

Analysis of the Compressed Video with HEVC under Optical Link Transmission

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Abstract – We study the feasibility of video transmission over optical fibre to optimise bandwidth with the implementation of HEVC codec features. We use simulation (Matlab and the OptiSystem software). Different values of the CRF are used to evaluate its impact on the visual quality and the size of the encoded file, as well as its influence on the video transmission performance. The simulation results show that by adjusting the CRF, the encoders can optimise the compression of the video data to reduce the file size while preserving an acceptable visual quality. This makes it possible to adapt the transmission to the bandwidth constraints of the optical fibre, by choosing higher CRF values to reduce the size of the files and save bandwidth, or lower values to maintain optimal quality when the bandwidth is sufficient. In addition, from the optical fibre point of view, the dispersion weakens and the eye opens, and it is observed that the length of the fibres is inversely proportional to the signal transmission quality. Thus, the judicious use of different CRF values can contribute to efficient and high-quality video transmission via optical fibre.

Keywords – CRF (Constant Rate Factor), HEVC, OptiSystem, PSNR, video coding, YUV.

I. INTRODUCTION

Current researchers are focusing on an in-depth analysis of video characteristics of different types of networks to optimise the transmission and efficient and adaptive routing of video data from source to destination that requires a transport protocol. A network path consists of a succession of links, each with its own bandwidth [1], which is not the only factor that affects the performance of a network. Therefore, it is necessary to minimise the error rate in the channels by designing a suitable means of transmission that allows a specific treatment for losses between connections on the wired network and on the wireless network [2], namely, compression, which is a viable part of video communication. A wide variety of codecs are available, none of which are suitable for all situations. In addition, HEVC, as a state-of-the-art video standard, has been developed to achieve better compression performance than previous standards, achieving a bit rate reduction range of 50 % for equal perceptual video quality [3]. Given the above facts, the use of HEVC is of the utmost importance in video compression, as it is well suited to network transmission

The migration to the use of optical fibre has required several developments, because nowadays it represents the most widely used transmission medium in a wide range of fields, especially video transmission [4]. Our work presented in this article is part of the efforts listed later to evaluate and analyse the performance of a transmission system that is data, images, videos. Given the market for optical fibre, its use in local and long-distance cabled transmission will eventually see rapid development and become more popular owing to its many advantages, especially, low cost, high transmission bandwidth and no electromagnetic interference. A lot of research has been conducted, first helping with the theoretical analysis of the system, and then moving towards system improvement.

Malik et al. [5] studied the design and modelling of a single and dual channel system using OptiSystem software. Alvarado et al. [6] demonstrated that when using the soft decision FEC boundary paradigm with low code rates and high order modulation formats, the spectral efficiencies can be underestimated. Poulou's [7] survey on VLC shows that it has a great influence on several communication domains and can be easily implemented in different applications such as vehicle-to-vehicle data transmission, position sensing, intelligent transportation systems and image sensor communications, as well as Internet access and audio and video transmission. The author [8] presents a simulation study of a transmission system model with software (OptiSystem) to study the optical communication link characteristics of POF and GOF under the same conditions to establish performance and cost based operating limits considering distance. Chakraborty's [9] objective was the design of a passive optical system in hospital environment with reduced noise figure, BER, gain and quality factor for efficient data transmission (data considered were image (X-ray) and video) using OptiSystem software. Ji et al. [10] introduced simulation in OptiSystem to study image transmission in a cross-layer security system that combined OCDMA and algorithmic cryptography.

We can transfer existing videos from reliable sources such as research folders, or create our own. The paper focuses on the examination of some video sequences transmitted via optical link. The proposed system was implemented in OptiSystem

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software and evaluations were performed by BER (bit error rate) measurements and PSNR (peak signal to noise ratio) objective metrics. We examined the characteristics of the operating techniques of each channel of the video transmission chain, and we found several issues, including the performance of the error correction codes, which relies on the coding and decoding algorithms, the optical fibre. These several criteria, such as the bit rate, the propagation distance and the good transmission quality, imply that there is still further research and improvements needed in this area.

