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Comparison of Signal Losses in Fibre Optic Cables

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ABSTRACT: In this paper, a direct comparison of signal loss on a network arising from both vibration and non – vibration source using the Anritsu Optical Time Domain Reflectometer (OTDR) has been made. The vibration was generated through a flask shaker, generator and heavy duty truck, which aims at ascertaining the effect of vibration on the network and the need to shield the network from vibration as much as possible. The results of this study was able to show that even in the absence of presumed vibration, a network of this kind can still experience signal losses, but greater losses are most likely to be recorded in the presence of a deliberate generation of vibration on the network. Hence; from this study, the OTDR has been used to acquire these signal losses on the optical fibre cable used for the network for the both cases above and at the end, an overall end – to – end loss of 3.90dB for both cases were observed and a reflected loss of -33.31dB and -33.34dB was obtained for both the non – vibration and vibration source respectively.

1. Introduction

In order to acquaint oneself with the effect of vibration on a network using optical fibre cables, there is need to compare from two or more sources of vibration on such network to validate the effect of vibration from these sources on the loss of signals. The motivation for carrying out this study arose from the information of poor reception for no just cause as often observed in many networks even after much troubleshooting techniques and approach have been administered. This implies that there may be other silent or hidden causes of poor reception aside from bad weather conditions, poorly terminated components and cables, bad or faulty equipment, EMI interferences, etc.

To actualize this, two sets of data have been acquired from the field on an established network running on optical fibre cable[1]. These data were acquired using an OTDR (Optical Time – Domain Reflectometer) when the field was assumed to be stable and calm without any obvious vibration or movement of vehicles within the vicinity and a generated vibration from a combination of a heavy duty truck, a generator, and a flask shaker. Hence, the two sets of data have been categorized as:

a. Source without vibration (WoV) and
b. Source with vibration (WV).

The essence of this categorization is to enable us study the trend of signal losses on the fibre optic cable network so effective administration can be implemented and guidelines drawn to avoid unnecessary poor network delivery within the area of study and possibly adoptive approach can be proffered on any of such network cables in any environment.

2. Materials for Study

a. Flask shaker (Gallenkamp brand)
b. Generator
c. Heavy duty truck
d. OTDR (Anritsu MT9083AI Access Master)

Below are figures (1 – 3) of the instruments used.

Figure 1: The flask shaker.

Figure 2: The OTDR being prepared for use.

Figure 3: The flask shaker connected to the generator.

3. Method of Study

The method through which this study was carried out was basically the use of the OTDR for the acquisition of data with and without vibration as categorized above (WoV and WV). These data were then presented in SPSS software from which line graphs have been plotted for the comparison of the signal losses from the two categories as contained in the results section (section 4) below.

First, from the data set without vibration (WoV), the data were acquired directly from the network server room using the OTDR by connecting it to the cable path running through the field of study on the patch panel. When these first sets of data were being acquired, we assumed there was no vibration of any kind within the vicinity and the OTDR was able to generate the signal losses on the optical fibre cable of the network along this path. These sets of data or signal losses acquired have been presented in the results below as Table 1 (see attached Appendix I).

Secondly, the flask shaker, generator and heavy duty truck were strategically positioned and powered on at some distance on the cable path indicating a splice joint on the fibre optic cable. While the three combined vibration source (flask shaker, generator, and heavy duty truck) were simultaneously powered on over a period of about 10 minutes, the OTDR was again connected to the cable path linking the location on the field and a second set of data showing signal losses on the network were acquired as shown also in the results as Table 2 below. The generator and flask shaker were much closer together and at the same time closer to the splice joint on the cable, whereas the truck was stationed at the closest distance accessible from the access road next to the generator, which was within a radius of 2meters. While the truck was on, to achieve a greater impact on the network path, it was continuously throttled and slightly moved to and fro within the spot. While data were to be acquired in both cases above, the OTDR was first configured according to single mode fibre optic system and other desired specifications put in place before being engaged to run and trace (see attached Appendix II).

4. Results

Table 1: Data set for non – vibration source (WoV).

