OPTICAL SOLITONS SIMULATION IN SINGLE MODE OPTICAL FIBER OVER 40GB/S

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Bachelor of Electrical Engineering (Power Electronic & Drive)
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This report is submitted in partial fulfillment of the requirements for the
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"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering
(Power Electronic & Drives)"

Signature : ………………………………………………

Supervisor's Name : MR. LOI WEI SEN

Date : 18TH JUNE 2013

I declare that this report entitle “Optical solitons simulation in single mode optical fiber over 40Gb/s” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ………………………………………………

Name : ARBAEYAH BINTI ABDUL RAZAK

Date : 18TH JUNE 2013

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ABSTRACT

This report indicates about the optical solitons simulation in single mode optical fiber over 40 Gb/s. This project develops the optical solitons modeling and simulates the signal propagation by using OptiSystem software. Two different types of pulse generators are being used in the simulation which is the optical Gaussian pulse generator and optical sech pulse generator. In addition, both of the pulse generators will be simulated at different distances varied by the nonlinear dispersive fiber total field. Then the data achieved from the simulation is compared and analysed and included in the discussion and analysis section. This project is significant for the ultrafast communication system that is using optical fiber as it simulates optical solitons for over 40 Gb/s.

ABSTRAK

Laporan ini menunjukkan tentang simulasi soliton optik di dalam mod tunggal gentian optik untuk kelajuan 40 Gb/s. Projek ini merangka model soliton optik dan menghasilkan penyebaran signal optik melalui simulasi mengunakan perisian OptiSystem. Dua jenis penjana signal optik yang berlainan digunakan di dalam simulasi ini iaitu penjana nadi Gaussian optik dan penjana nadi sech optik. Disamping itu, kedua-dua jenis penjana optik yang digunakan akan dijalankan simulasi mengikut jarak yang berbeza dgn mengubah nilai di komponen serakan linear jumlah serat. Kemudian data yang diperoleh daripada simulasi tersebut akan dibandingkan dan dianalisis dan ditempatkan di dalam ruang diskusi dan analisis. Projek ini boleh member manfaat kepada system komunikasi had laju tinggi yang mengunakan gential optik kerana ianya menjalankan simulasi soliton optic pada had laju 40 Gb/s.

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$\propto$	-	Fiber loss
γ	-	Self-phase modulation
A_{eff}	-	Cross section area of optical fiber
B	-	Magnetic field density
β_2	-	Group velocity dispersion
D	-	Electric flux density
E	-	Electric field vector
H	-	Magnetic field vector
J	-	Current density vector
L_D	-	Dispersion length
n_2	-	Nonlinear reference index
P_N	-	Power value
ρ	-	Charge density
z_0	-	Soliton period

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Communication can be widely divided into voice communication (telephone, radio, mobile phone), video communication (pictures, moving objects, television broadcasting) and also data communication. Over the years, the medium through which the information for the communication is passed such as from mere smoke signals or reflecting sun rays as simple ways of communication between two points from long time ago has been greatly evolved to the advanced technology of wireless communication and even to the advancement technology of optic systems connecting continents for high speed data communication.

Solitons are a special type of optical pulses that can travel through an optical fiber undistorted for tens of thousands of kilometers. Optical solitons can be formed when dispersion and nonlinearity counteract one another. This project undergo optical solitons simulation in single mode optical fiber for over 40 Gb/s by using optical Gaussian and optical sech as pulse generator with different length of distance to analyse the effect of the nonlinear dispersive fiber.

1.2 Problem Statement

Nowadays, many countries are using optical fiber for the communication systems regardless for the internet connection, phone telecommunication or internet protocol television. This means that ultrafast optical solitons are in demand as it means higher speed of communication, lower losses and provides stability. In Malaysia, the leading communication systems that use optical fiber is most probably the UniFi provided by the TM Berhad. However, the highest bit/rate package available is only over 50Mb/s. Meanwhile, the demonstration from Thierry Georges on 1998 has shown that the highest speed that the optical solitons could be achieved is 1 terabit per second. This shows that there are lots of rooms for improvement in optical fiber communication systems. In fact, the bandwidth was increase exponentially after the millennium due to overwhelming demand of internet users and the broom of information technology (IT). Ultra-fast telecommunications was trend of the current telecommunication development which allows more data can be transfer from a part to another part.

Optical solitons is nonlinear wave that exhibit dual nature properties, i.e. particle wavelike that travel in nonlinear dispersive fiber. Optical solitons is one of the idea of signal used to transfer despite of higher bandwidth, it can balance the effect of nonlinearity and dispersion in optical fiber that the undistorted signal travel over a distance.

This project examines the possibility of generating optical solitons propagation in fiber optics at the rate of 40Gb/s in nonlinear fiber optics by undergoing the simulation of optical solitons in single mode optical fiber with the use of OptiSystem software. Besides that, this project also determines whether the effect of the nonlinearity and dispersion could be observed with the use of sech pulse and Gaussian pulse signals over a distance.

1.3 Project Objectives

This project will embark on the following objectives:

1. To simulate the signal of optical solitons propagate in fiber optics at the rate of 40Gb/s.
2. To investigate the effect of the nonlinearity and dispersion in the optical fiber with sech pulse and Gaussian pulse signals over a distance.

1.4 Project Scope

This project cover the simulation of the optical solitons signal propagation for only the single mode nonlinear optical fiber with the transmission rate of over 40Gb/s. The optical soliton modelling is design and simulated using the OptiSystem software in order to study the physical properties of the optical solitons wave propagation. The simulation is simulated by using two types of optical generators only which are the optical Gaussian pulse generator and optical sech pulse generator with the nonlinear dispersive fiber total field varied from 3.9482 km to 10 km, 20 km and 30 km to study the effect of the nonlinearity and dispersion. The output parameters that will be analyze is the peak values, dispersion length, solitons periods, overshoots and undershoots.

1.5 Project Summary

From this chapter it can be summarised in short that the project is about the development of optical solitons wave propagations through the simulation of the optical solitons modelling by using two different types of optical pulse generators that are the optical Gaussian pulse generator and optical sech pulse generator. These two types of generators are simulated at different length of distances using the nonlinear dispersive fiber total field in order to examine the effect of the nonlinearity and dispersion in optical solitons wave propagations. As for that, the next chapter will explained in detailed on how optical solitons are formed theoretically along with their unique characteristics and also the predicted formed of the optical solitons simulation propagation.

CHAPTER 2

LITERATURE REVIEW

2.1 Solitons History

Solitons is formerly known as solitary waves and it is first introduced by James Scott Russel on 1834 in which he had noticed a mass of water in a canal travel undistorted for over several kilometer and he named it as Wave of Translation[1][2]. This particular wave was then recognized as solitary waves. But before 1960s their characteristics were not fully learned until the inverse scattering method is introduced [1][3].

In 1965 the word *solitons* was developed to imitate the particle-like nature of solitary waves that stay undamaged even after mutual collisions [4]. For nonlinear optics, solitons are characterized as being either *temporal* or *spatial*, depending on whether the captivity of light occurs in time or space during wave propagation.

Temporal solitons signify optical pulses that maintain their shape, while spatial solitons signify self-guided beams that stay confined in the transverse directions orthogonal to the direction of propagation. Both temporal solitons and spatial solitons are develop from a nonlinear change in the refractive index of an optical material induced by the light intensity in which it is the *optical Kerr effect* [5-7]. The intensity that depends on the refractive index causing spatial self-focusing (or self-defocusing) and temporal self-phase modulation (SPM), the two most significant nonlinear effects that are accountable for the development of optical solitons. The formation of spatial solitons happens when the self-focusing of an optical beam balances its natural diffraction-induced broadening.