This paper is organised into four sections. In Section I, we review the current active research areas in the field of optical transmission. Specifically, in Sections II and III, we present a general conceptual framework for defining video transmission over optical fibre using the HEVC encoder. Based on this framework, we present a simple but systematic procedure whose experimental results and conclusions will be presented in Sections IV and V, including our proposals for future work.

II. OPTICAL TRANSMISSION SYSTEM ANALYSIS AND QUALITY ASSESSMENT

The video transmission could consist of comparing the visual quality and the file size of different videos encoded with the HEVC encoder with different values of a well-defined characteristic, then transmitting them over a network to evaluate the performance of transmission. Figure 1 shows a schematic diagram of the transmission by an optical link.

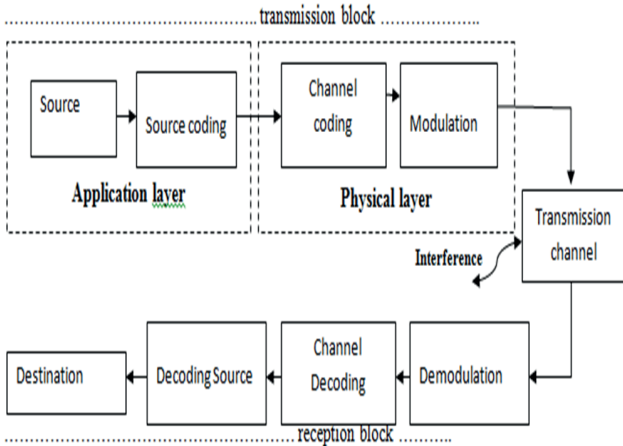


Fig. 1. Schematic diagram of an optical link.

In this article, for a basic link of optical transmission, the essential elements are the following: on the transmitter side – bit generator, MZ modulator, a modulator driver, laser source; on the channel side – optical fibre, amplifier, multiplexer; and on the receiver side – PIN photodiode, Analyser. As shown in Fig. 2. The transmitter section consists of a data source that produces a pseudo-random sequence of bits at 10 Gbit/s. The electrical pulse generator (NRZ or RZ depending on the required modulation format) converts the basic data into electrical pulses that modulate the laser ignition via the external Mach-Zehnder modulator. After modulation, the data is sent via an SMF fibre optic cable, the wavelength of the source signal propagating in the latter is around 1550 nm, the characteristics

of which are shown in Table I. On the receiver side, the data received from the SMF fibre optic output is detected by a photo detector, PIN type, and then passed through an electrical low-pass Bessel filter and a BER analyser or an eye diagram analyser.

TABLE I
ALL PARAMETERS OF THE PROPOSED LINK

Parameters	Values
Channel wavelength	193.1 THz
Channel bit rate	10 Gbps
SMF dispersion	17 ps/nm/km
SMF attenuation	0.2 dB/km

Simulation of the optical system was performed using the OptiSystem simulation software. The performance of the designed and modelled lightwave system and its received data are measured, evaluated and analysed.

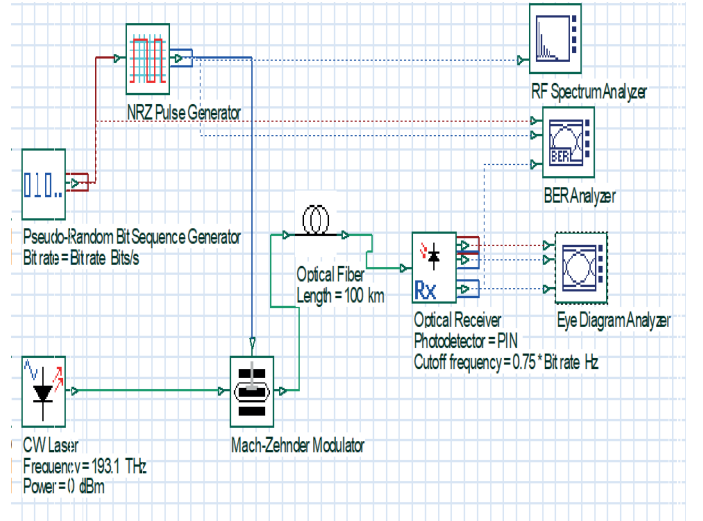


Fig. 2. Block diagram of an optical link under OptiSystem software.