S/N	Feature/ Type	Location (Km)	Event – Event (dB)/ (dB/Km)	Loss (dB)	Ref1 (dB)
1	1/N	0.0278	-0.13 -4.786	0.05(2P)	
2	2/N	0.1941	-0.10 -0.584	0.20(2P)	
3	3/N	0.4747	0.04 0.132	-0.13(2P)	
4	4/N	0.6063	-0.00 -0.020	0.06	
5	5/N	0.7595	0.02 0.161	0.19	
6	6/N	1.1731	0.12 0.285	0.21	
7	7/N	1.4683	0.08 0.255	0.05	
8	8/N	1.4861	0.01 0.297	0.46(2P)	
9	9/N	1.7644	0.03 0.092	0.04(2P)	
10	10/N	1.8100	-0.01 -0.129	0.93(2P)	
11	11/N	1.9015	0.01 0.148	0.24(2P)	
12	12/N	2.3794	0.07 0.152	1.21(2P)	
13	13/N	2.4937	0.02 0.135	-0.10(2P)	
14	14/N	2.5288	0.02 0.464	0.33(2P)	
15	15/E	2.6639	0.00 0.010	>3.00	-33.31
	Overall (End-to-End) Loss: 3.90dB				

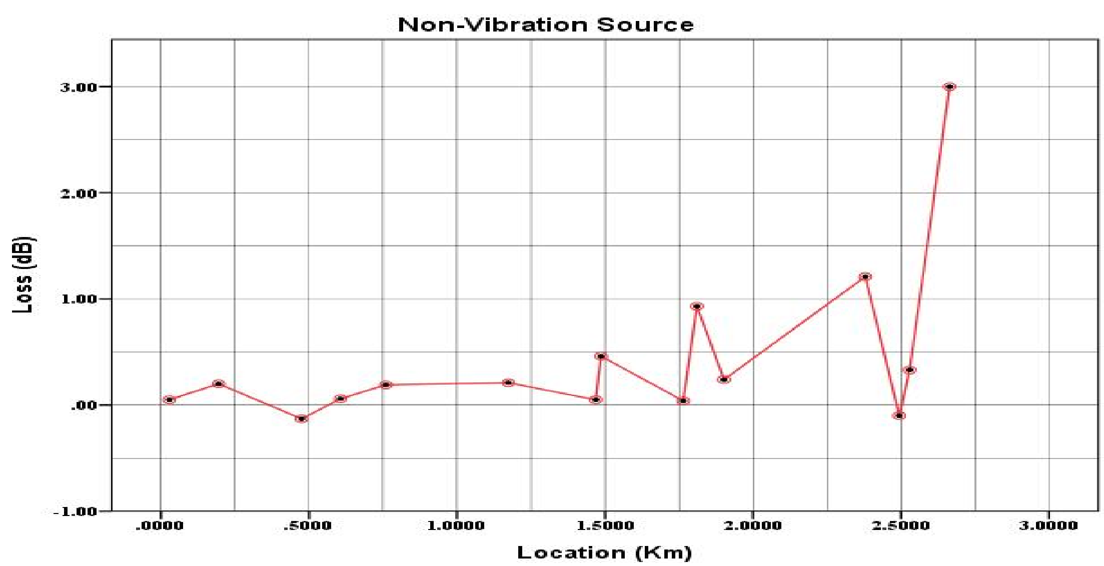


Figure 1: Line graph of data set WoV.

Table 2: Data set for vibration source (WV).

S/N	Feature/ Type	Location (Km)	Event – Event (dB)/ (dB/Km)	Loss (dB)	Ref1 (dB)
1	1/N	0.0278	-0.12 -4.294	0.02(2P)	
2	2/N	0.1929	-0.12 -0.706	0.24(2P)	
3	3/N	0.4769	0.02 0.060	-0.13(2P)	
4	4/N	0.6073	0.01 0.041	0.08(2P)	
5	5/N	0.7593	0.02 0.124	0.20(2P)	
6	6/N	1.1729	0.08 0.186	0.22	
7	7/N	1.4855	0.13 0.407	0.49	
8	8/N	1.8098	0.02 0.069	0.94(2P)	
9	9/N	1.9017	0.03 0.379	0.23(2P)	
10	10/N	2.3796	0.08 0.172	1.24(2P)	
11	11/G	2.4928 - 2.5235	0.04 0.376	-0.12(P2)	
12	12/N	2.5288	-0.01 -0.291	0.32(2P)	
13	13/E	2.6639	-0.01 -0.094	>3.00	-33.34
	Overall (End-to-End) Loss: 3.90dB				