However, it is the SPM that counteracts the dispersion-induced broadening of an optical pulse and leads to the formation of a temporal solitons [8]. For both situations, the pulse or the beam travel through an intermediate undistorted without changing its shape. It is later on studied when the group-velocity dispersion (GVD) is normal, optical fibers can support another type of temporal solitons which is the *dark solitons* and it usually appear as the intensity dips within clockwise background [9]. Besides that the standard pattern pulse-like solitons are known as *bright solitons*.

2.2 Spatial Optical Solitons

The bright or dark spatial solitons appear only when the nonlinear effects balance the diffractive effects accurately. The formation of spatial solitons in a self-focusing nonlinear medium can be studied by taking into account how light is restricted by optical waveguides. Optical beams are known that they have the inclination to diffract as they travel in any harmonized intermediate. But, by using refraction this diffraction can be fixed if the material refractive index is increased in the transverse region that is filled by the beam.

This kind of configuration becomes an optical waveguide and limits light to the high-index area by providing a balance between diffraction and refraction. The transmission of the light in an optical waveguide is described by a linear but inhomogeneous wave equation whose resolution produces a set of guided modes that are spatially restricted eigenmodes of the optical field in the waveguide that maintain their shape and met all boundary conditions. The similar effect is discovered before in which the restraint of diffraction through a local change of the refractive index can be created only by the nonlinear effects if they guide to a change in the refractive index of the intermediate in such a way that it is larger in the region where the beam intensity is large [10].

Basically, an optical beam can form its own waveguide and be trapped by this self-induced waveguide. On another note the creation of spatial solitons can also be learned by using the lens analogy. Diffraction forms a curved wavefront alike to that formed by a concave lens and spreads the beam to a wider area. The index gradient formed due to the self-focusing effect however, acts like a convex lens that tries to focus the beam toward the beam center. Fundamentally, a Kerr intermediate play role as convex lens and the beam can become self-trapped and travel without changing the shape if the
two lens effects cancel each other.

2.3 Temporal Optical Solitons

Some might ponder if solitons can be formed in a waveguide where an optical beam is restricted at both transverse dimensions. Although it is obviously impossible as far as spatial solitons are concerned but it turns out a new type of solitons can still be created in such waveguides if the occurrence light is in the form of an optical pulse. That particular temporal solitons signify optical pulses that preserve its own shape during propagation. In 1973, the existence of this specific temporal solitons was predicted in the context of optical fibers [11].

The most important thing that differentiate temporal optical solitons from the clockwise case explained in the spatial solitons before is that the pulse envelope has now become time dependent and can be expressed as

$$E\ (r,t) = \ A(Z,t)\ F(X,Y)exp(i\beta_0 Z) \qquad (2.1)$$

In which F (X, Y) is the transverse field distribution associated with the essential mode of a single mode fiber. Meanwhile, from the equation it is observed that the time dependence of A (Z, t) indicates that all spectral components of the pulse might not travel at the same pace inside an optical fiber because of the chromatic dispersion. This effect is included by modifying the refractive index

$$\tilde{n} = n(\omega) + n_2\ |E|^2 \qquad (2.2)$$

Where it can be said that the frequency dependence of n(ω) acts as a vital role in the development of temporal solitons. This creates the broadening of optical pulses in the nonexistence of the nonlinear effects and acts as the part corresponding to that of diffraction in the context of spatial solitons. By obtaining an equation satisfied by the pulse amplitude A (Z, t) it is useful to work in the Fourier domain for including the effects of chromatic dispersion and to treat the nonlinear term as a small perturbation [12].

2.4 Nonlinear Schrödinger Equation

The nonlinear effects in optical fibers are usually studied by using short optical pulses because the dispersive effects are improved for such pulses. The wave propagation of optical pulses through fibers can be examined by solving Maxwell's equations

$$\Delta \times H = J + \frac{\partial D}{\partial t} \tag{2.3}$$

$$\Delta \times E = - \frac{\partial B}{\partial t} \tag{2.4}$$

$$\Delta B = 0 \tag{2.5}$$

$$\Delta D = \rho \tag{2.6}$$

Where H and E are the magnetic and electric field vector, while B and D are magnetic and electric field vector respectively and J denotes the current density vector and ρ is the charge density in which if we slowly varying the envelope approximation, these equations will eventually lead to the following Nonlinear Schrödinger (NLS) equation [13].

$$\frac{\delta A}{\delta z} = \frac{\alpha}{2} A + \frac{j}{2} \beta_2 \frac{\partial^2}{\partial t^2} - j\gamma |A|^2 A \tag{2.7}$$

Where the linear part represents in the above equation is,

$$\frac{\partial \mathrm{A}}{\partial \mathrm{z}} = \frac{\propto}{2} \mathrm{A} + \frac{\mathrm{j}}{2} \beta_2 \frac{\delta^2 \mathrm{A}}{\delta \mathrm{t}^2} \tag{2.8}$$

In which it is the slowly varying envelope associated with the optical pulse and $\propto$ indicates the fiber losses meanwhile B_2 signify the group-velocity dispersion. However, the nonlinear part represent in the above NLS equation is,

$$\mathrm{j}\gamma |A|^2 A \tag{2.9}$$

As the γ is the self-phase modulation and from that govern the A_{eff} which is the cross section area of optical fiber [13][14].

Moreover according to Thomas E. Murphy in 2001 [14] it is stated that by solving the following mathematical modeling expression,

$$u(z,t) = \sqrt{\frac{|\beta_2|}{\gamma {T_0}^2} sech\left(\frac{t}{T_0}\right) exp\left(j\frac{\beta_2 z}{2{T_0}^2}\right)} \qquad (2.10)$$

The optical solitons pulse shape obtained is approximately as shown in Figure 2.1 below,

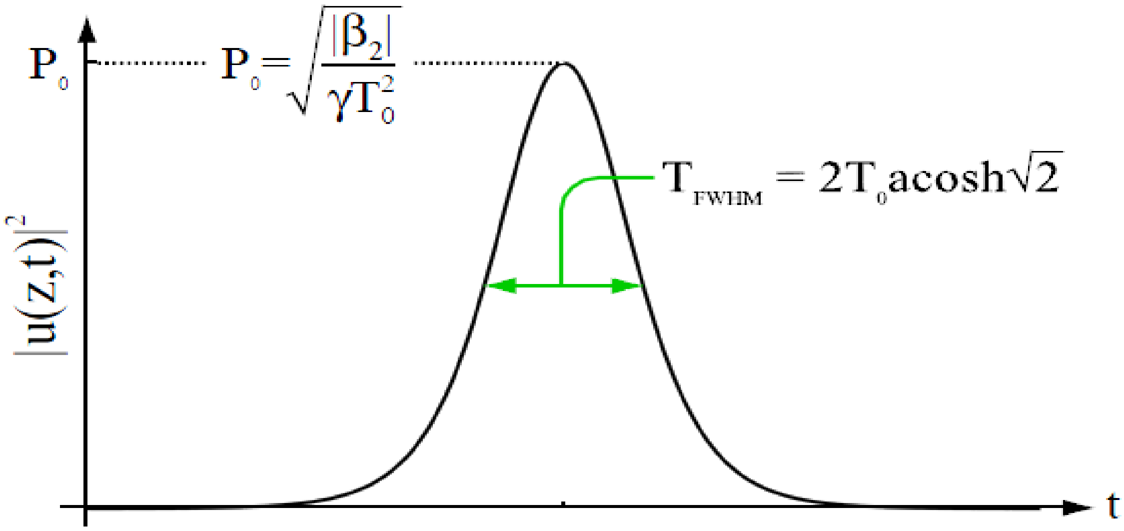


Figure 2.1: Pulse shape of optical soliton

From the figure 2.1 it can be determine that in contrast with the amplitude, solitons phase which is

$$exp\left(j\frac{\beta_2 z}{2{T_0}^2}\right) \qquad (2.11)$$

Where the above equation is not stationary and this phase evolution is known as solitons period. Besides, solitons period which is nominated as,

$$z_0 = \frac{\pi {T_0}^2}{2|\beta_2|} \qquad (2.12)$$

can be one of the parameter for a soliton [14].