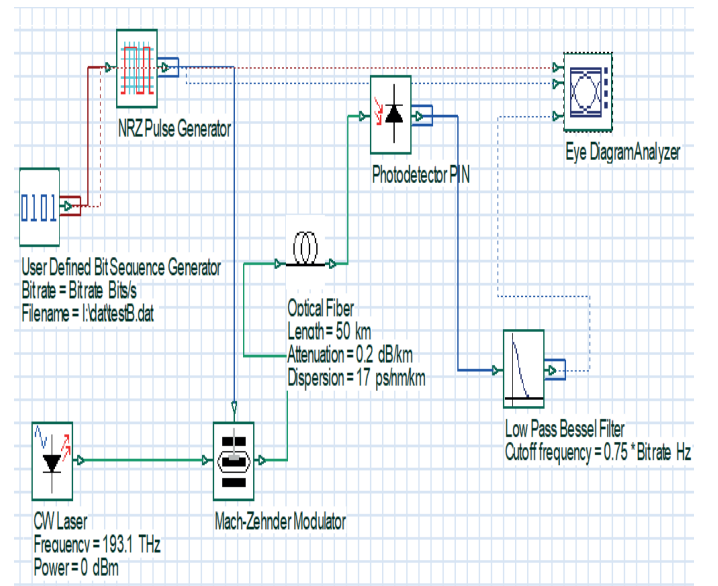


Fig. 3. Basic diagram of an optical link with generator change.

The work involves the modelling and simulation of two link transmitters. The first is a random sequence transmitter (Fig. 2). The second is a transmitter whose generator is changed to be able to download our video sequence, and we redo the same work: we keep the same chain with the same fibre but with a downloaded sequence, different lengths, and different rates (Fig. 3). Both transmitters were designed using several components provided by the optiwave library.

III. METHOD OF COMPRESSION

HEVC can save nearly half of the bit rate with the same video quality and can effectively reduce video transmission costs [11]. A good balance can be achieved in terms of computational complexity, compression ratio, error resistance and system latency. Using HEVC to design video transmission solutions for specific applications is an important research field with broad application prospects.

A. Generating a Video Signal Using the HEVC Standard

The input is raw video files recorded in (YUV) format with 1080 p (FHD) resolution. Using FFMPEG software (Fast Forward MPEG), we compress the sequences by choosing libx265 library at different CRF (Constant Rate Factor) values. CRF should be used to define a constant image quality. The CRF scale is logarithmic between 0 and 51. A difference of 6 points doubles or divides the final file size by about 2. A small number equals better quality but more computing time, the default value is often 23. The choice of CRF depends on the type of image to encode the resolution of the image, the desired quality or the desired file size. In our work, we encoded the same video with CRF values ranging from 17 to 32, then measured the resulting visual quality and the file size for each encoding. We then transmitted these videos over a local or remote network, measuring the delay, the loss rate and the quality perceived by the end user.

TABLE II
COMPRESSION RESULTS USING LIB265 OF FFMPEG SOFTWARE WITH DIFFERENT CRFS

Video sequence (YUV)		YachtRide (Size 1.73 Go)	Beauty (Size 1.73 Go)	ReasySteady (Size 1.73 Go)
CRF = 17	Bitrate Kb/s	17 509.38	28 372.24	10 375.49
	Size Mo	50.1	81.1	29.6
	PSNR (dB)	44.620	41.465	45.180
CRF = 22	Bitrate Kb/s	9229.67	5176.51	5273.07
	Size Mo	26.4	14.8	15.0
	PSNR (dB)	42.037	39.803	42.992
CRF = 27	Bitrate Kb/s	4682.24	1218.73	2869.84
	Size Mo	13.4	3.49	8.21
	PSNR (dB)	39.394	39.187	40.490
CRF = 32	Bitrate Kb/s	2196.21	594.71	1572.76
	Size Mo	6.29	1.70	4.50
	PSNR (dB)	36.763	38.396	37.789

B. Performance Evaluation of the Proposed Single Optical Link

The objective in this part is to evaluate the performance of the proposed simple optical link as mentioned in Fig. 2 according to the variation of the distance of SMF optical fibre

at 10 Gbit/s, in order to observe the effect of the latter and suggest other solutions. Fig. 5 illustrates the eye diagrams corresponding to this simple simulation. The poorer the signal, the more the eye diagram is closed, the lower the quality factor, and the more difficult it is to detect the signal without error.