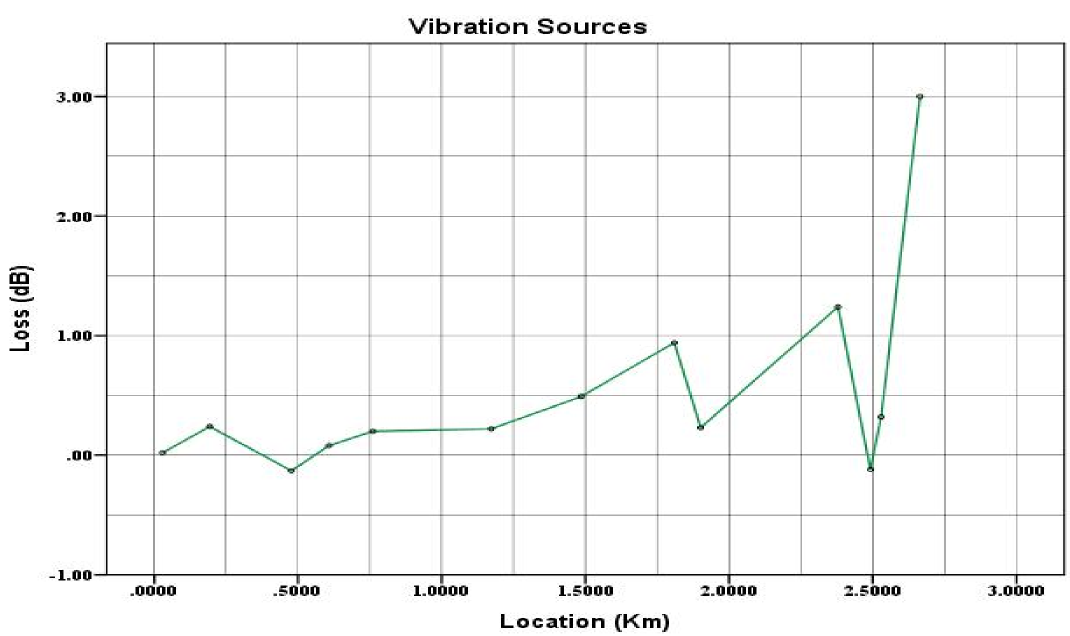


Figure 2: Line graph of data set WV.

5. Discussion

The results of figure 1 and figure 2 above can be said generally to have shown that the distance or location is directly proportional to the signal loss from the optical fibre cable of the network. In figure 1 precisely (WoV), within the first 500m, a slight signal loss increment was recorded within a space interval of two events, which showed a significant four times increase (from 0.05dB to 0.20dB) from initial point event to about 250m point event. This loss difference was due to poor connection terminal with the router and at the third event, at approximately 500m, an end to end negative loss was recorded indicating a splice joint on the cable. At over 500m there was a progressive signal loss against distance due to path or bending losses and a drop in signal loss within 1Km from the 500m distance, this drop in signal loss informed of another possible splice joint due to difficulty in laying a direct composite pipe path underground. Between these distances (1.5Km to 2.5Km) a continuous bending loss were recorded due to the said difficulty in pipe laying and a minute vibration sources from passing vehicles and possible natural underground movements, which were neglected while these data set was being recorded within the field of this study and finally from same figure 1, at about 2.66Km distance, there was recorded a steady increase of signal losses at two distinct events, which also correlated to the direct relationship between the distance and signal loss, but this steady increase in signal loss observed could also be due to minimized bending loss and avoidable splice joints.

In figure 2 (WV) above, the data set were acquired by subjecting the optical fibre cable of the network to vibration from a combination of the shaker, generator and heavy duty truck. The result showed a similar trend to that acquired without vibration (WoV) in figure 1, but in this case, the line graph indicated a smoother path of signal losses, which arose from the attempted normalization of the bending losses, implying there were fewer bending losses in comparison with the results of figure 1. More so, at the initial events recorded, it can be seen that there was also a greater impact of vibration as the first two event points indicated a huge marginal difference of twelve times magnitude in signal loss. At about 1.8Km and 2.5Km, it can be confirmed that there was a major splice joint set back or fault and due to truncation in line of path, a negative signal loss was hence recorded at the said 2.5Km point, which also coincided approximately to the spot where the generator and shaker were strategically positioned on the optical fibre path.