2.5 Full Width at Half Maximum

A pulse has an optical power *P* which is energy per unit time that is substantial only within some short time intermission and is close to zero at all other times in the time varying domain. The pulse duration is usually defined as a full width at half maximum (FWHM) which is the width of the time interval within which the power is as a minimum half the peak power. The pulse shape of power versus time usually has a rather simple shape, explained for example with a Gaussian function or a sech^2 function, even though complicated pulse shapes can occur, in instance, as the effect of nonlinear and dispersive distortions, when a pulse travel through some intermediate [15].

Besides that FWHM could also be defined as a parameter normally used to explain the distance across of a "bump" on a curve or function. It is given by the length between points on the curve at which the function reaches half its maximum value [16].

CHAPTER 3

OPTICAL SOLITONS SIMULATION

3.1 Overview

From the previous chapter, this chapter will cover on the methodology for this project. Project methodology is important in order to decide the technique that is to be used in the project. Besides that, this section will describe the flow of this project. It is an important criterion that will be implemented in this project. This chapter also will discuss about procedures that will be use in this project when undergo the simulation of the optical solitons.

3.2 Project Methodology

This project methodology describes the step by step procedure from developing the optical solitons modeling circuit until the simulation of the optical solitons using both the optical Gaussian pulse generator and optical sech pulse generator. Besides that this project methodology will also explained how the optical solitons undergo simulation for both optical pulse generators at different distances of the nonlinear dispersive fiber total field. Moreover, this chapter will also portray how the simulation parameters are set up throughout the project along with the details how the result from the simulation is compared and analysed. The flow chart in Figure 3.1 illustrated in brief about the step by step procedure of the optical solitons simulation for single mode optical fiber over 40Gb/s in this project and the Gantt chart of the project is attached at Appendix A.

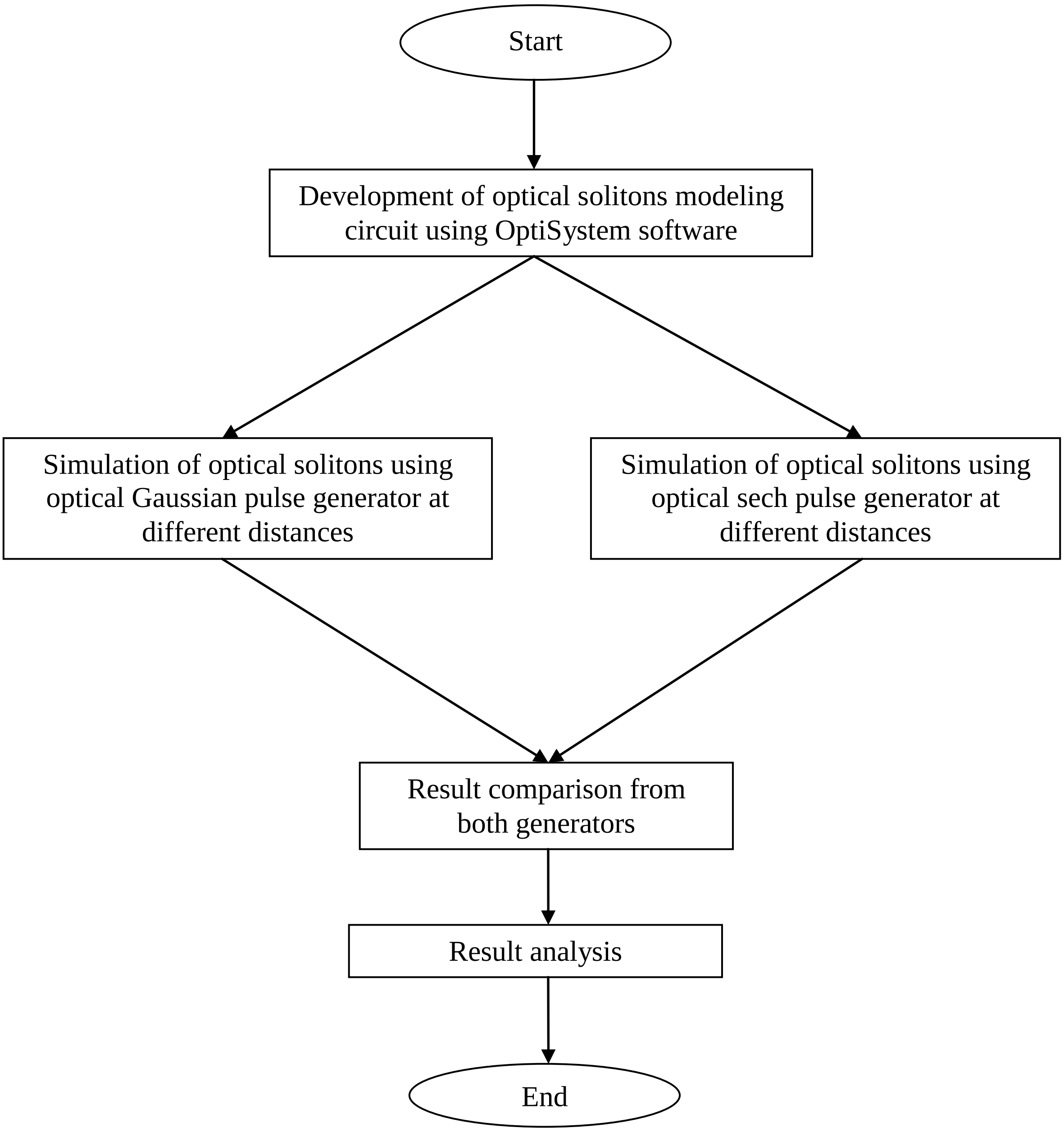
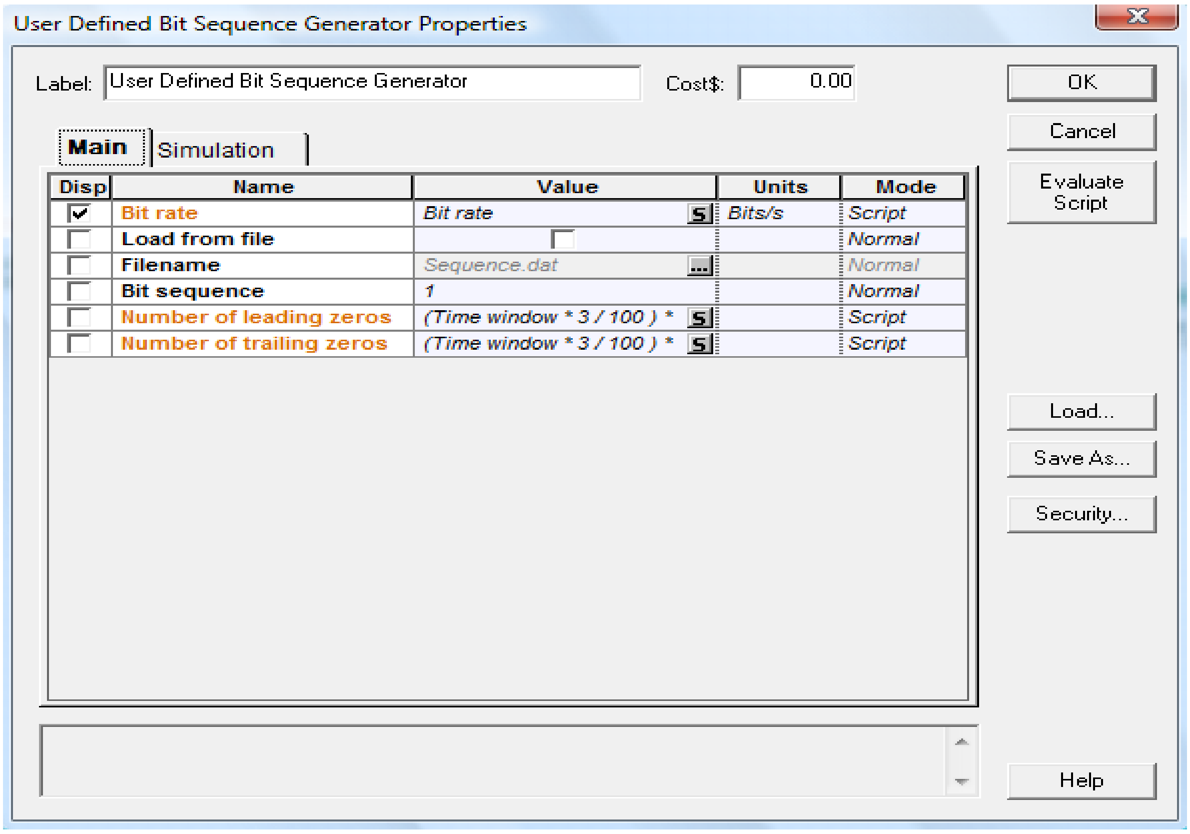