In Table II, we report the results of the simulation of metrics parameter evaluations (Quality factor and BER). For the second step, the algorithm is followed as illustrated in Fig. 4.

TABLE III
EFFECT OF THE LENGTH (BER, Q)

Length (L), km	Quality factor (Q), dB	Binary Error Rate (BER)
10	34.152	0
50	12.749	$1.500 \cdot 10^{-37}$
70	3.812	$6.647 \cdot 10^{-5}$
80	3.844	$5.755 \cdot 10^{-5}$
100	3.324	$3.992 \cdot 10^{-4}$
105	3.019	$1.225 \cdot 10^{-3}$

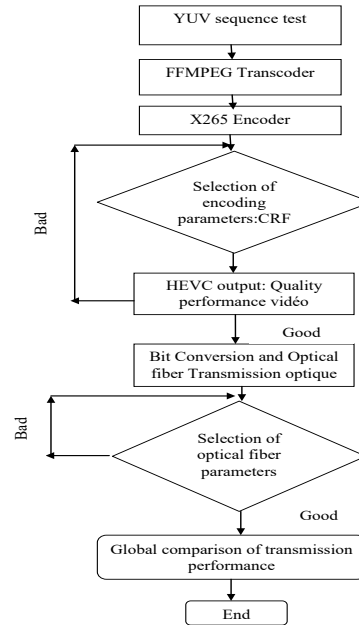


Fig. 4. Transmission algorithm.

Now we change the generator to be able to download our video sequence and we redo the same work: we keep the same channel with the same fibre but with a downloaded sequence, different lengths, and different speeds (Fig. 5). In this part, we relied on the evaluation of the impact of the CRF on the visual quality and the size of the encrypted file, as well as on its impact on video transmission performance, mainly, and also on the choice of determining the best CRF value to use according to storage and network bandwidth limitations.

To have good transmission, it is necessary to evaluate the performance of the studied system, which is among others the factor of quality and the diagram of the eye. Knowing that the standards fixed in the field of telecommunications require, to maintain the quality of transmission, a factor Q should be higher than 6, which corresponds to a BER lower than 10^{-9} . For this

purpose, several simulations have been made for different variations of the flow in order to show the transmission quality.

For the generation and transmission of a video stream (Bit-Stream video), we downloaded raw video sequences (YUV), converted them to bit and saved them as .dat file using Matlab. For the implementation of a transmission system based on an optical fibre, we used the OptiSystem software. Both steps were performed in simulation mode (Matlab and OptiSystem). We then tried to ensure a direct link using a compressed video with standard HEVC (the FFMPEG software) but with two different optical links (different fibres, or the same one with different parameters).

