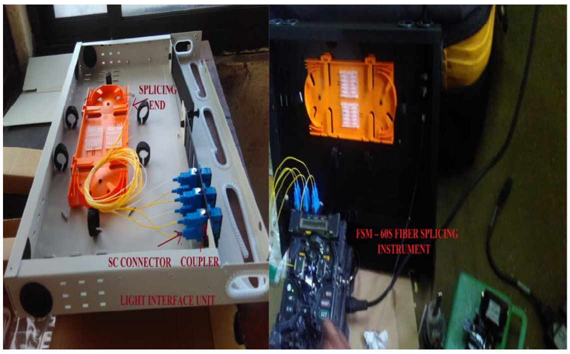

Fig. 2. LIU and FSM 60 S Fiber splicing

D. ReVeal MTX software

The ReVeal MTX software was used to create, edit , manage test profiles, download test results and generate test report.

IV. TEST PROCEDURE

As the ethernet analyzer is capable of measuring the network performance metrics like BER, throughput and latency, it was configured for the following three tests:

1. BER Test : The testing of BER defines unframed/framed layer 1 traffic and framed layer 2/3 ethernet traffic generation with user selectable test pattern for bit error rate analysis.

2. Throughput Test: This test defines ethernet traffic generation and analysis with multiple streams to verify network throughput and jitter.

3. RFC 2544 Test: This test states throughput, frame loss, jitter and latency tests in accordance with RFC2544 standards.

The two types of test procedure (with fiber port and copper port) for performance measurements of fiber optic network are detailed in the following sessions.

A. BER PERFORMANCE MEASUREMENT USING OPTICAL ***FIBER*** PORTS

The schematic diagram of BER performance measurement test setup using fiber ports at both the ends is given in fig 3. The Ethernet analyzer A is connected directly to the fiber port of LIU of transmitting end and analyzer B is connected to the fiber port of LIU of receiving end.

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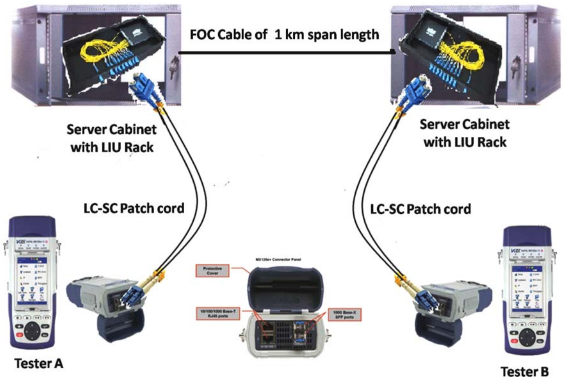

Fig. 3. Realized fiber optic network with performance testing

The analyzer A is configured with BERT application mode whereas analyzer B is configured with loopback mode. BERT test sequence is given below

1) Port Configuration

The port was selected as high speed fiber port of 1000Base – X with the following configuration given in fig.4 below.

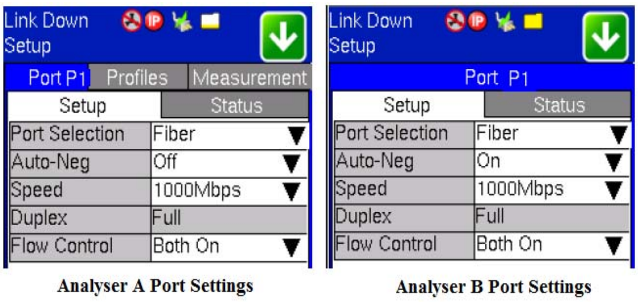

Fig 4 BER testing through high speed fiber

2) IP Configuration setting

The IP configuration settingsfor BER test is shown in figure 5.

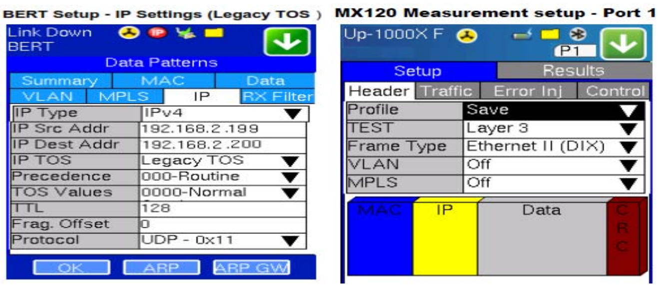

Fig 5.IP configuration for BERT

3) Ping test

The end to end connectivity of the fiber optic network is verified with the ping test as shown in fig 6 below.