6. Conclusion

In conclusion, it has been observed that though an optical fire cable network subjected to vibration may have a number of advantages in theory and applications, it significantly leads to signal losses in the network if properly studied. In this study among a key constraint of not observing the safe vibration degree of the used instruments, both results showed that there was no difference in their overall end – to – end losses as both results recorded an overall end – to – end loss of 3.90dB and a reflectance loss of -33.31dB for data set without vibration (WoV) and -33.34dB data set with vibration (WV) from table 1 and table 2 above respectively. The close range of these values for both the end – to – end losses and reflectance losses are due to the inability of the heavy duty truck to access direct path over the optical fibre cable path.

More so, the losses as recorded in this study does not imply solely to the exposure of the fibre cable to vibration, neither does it imply that there must be a splicing fault, but it could also mean that the light intensity was not enough to propagate the data across the length of the cable as observed at the end points of about 2.66Km in both instances of the results above.

Finally, from this study, a database of various vibration degrees from different equipment and machinery, including earthquake magnitudes could be created for easy prediction of environmental threats or hazards related to vibration and underground movements on land and in sea as well as faulty engineering structures like buildings, roads, and masts.

References

[1] Igwele, M. M. and Ogobiri, E. G., (2018), *Measurement of Signal Losses in Optical Fibre Cables under Vibration Using Optical Time-Domain Reflectometer (OTDR),* International Journal of Scientific and Engineering Research, Volume 9, Issue 7, July-2018, pp. 1547–1552, ISSN 2229-5518.

[2] Anusha M., Abi W., et al., *Loss Analysis in Optical Fiber Transmission*, SIR SYED UNIVERSITY RESEARCH JOURNAL OF ENGINEERING AND TECHNOLOGY, VOLUME 5, ISSUE 1, 2015.

[3] Elebi, M. C., *Real-time seismic monitoring of the New Cape Girardeau Bridge and preliminary analyses of recorded data: an overview, Earthquake Spectra* 22, pp. 609–630, 2006.

[4] Gholamzadeh, B. and Nabovati, H., (2008), *Fiber Optic Sensors, World Academy of Science, Engineering and Technology*, Vol. 18, pp 297-307.

[5] Glišić, B., Inaudi, D., (2007), *Fibre Optic Methods for Structural Health Monitoring*. [online]. ISBN 978-0470-06142-8.

[6] Mahmudah S. G., Edi P., et al., *Vibration Measurement of Mathematical Pendulum based on Macrobending – Fiber Optic Sensor as a Model of Bridge Structural Health Monitoring*, 2016.

[7] Sensors 2016, 16, 1164; *a review*, www.mdpi.com/journal/sensors).

[8] Sharma, R., Rohilla, R., Sharma, M., and Manjunath, T. C., *Design and Simulation of Optical Fiber Bragg Grating Pressure Sensor for Minimum Attenuation Criteria*, Journal of Theoretical and Applied Information Technology, vol. 5, no. 5, pp. 515-530, 2009.

[9] Taylor B. and Dr. La Rosa, *Optical Fibers: History, Structure and the Weakly Guided Solution*, Journal of Physics, 464 Portland State University (May 30, 2008).

[10] Thyagarajan, K., Ghatak, A. K., (2007), *Fiber Optic Essentials*. Wiley-Interscience, 2007. 242 p. ISBN 978-0-470-09742-7.

[11] Van Leeuwen, K. A. H. and Nijnuis H. T., *Measurement of higher-order mode attenuation in single-mode fibers: effective cutoff wavelength*, Optics letters, Volume 9, Issue 6, pp.252-254.

[12] Wenzel, H., (2009), *Health Monitoring of Bridges*. John Wiley & Sons, Ltd. 2009. 643 pp. ISBN 978-0-470-03173-5.