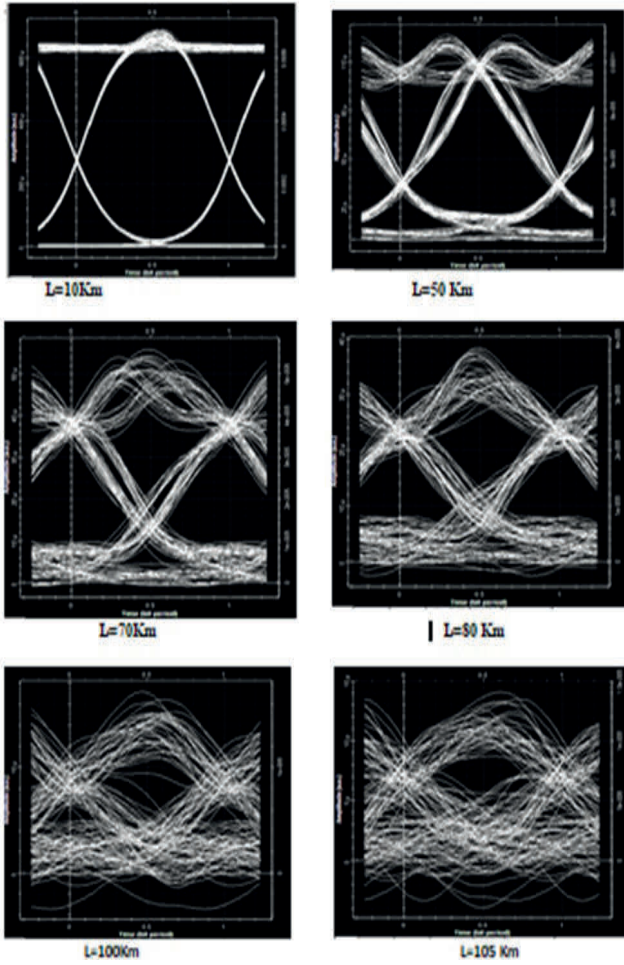


Fig. 5. Eye diagrams as a function of SMF length.

IV. RESULTS AND DISCUSSION

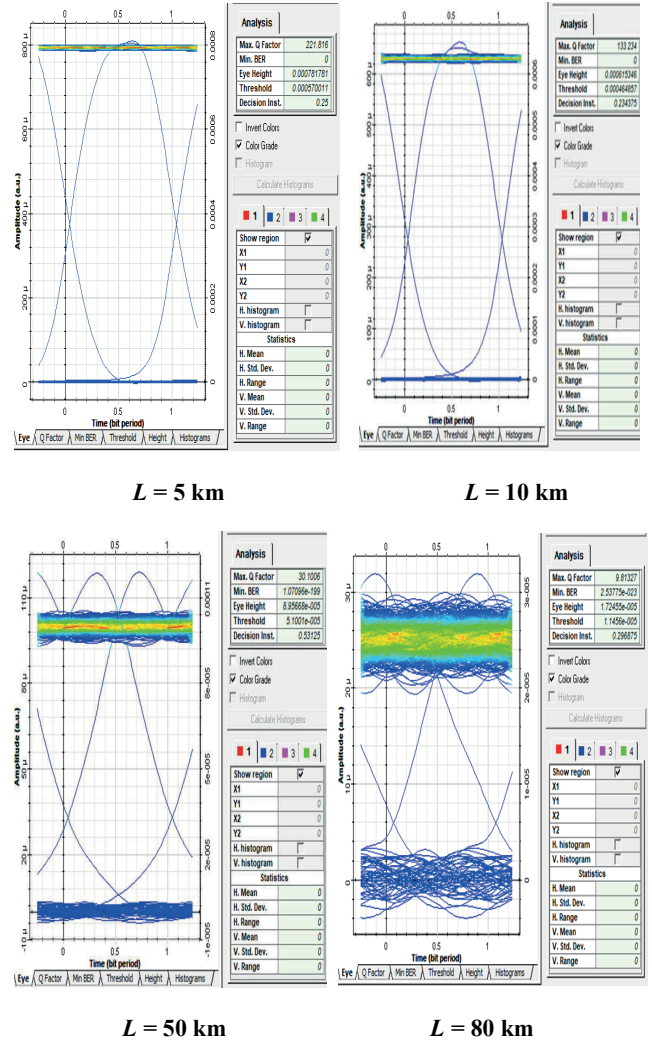
For the generation and transmission of the video stream (Bit-Stream video), we downloaded raw video sequences (YUV) and converted them to bit and saved them in a .dat file using Matlab. For the implementation of a transmission system based on an optical fibre, we used the OptiSystem software. The two steps were performed in simulation mode (Matlab and OptiSystem). Then we tried to ensure a direct link with the use of a compressed video to the HEVC standard (using the FFMPEG software) but with two different optical links (the same fibre with different parameters). This algorithm was