Figure 3.1: Flow chart of the optical solitons simulation

3.2.1 Development of simulation circuit using OptiSystem software.

The circuit of this project simulation is developed using OptiSystem software. Firstly, the user defined bit sequence generator is used to generate the signal with the predefined bit set by user which in this case 1 bit sequence is set as shown in Figure 3.2.



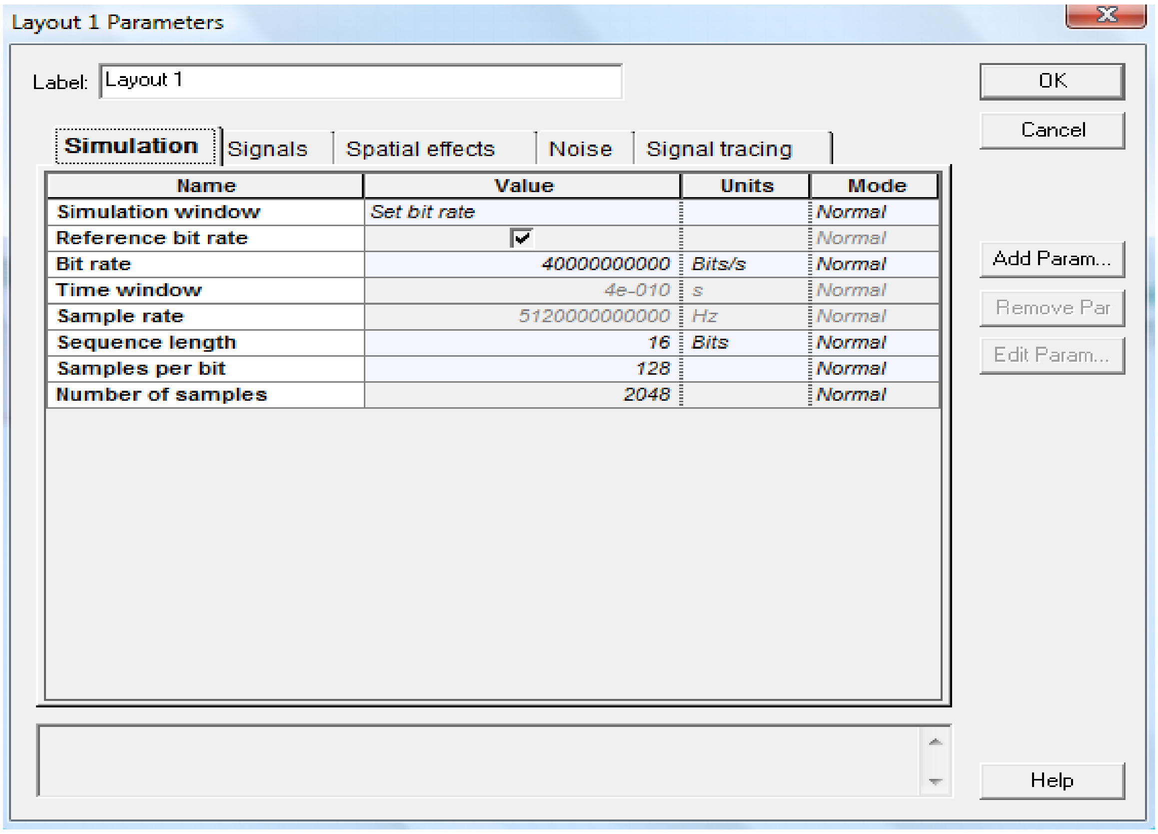
Label: User Defined Bit Sequence Generator

Cost$: 0.00

Disp	Name	Value	Units	Mode
☑	Bit rate	*Bit rate*	*Bits/s*	*Script*
☐	Load from file	☐		*Normal*
☐	Filename	*Sequence.dat*		*Normal*
☐	Bit sequence	*1*		*Normal*
☐	Number of leading zeros	*(Time window * 3 / 100) **		*Script*
☐	Number of trailing zeros	*(Time window * 3 / 100) **		*Script*

Figure 3.2: User Defined Bit Sequence Generator Properties

Then, the optical sech pulse generator is being used as the comparison with that of the optical Gaussian pulse generator where both transmit sech and Gaussian pulses respectively. Besides that the optical time domain visualizer is also used to visualize the pulses signal input and output in time domain. Next, the nonlinear dispersive fiber total field component is use with the purpose of varying the distances of the nonlinear dispersive of the optical solitons to be simulated in which it is set to 3.9482 km because the optical solitons propagation is almost losses free at this distance and then followed by 10 km, 20 km and 30 km for both generator types to observed the nonlinearities and dispersion effects at different distances. Finally, the parameters of the optical solitons simulation circuit of the project layout are defined as in Figure 3.3 [17].



Label: Layout 1

Name	Value	Units	Mode
Simulation window	Set bit rate		Normal
Reference bit rate	☑		Normal
Bit rate	40000000000	Bits/s	Normal
Time window	4e-010	s	Normal
Sample rate	5120000000000	Hz	Normal
Sequence length	16	Bits	Normal
Samples per bit	128		Normal
Number of samples	2048		Normal

Figure 3.3: Optical solitons simulation layout parameters

From Figure 3.3 the bit rate for the layout parameters is set to be 40Gb/s in order for the simulation of this project to be simulated at that specific speed. Besides that, the sequence length is defined as 16 Bits in order to obtained 16 Bits pulses of the optical solitons in which it will later on focus on only the 3rd Bits of the pulses to be compared and analysed in order to determine the effect of nonlinearities and dispersion on the optical solitons propagation. The 3rd Bits is choose because the 1st and the 2nd Bits are considered being affected by noises and thus the earliest bits that isn’t affected by noises after the 1st and 2nd Bits is selected which is the 3rd Bits.

In whole, the completed optical solitons simulation circuit using the optical Gaussian pulse generator is illustrated as in Figure 3.4.