Fig 6. Ping testing for BERT

4) Loop up with remote device discover feature

The analyser of location B is discovered remotely through control tab of BERT configuration setting. Following to the discovery of the remote analyser, the loop back of the device is enabled through Loop Up button. Then the Laser was turned ON from the setup/port screen for the BER testing.The device discover from the local device and Loop up procedure is shown in the below fig 7.

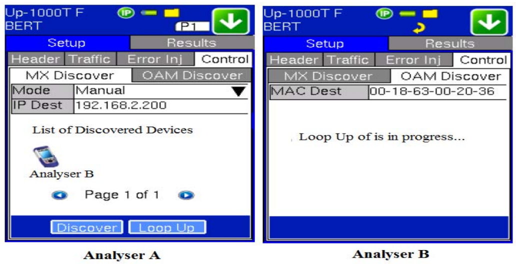

Fig 7. Loop up of remote analyser

5) BER test

After turning Laser ON, the BER testing at layer 3 was performed with pseduo random data patterns, constant / burst traffic settings and error injection activation as shown in fig.8,fig.9 and fig 10.

Fig 8. Pseduo random data patterns settings for BERT

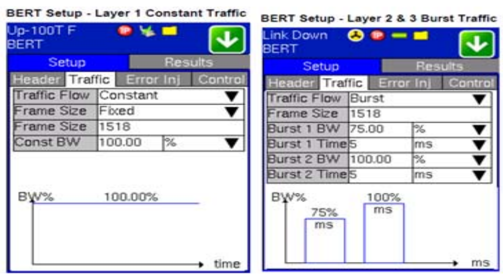

Fig 9. Bandwidth settings for BERT

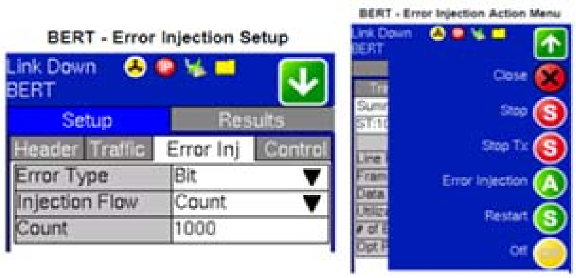

Fig 10. Error injection/activation settings for BERT

B. THROGHPUT PERFORMANCE MEASUREMENT USING FIBER PORTS

The selection of throughput application in the main menu performs the measurements like throughput, frame loss analysis, delay analysis, frame/packet arrival analysis, received traffic type analysis and received traffic frame size.

The set up for testing the throughput performance is same as the BER test procedure as presented in section IV.1 to 5. The single stream was taken for throughput testing as shown in figure 11.

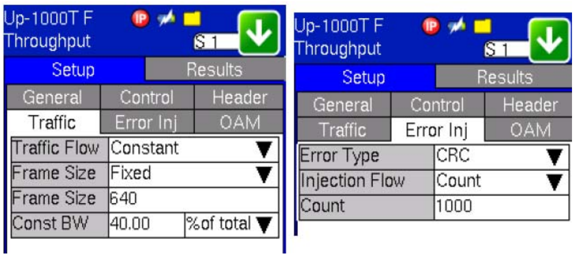

Fig 11. Throughput testing

C. *RFC 2544 END TO END FIBER OPTIC NETWORK PERFORMANCE TESTING*

The selection of RFC 2544 application in the main menu validates the parameters like throughput, latency, jitter and frame loss of the network. In addition to the configuration parameters settings of BER & throughput measurement, the RFC2544 testing includes the settings for frame loss, latency and throughput. The frame size settings of 128 bytes and 1518 bytes were configured for RFC 2544 testing. The throughput, latency and frame loss settings under RFC 2544 testing is shown in fig.12 below.

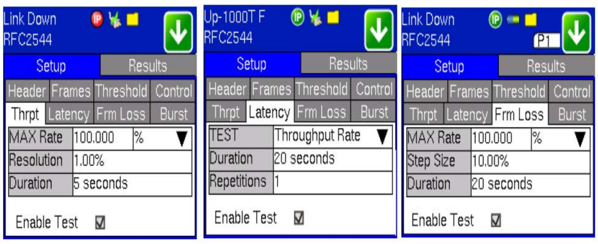

Fig 12. RFC 2544 throughput, latency and frameloss settings

D. *BER. THROGHPUT AND RFC 2544 PERFORMANCE MEASUREMENT USING ELECTRICAL* ***COPPER****/ RJ45 PORTS*

The schematic diagram of fiber optic network performance test setup using copper ports at both the ends is given in figure 13. The copper port of Ethernet analyzer A is connected to the media converter of LIU at transmitting end and analyzer B is also connected in the same manner at the receiving end. The measurement set up of BER, throughput, RFC2544 testing with similar test procedure of fiber ports was conducted using copper ports and the results were discussed in the following section.