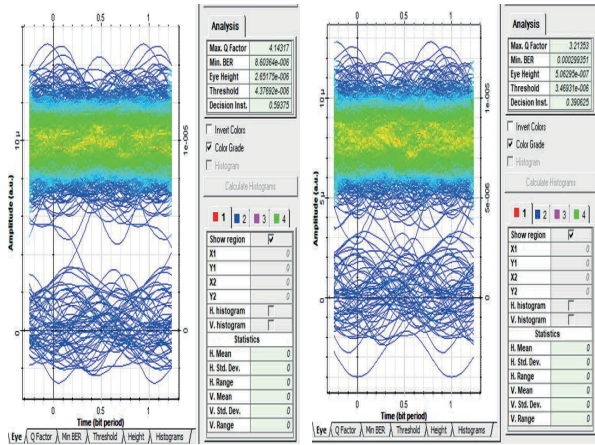
calculated as illustrated in Fig. 4. The choice of the CRF allowed us to observe that the results obtained showed that by increasing its value the value of the PSNR (peak signal to noise ratio) decreased (Table II). We could, therefore, control the rate of the input signal.

The lower the CRF, the higher the quality of the video, but the higher the bit rate required to transmit the video. Conversely, a higher CRF reduces the quality of the video, so it requires less bandwidth to be transmitted.

We note that the results obtained in Figs. 6–8 show that the simple optical link for different lengths and different rates does not meet the requirements of good transmission, i.e., the more the rate increases, the value of the quality factor at the output of the signal becomes low. Knowing that the standards set in the field of telecommunications require, to maintain transmission quality, a Q factor should be greater than 6, which corresponds to BER that is less than 10^{-9} .

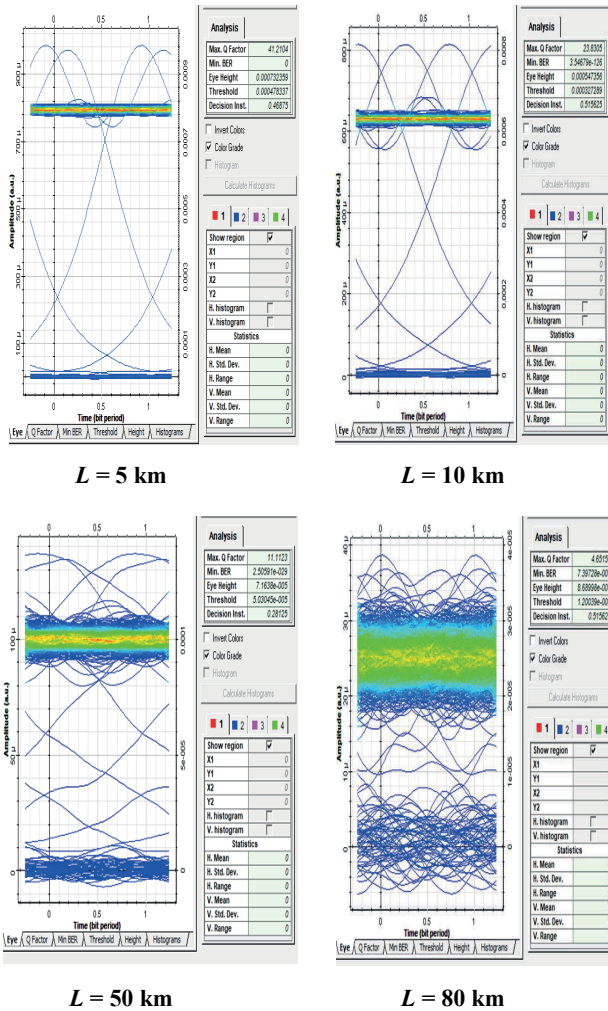
FOR A THROUGHPUT OF 10 Gb





$L = 100 \text{ km}$ $L = 105 \text{ km}$
Fig. 6. Eye diagrams as a function of SMF length for a 10 Gb throughput.

FOR A THROUGHPUT OF 40 Gb



$L = 5 \text{ km}$ $L = 10 \text{ km}$ $L = 50 \text{ km}$ $L = 80 \text{ km}$
Fig. 7. Eye diagrams as a function of SMF length for a 40 Gb throughput.

We can see from the eye diagrams obtained that with a minimum rate, the effect of dispersion becomes weaker and the eye opens, and we can also see that the length of the fibre is inversely proportional to the quality of signal transmission.