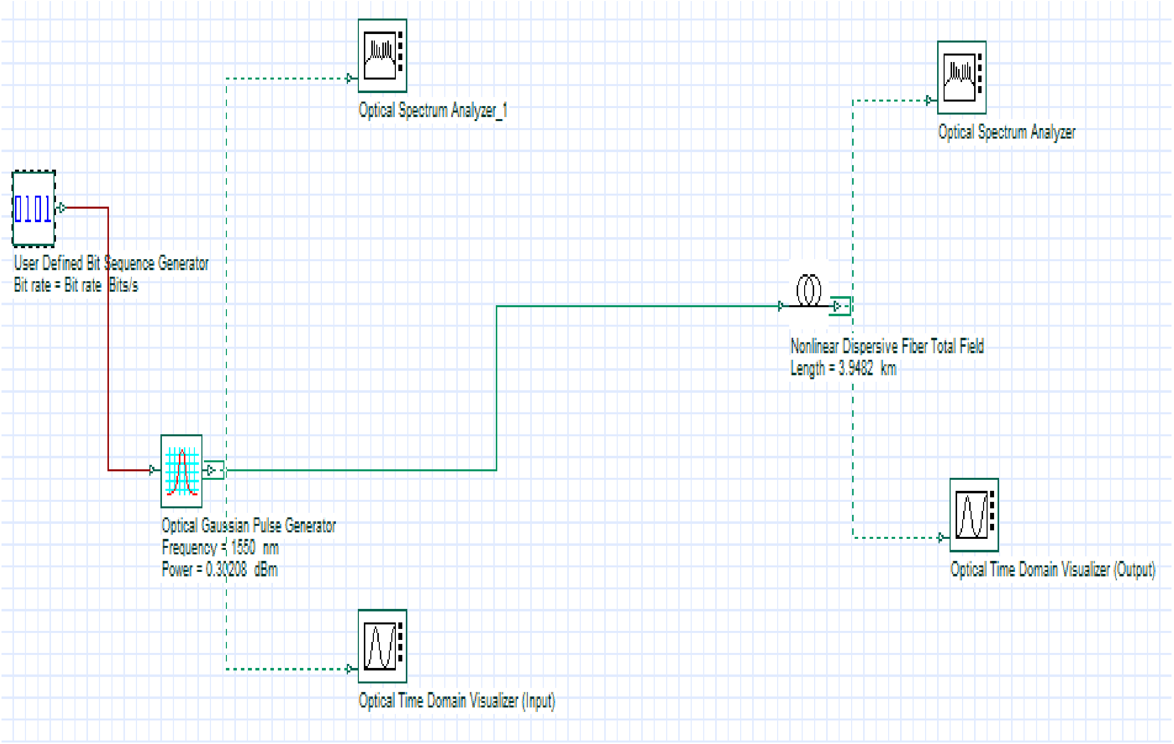


Figure 3.4: Optical solitons modeling circuit with optical Gaussian pulse generator

Figure 3.4 shows the optical solitons modeling circuit simulated using optical Gaussian pulse generator while varying the nonlinear dispersive fiber total field from 3.9482 km to 10 km, 20 km and 30 km. All the optical solitons pulses for overall and one cycle obtained at each distance of the nonlinear dispersive fiber total field from the simulation are then captured and from the data obtained the results are being calculated, compared and analyzed.

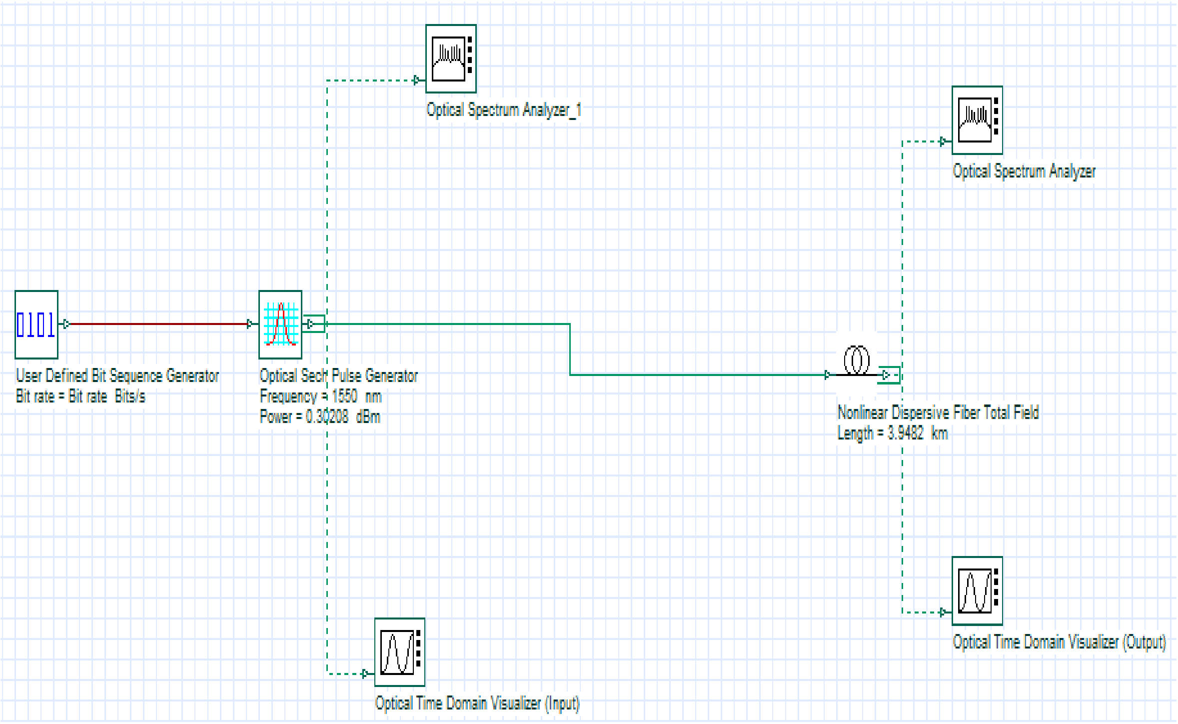


Figure 3.5: Optical solitons modeling circuit with optical sech pulse generator

Figure 3.5 above shows the optical solitons modeling circuit simulated using optical sech pulse generator while varying the nonlinear dispersive fiber total field from 3.9482 km to 10 km, 20 km and 30 km. All the optical solitons pulses for overall cycle and one cycle obtained at each distance of the nonlinear dispersive fiber total field from the simulation are then captured and from the data obtained the results are being calculated, compared and analyzed.

From the simulation result of the optical solitons by using both optical Gaussian pulse generator and optical sech pulse generator at different lengths firstly the bit slot could be determine from the graph of the one cycle pulses obtained. Then from the bit slot the full width half maximum time, T_{FWHM} is calculated [16]. Then the relation between T_0 parameter and T_{FWHM} can be find by using the formula of,

$$T_0 = \frac{T_{FWHM}}{1.763} \qquad (3.1)$$

The parameter for the values of nonlinear reference index, n_2 = 2.6 x 10^{-2} m^2/ W and cross-section area of optical fiber A_{eff} = 80 μm^2 is used. The power value, P_N is then calculated by using the formula of,

$$P_N = N^2 \frac{|\beta^2|}{\gamma {T_0}^2} \tag{3.2}$$

The parameter for the value of the group velocity dispersion, β^2 is set to -20p$s^2/\mu m$. Next, the value for the dispersion length, L_D of the optical soliton pulse is calculated by using the formula of,

$$L_D = \frac{{T_0}^2}{|\beta^2|} \tag{3.3}$$

Later on the solitons period, Z_0 is calculated by using the formula of,

$$Z_0 = \frac{\pi}{2} L_D \tag{3.4}$$

After all the parameter values are obtained and calculated it is then being tabulated in table at the next chapter and analysed.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.0 Data Analysis of Optical Solitons

Based on the optical solitons simulations on previous chapter, the results are recorded according to the distance of the optical signal travel and also pulses generator used. The detail results for each of pulses generator used will further analyse and discuss on next section.