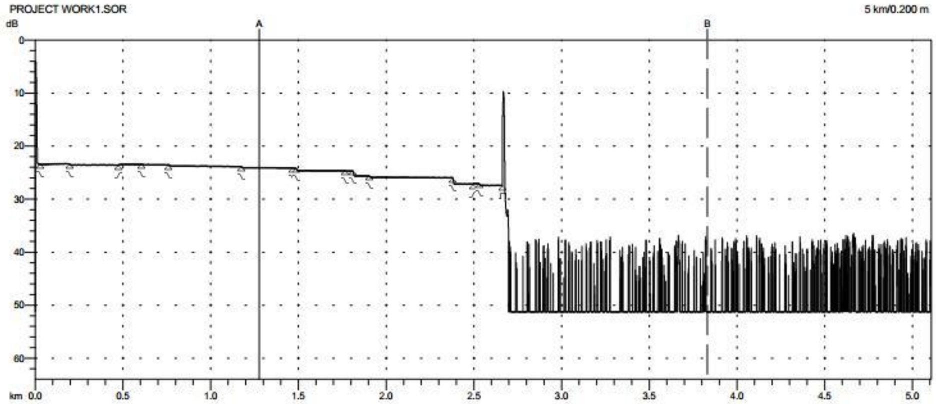
[13] Zendehnam, A., Mirzaei, M., Farashiani A. and Horabadi F. L., *Investigation of bending loss in a single-mode optical fiber*, Vol. 74, No. 4, journal of April 2010 physics pp. 591(603).

Appendix I

OTDR Trace for Data Set without Vibration (WoV).

Anritsu NetWorks/OTDR - Version 4.1
Date: 02/19/18 Time: 03:58 PM

PROJECT WORK1.SOR 5 km/0.200 m



A: 1.2771 km B: 3.8312 km A -> B: 2.5541 km	Index: 1.468200 Splice Loss: -0.076 dB Reflectance: N/A	[H] 50ns / 5.0m Avg: Fast 3584 /1550 nm/SM

```
-------------------- Page  1 --------------------
[   Language:                                    ]
[   Cable ID:                                    ]
[   Fiber ID:                                    ]
[ Wavelength: 1550                               ]
[   Org. Loc:                                    ]
[  Term. Loc:                                    ]
[ Cable Code:                                    ]
[  Condition:                                    ]
[   Operator:                                    ]
[    Comment:                                    ]
[   Supplier: Anritsu                            ]
[ OTDR Model: MT9083A-063                        ]
[        S/N: 6200763765                         ]
[ Optics Mod:                                    ]
[        S/N:                                    ]
[   S/W Rev.: 4.00                               ]
[      Other:                                    ]
--------------------------------------------------
```

```
Primary Trace: PROJECT WORK1.SOR
         Date: 02/13/19           Range:          5 km
         Time: 10:18 AM      Resolution:      0.200 m
 Product Type: MT9083A-06   Pulse Width:         50 ns
  Opt. Module:                    Index:   1.468200
   Fiber Type: Singlemode    WaveLength:       1550 nm
FAS Thresholds:             Horz. Shift:     0.0000 km
         Loss:      0.01 dB Vert. Shift:       0.00 dB
  Reflectance:    -60.00 dB No. Averages:      3584
  Fiber Break:      3.00 dB
  Backscatter:    -81.50     Trace Type: Anr SR4731
  Trace Flags: Analysis
          ORL: N/A
```