From these results, we can see that if the length of the fibre increases, the effects of chromatic dispersion increase, which leads to poor signal quality at the reception side (Table IV). To overcome this problem, we must recommend solutions. This requires a modification of our transmission chain by a compensation to improve the diagrams and seek to optimise the bandwidth imposed in our work, which is part of two research areas. The first concerns the architectural design of a transmission chain with high speed, optimisation of the bandwidth and low cost. The second one aims at developing an encoder/decoder system (HEVC), which is safe in operation and allows for an optimal protection of the data.

FOR A THROUGHPUT OF 100 Gb

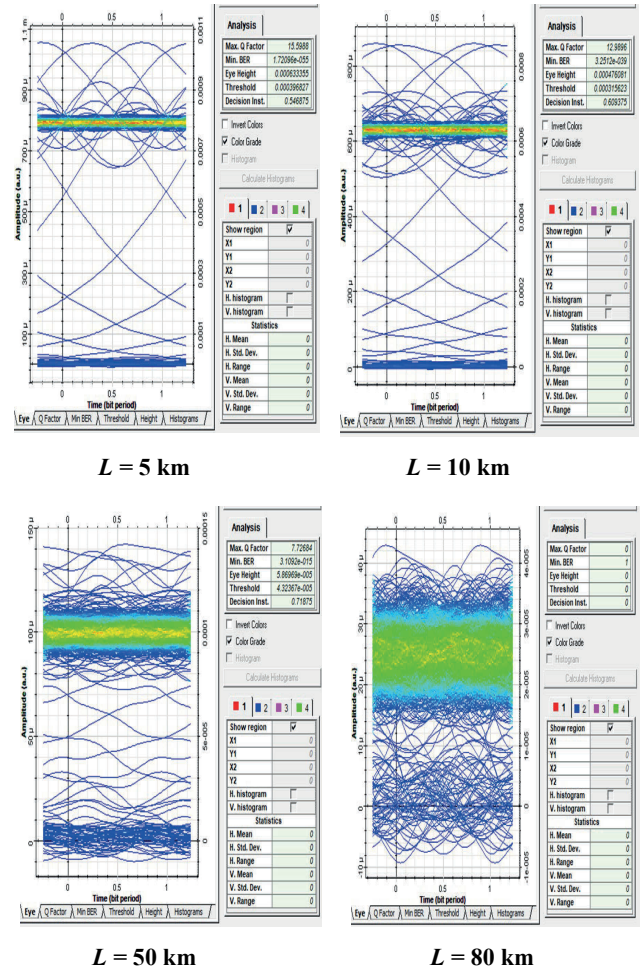


Fig. 8. Eye diagrams as a function of SMF Length for a throughput of 100 Gb

TABLE IV
KEY EVALUATION PARAMETERS (BER AND Q) OF VARIOUS BIT RATES

Bit rate	Length				
		5 km	10 km	50 km	80 km
10 Gb	Q	221.81	133.23	30.10	9.81
	BER	0	0	$1.07 \cdot 10^{-19}$	$2.53 \cdot 10^{-23}$
40 Gb	Q	41.21	23.83	11.11	4.65
	BER	0	$3.54 \cdot 10^{-126}$	$2.50 \cdot 10^{-29}$	$7.39 \cdot 10^{-007}$
100 Gb	Q	15.59	12.98	7.72	0
	BER	$1.72 \cdot 10^{-55}$	$3.25 \cdot 10^{-39}$	$3.10 \cdot 10^{-29}$	0

V. CONCLUSION

We have demonstrated the feasibility of video compression under optical link transmission in this simulation study.

The simulation results obtained show that transmission performance depends on several component link parameters.

Key performance parameters decreased and degraded due to the phenomenon of dispersion and optical fibre loss at the operating wavelength. Furthermore, the relationship between the CRF of the HEVC encoder and video transmission is that the choice of CRF directly affects the bandwidth requirements for video transmission. By choosing an appropriate CRF, content providers can optimise visual quality, while minimising transmission costs.

It is, therefore, necessary to find a solution to optimise video transmission using fibre compensation and filters in the received blocks. Finding more efficient feature extraction methods is a future task.

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