4.1 Optical Gaussian Pulse Generator

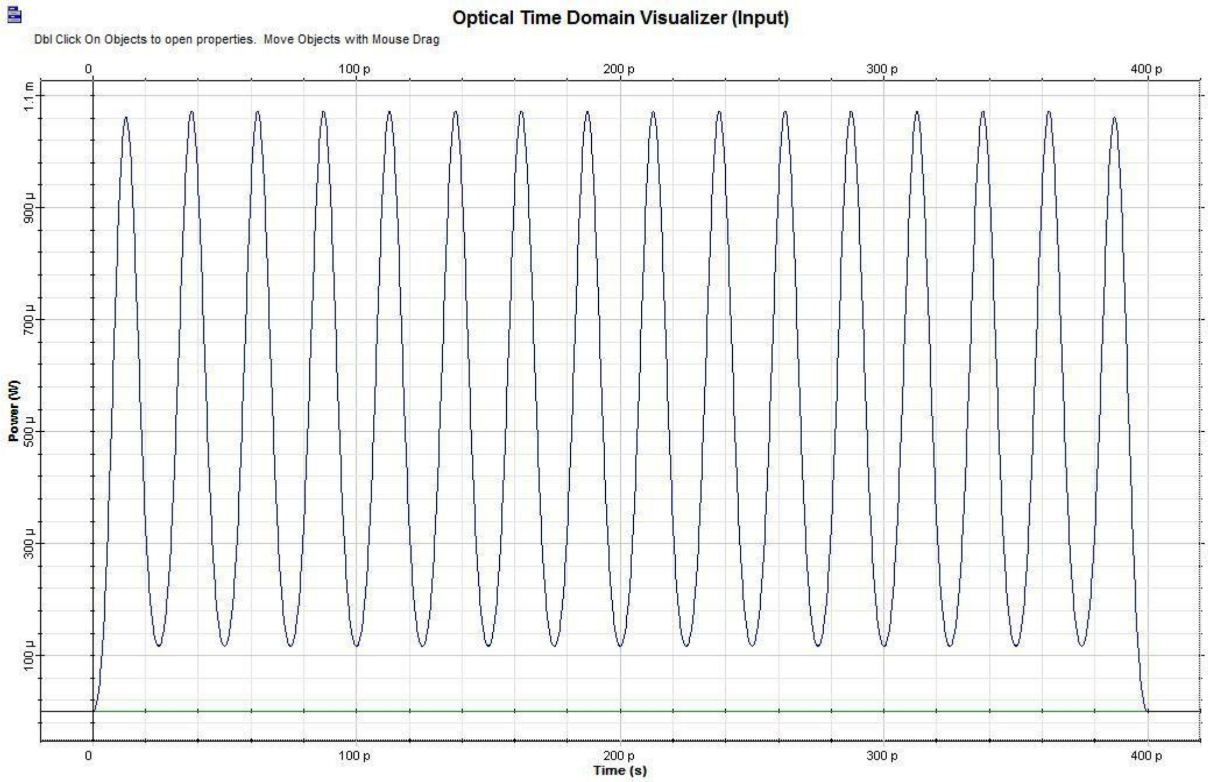
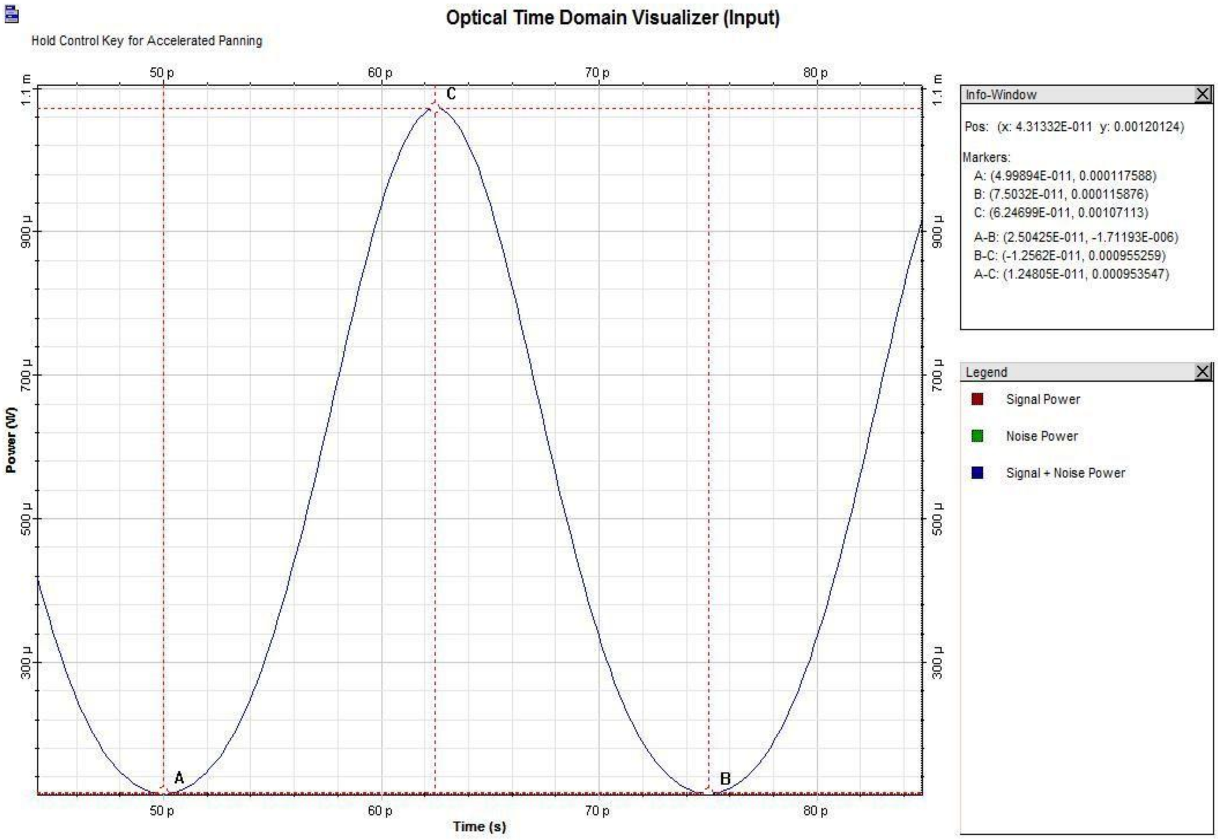


Figure 4.1: Optical solitons overall input propagation before travel over 3.9482 km using optical Gaussian pulse generator

Figure 4.1 shows the overall pulses for input of optical solitons propagation before it travel for over 3.9482 km of the nonlinear dispersive fiber total field when using optical Gaussian pulse generator. It shows that the solitons propagation when at the input travels smoothly without any distortion and preserved its own shape.



```
Pos:  (x: 4.31332E-011  y: 0.00120124)

Markers:
  A: (4.99894E-011, 0.000117588)
  B: (7.5032E-011, 0.000115876)
  C: (6.24699E-011, 0.00107113)

  A-B: (2.50425E-011, -1.71193E-006)
  B-C: (-1.2562E-011, 0.000955259)
  A-C: (1.24805E-011, 0.000953547)
```

Figure 4.2: Optical solitons one cycle input propagation before travel over 3.9482 km using optical Gaussian pulse generator

Figure 4.2 shows the one cycle input of optical solitons propagation at the 3rd bit pulse when using optical Gaussian pulse generator before it travel at 3.9482 km of the nonlinear dispersive fiber total field. It can be seen that from the graph, the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape. Besides that, it doesn't have any overshoots or undershoots. The input peak power at the 3rd bit pulse of the optical solitons propagation before travel for 3.9482 km distance is $1071.13\mu W$ that is obtained from the markers C at y-axis.