Analysis Results -- PROJECT WORK1.SOR

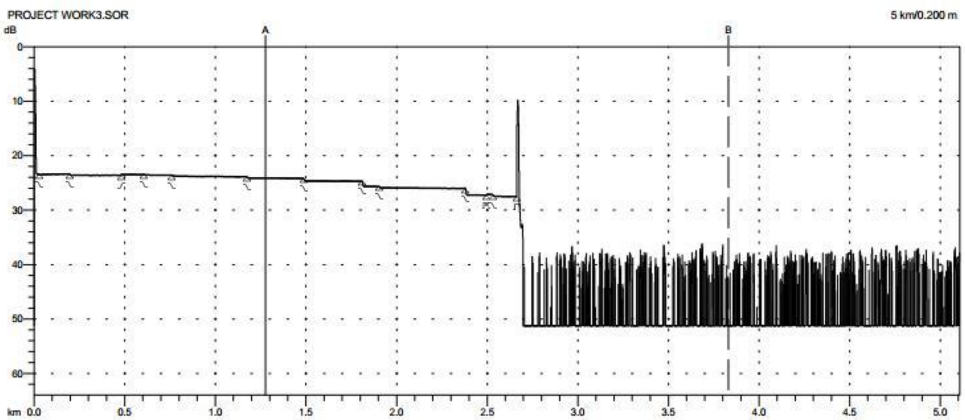
Feature #/Type	Location (km)	Event-Event (dB)	(dB/Km)	Loss (dB)	Refl (dB)
1/N	0.0278	-0.13	-4.786	0.05(2P)	
2/N	0.1941	-0.10	-0.584	0.20(2P)	
3/N	0.4747	0.04	0.132	-0.13(2P)	
4/N	0.6063	-0.00	-0.020	0.06	
5/N	0.7595	0.02	0.161	0.19	
6/N	1.1731	0.12	0.285	0.21	
7/N	1.4683	0.08	0.255	0.05	
8/N	1.4861	0.01	0.297	0.46(2P)	
9/N	1.7644	0.03	0.092	0.04(2P)	
10/N	1.8100	-0.01	-0.129	0.93(2P)	
11/N	1.9015	0.01	0.148	0.24(2P)	
12/N	2.3794	0.07	0.152	1.21(2P)	
13/N	2.4937	0.02	0.135	-0.10(2P)	
14/N	2.5288	0.02	0.464	0.33(2P)	
15/E	2.6639	0.00	0.010	>3.00	-33.31

Overall (End-to-End) Loss: 3.90 dB

Appendix II

OTDR Trace for Data Set with Vibration (WV).

Anritsu NetWorks/OTDR - Version 4.1
Date: 02/19/18 Time: 04:00 PM



A: 1.2771 km B: 3.8312 km A -> B: 2.5541 km	Index: 1.468200 Splice Loss: -0.060 dB Reflectance: N/A	[H] 50ns / 5.0m Avg: Fast 3584 /1550 nm/SM

```
-------------------- Page   1 --------------------
[   Language:                                     ]
[   Cable ID:                                     ]
[   Fiber ID:                                     ]
[ Wavelength: 1550                                ]
[   Org. Loc:                                     ]
[  Term. Loc:                                     ]
[ Cable Code:                                     ]
[  Condition:                                     ]
[   Operator:                                     ]
[    Comment:                                     ]
[   Supplier: Anritsu                             ]
[ OTDR Model: MT9083A-063                         ]
[        S/N: 6200763765                          ]
[ Optics Mod:                                     ]
[        S/N:                                     ]
[   S/W Rev.: 4.00                                ]
[      Other:                                     ]
---------------------------------------------------
```

```
Primary Trace: PROJECT WORK3.SOR
         Date: 02/13/19          Range:         5 km
         Time: 10:32 AM     Resolution:     0.200 m
 Product Type: MT9083A-06  Pulse Width:        50 ns
  Opt. Module:                   Index:  1.468200
   Fiber Type: Singlemode   WaveLength:      1550 nm
FAS Thresholds:            Horz. Shift:    0.0000 km
         Loss:     0.01 dB Vert. Shift:      0.00 dB
  Reflectance:   -60.00 dB No. Averages:     3584
  Fiber Break:     3.00 dB
  Backscatter:   -81.50     Trace Type: Anr SR4731
  Trace Flags: Analysis
          ORL: N/A
```

Analysis Results -- PROJECT WORK3.SOR

Feature #/Type	Location (km)	Event-Event (dB)	Event-Event (dB/Km)	Loss (dB)	Refl (dB)
1/N	0.0278	-0.12	-4.294	0.02(2P)	
2/N	0.1929	-0.12	-0.706	0.24(2P)	
3/N	0.4769	0.02	0.060	-0.13(2P)	
4/N	0.6073	0.01	0.041	0.08(2P)	
5/N	0.7593	0.02	0.124	0.20(2P)	
6/N	1.1729	0.08	0.186	0.22	
7/N	1.4855	0.13	0.407	0.49	
8/N	1.8098	0.02	0.069	0.94(2P)	
9/N	1.9017	0.03	0.379	0.23(2P)	
10/N	2.3796	0.08	0.172	1.24(2P)	
11/G	2.4928-2.5235	0.04	0.376	-0.12(2P)	
12/N	2.5288	-0.01	-0.291	0.32(2P)	
13/E	2.6639	-0.01	-0.094	>3.00	-33.34

Overall (End-to-End) Loss: 3.90 dB