Fig 13.Fiber optic network performance testing with copper port

V. RESULTS AND CONCLUSIONS

Through the BER and throughput testing using fiber as well as copper ports, it was observed that as the bandwidth increases, the BER decreases as tabulated in Table.1 and 2. It was also established that the results of BER performance with fiber port is much better than copper port testing. For higher data rates, the optical interface provides better transmit and receive utilization than the electrical interface.

Table 1. BER test for optical and electrical interface

BER Test		
Description	**Fiber**	**Copper**
BER @ 10 Mbps Bandwidth	$7.69\ e^{-7}$	$9.67\ e^{-6}$
BER @ 100 Mbps Bandwidth	$7.72\ e^{-8}$	$3.63\ e^{-7}$
BER @ 1000 Mbps Bandwidth	$8.37\ e^{-9}$	$6.18\ e^{-8}$

Table 2. Throughput test for optical and electrical interface

Throughput Test 10 Mbps Bandwidth		
Description	**Fiber**	**Copper**
Transmit Data rate	9.626 Mbps	9.626 Mbps
Transmit Utilization	10 Mbps	10 Mbps
Received Data rate	9.626 Mbps	9.614 Mbps
Receive Utilization	10 Mbps	9.99 Mbps

The acquired graphs of % utilization of throughput, latency, jitter and frame loss of both the fiber and copper ports testing under RFC 2544 validation with 100 Mbps traffic bandwidth are depicted in fig.14 to 17.

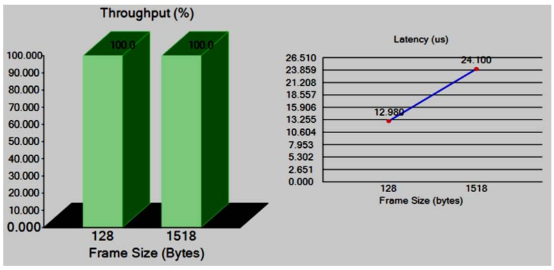

Fig 14.Throughput & latency graphs with **fiber** port

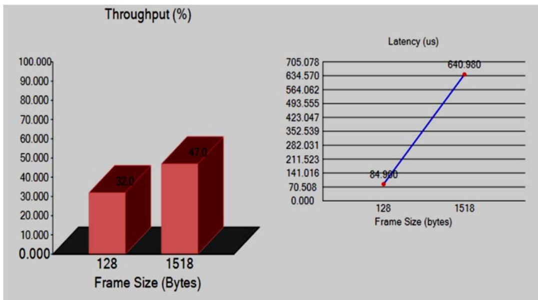

Fig 15. Throughput & latency graphs with **copper** port

From the above graphs, it was observed that the % utilization of throughput is relatively better in the case of fiber port testing when compared to copper port testing.

Similarly the latency in the case of fiber port testing for variation in frame size from 128 bytes to 1518 bytes resulted from 12.98 µs to 24.1 µs. But the latency in the counter part copper port testing resulted from 84.9 µs to 640.98 µs for the same span of frame size.

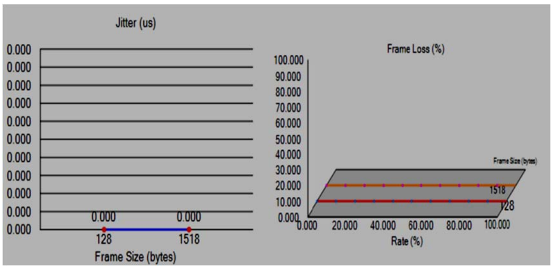

Fig 16. Jitter & frame loss graphs with **fiber** port

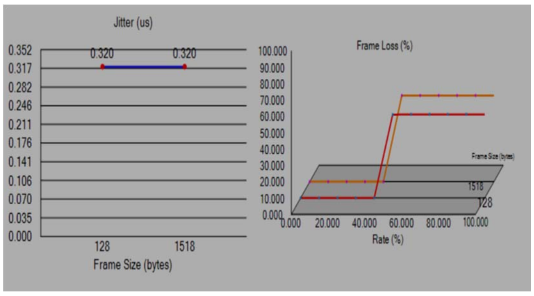

Fig 17. Jitter & frame loss graphs with **copper** port

Correspondingly, from the graphs of fig.21 & 22, it was observed that the jitter variation and frame loss values are negligible in the case of fiber port testing. In the copper port testing, the jitter value resulted as 0.32 µs for the frame size varied from 128 bytes to 1518 bytes and the frame loss resulted as approximately 52 µs. Hence, the end to end performance testing of fiber optic network with ethernet analyzers using fiber port testing yielded much better performance than copper port testing.

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