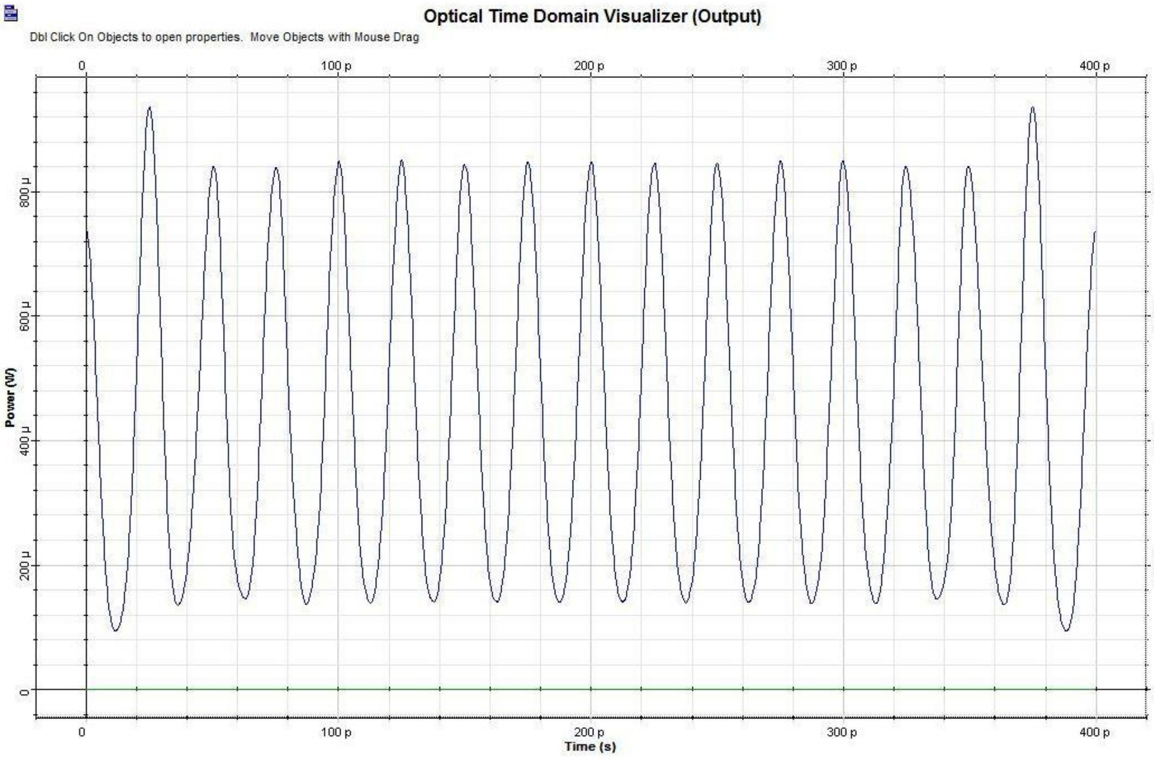
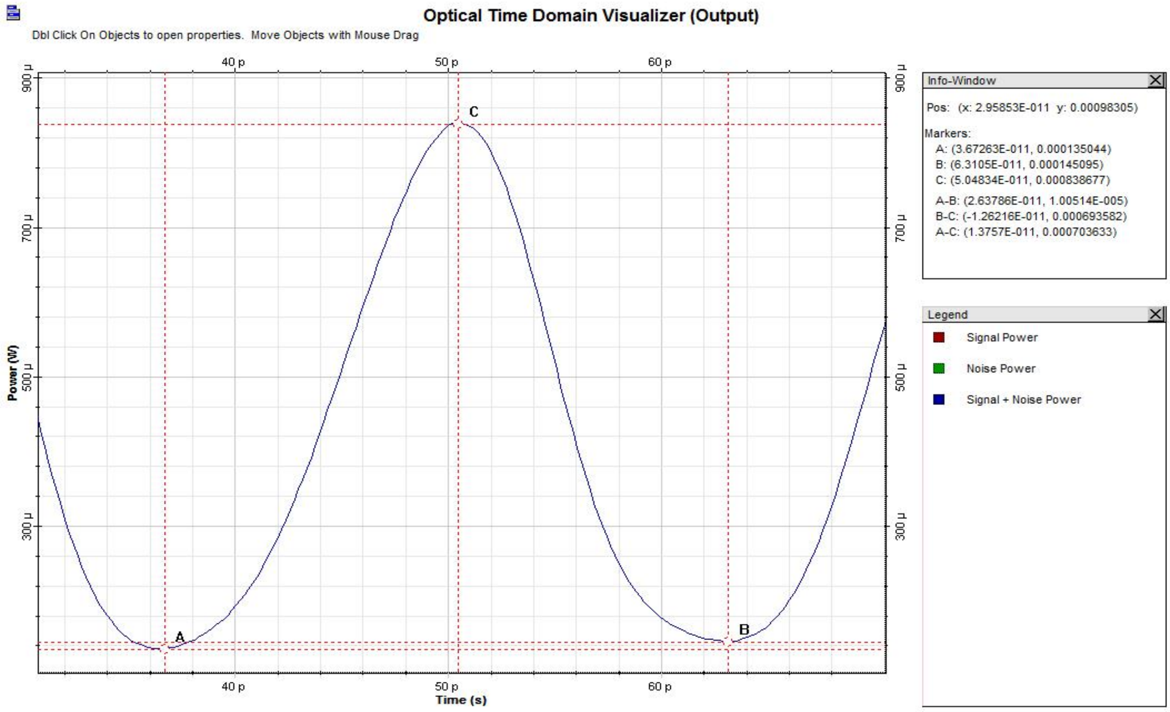


Figure 4.3: Optical solitons overall output propagation after travel over 3.9482 km using optical Gaussian pulse generator

Figure 4.3 shows the overall output graph for simulation of the optical solitons when using the optical Gaussian pulse generator after travel for 3.9482 km with the aid of nonlinear dispersive fiber total field. It shows that the signal propagates without changing it shapes and almost have the same peak value and period except at the starting and ending of the pulses where they could be neglected as they are affected by noises.



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Pos:  (x: 2.95853E-011  y: 0.00098305)

Markers:
  A: (3.67263E-011, 0.000135044)
  B: (6.3105E-011, 0.000145095)
  C: (5.04834E-011, 0.000838677)

  A-B: (2.63786E-011, 1.00514E-005)
  B-C: (-1.26216E-011, 0.000693582)
  A-C: (1.3757E-011, 0.000703633)
```

Figure 4.4: Optical solitons one cycle output propagation after travel over 3.9482 km using optical Gaussian pulse generator

Figure 4.4 shows one complete cycle of the third pulse from the optical solitons pulses propagation taken from Figure 4.1. It is observed that there is no distortion happening at the pulse. The peak value obtained for this optical pulse is 838.677μW which is obtained from the marker C at y-axis that means there are power losses when compared with the input power that is 1071.13μW and the period for this one cycle pulse is 26.3786 ps thus the bit slot calculated is 13.1893 ps. Then, from the bit slot the full width half maximum time, T_{FWHM} is calculated as 6.5946 ps. After that, the relation between T_0 parameter and T_{FWHM} can be find by using the formula as,

$$T_0 = \frac{T_{FWHM}}{1.763} \quad T_0 = \frac{6.5946}{1.763} = 3.7405 \text{ ps}$$

The power value, P_N is then calculated,

$$P_N = N^2 \frac{|\beta^2|}{\gamma {T_0}^2} = N^2 \frac{20}{1.317\ (3.7405)^2} = 1.0853N^2[\text{W}]$$

Next, the value for the dispersion length, L_D of the optical solitons pulse is calculated,

$$L_D = \frac{{T_0}^2}{|\beta^2|} = \frac{(3.7405)^2}{20} = 0.6995 \text{ km}$$

Later on the solitons period, Z_0 is calculated by using the formula of,

$$Z_0 = \frac{\pi}{2} L_D = \frac{\pi}{2} 0.6995 = 1.0988 \text{ km}$$

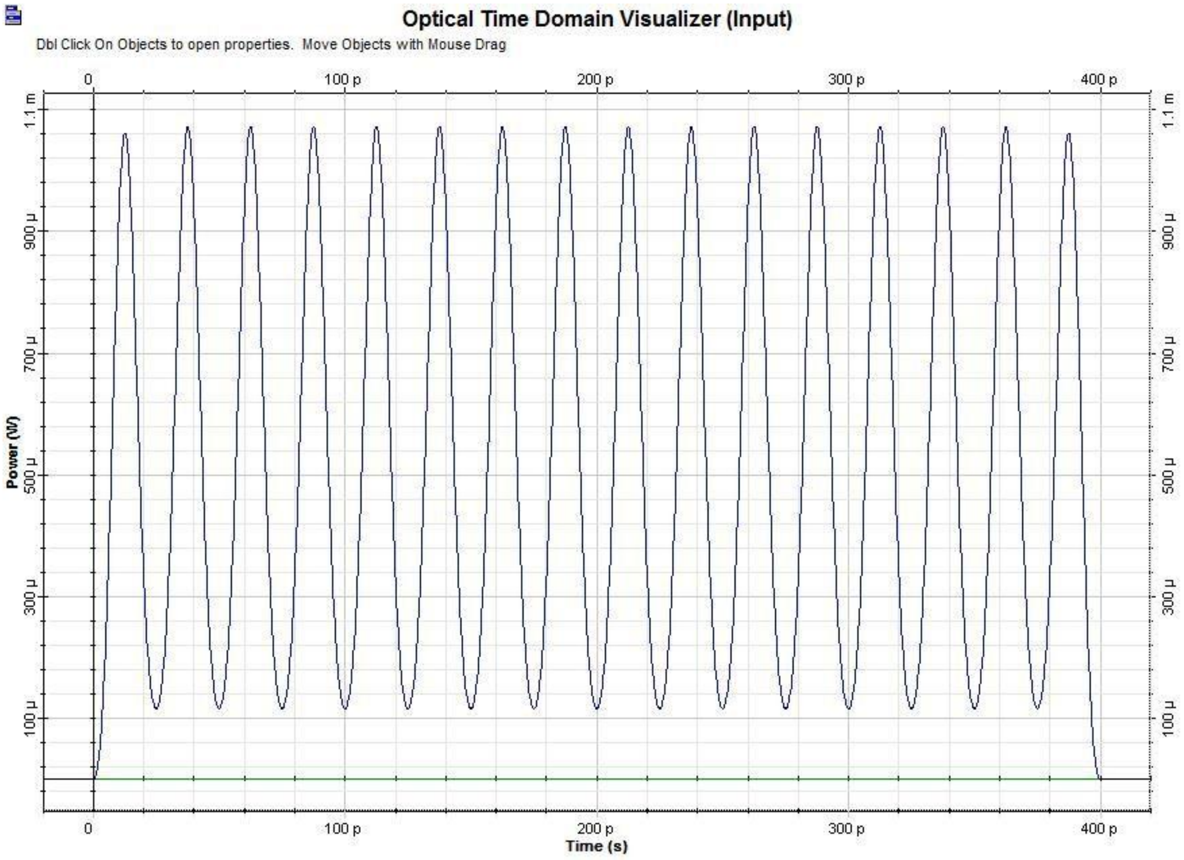
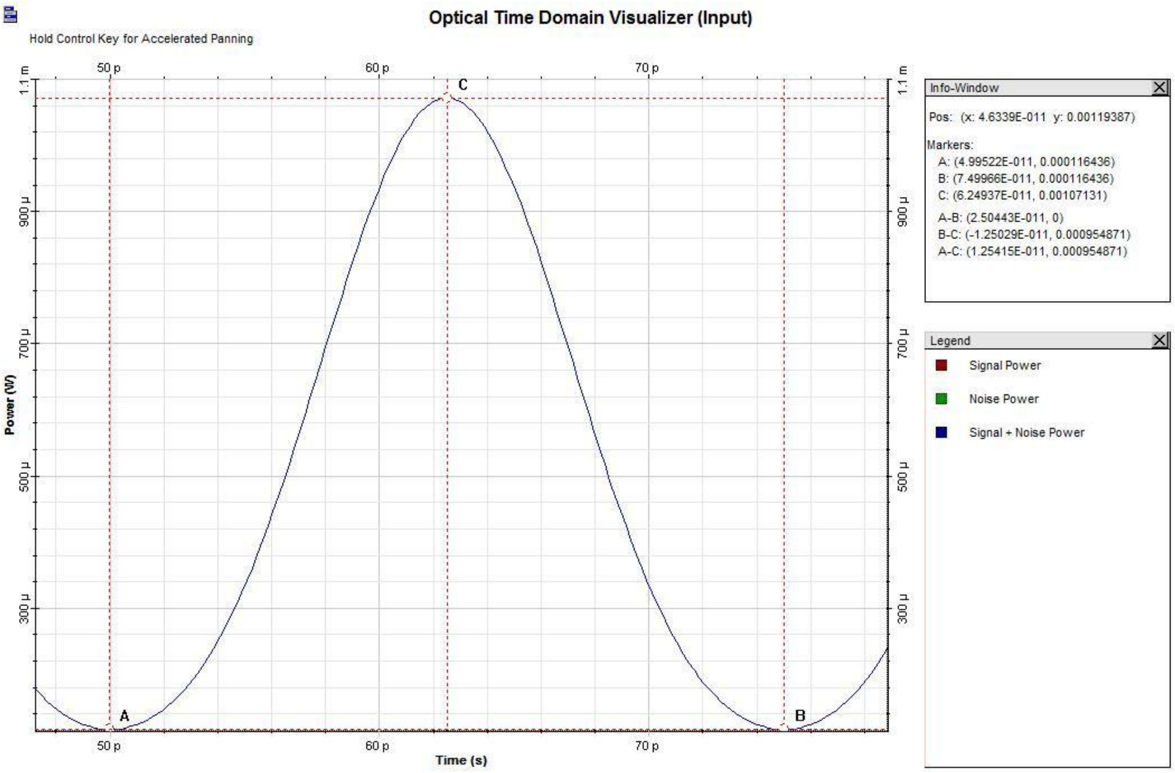


Figure 4.5: Optical solitons overall input propagation before travel over 10 km using optical Gaussian pulse generator

Figure 4.5 shows the overall input of optical solitons propagation when using optical Gaussian pulse generator before travel for 10 km with the aid of nonlinear dispersive fiber total field. It shows from the Figure 4.5 that the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape.



```
Pos:  (x: 4.6339E-011  y: 0.00119387)

Markers:
  A: (4.99522E-011, 0.000116436)
  B: (7.49966E-011, 0.000116436)
  C: (6.24937E-011, 0.00107131)

  A-B: (2.50443E-011, 0)
  B-C: (-1.25029E-011, 0.000954871)
  A-C: (1.25415E-011, 0.000954871)
```

Figure 4.6: Optical solitons one cycle input propagation before travel over 10 km using optical Gaussian pulse generator

Figure 4.6 shows the one cycle input of optical solitons propagation at the 3rd bit pulse when using optical Gaussian pulse generator before travel for 10 km with the aid of the nonlinear dispersive fiber total field. It shows from the graph, the solitons propagation at the input travels smoothly without any distortion and could preserve its own shape. Besides that, it doesn't have any overshoots or undershoots. The input peak power at the 3rd bit pulse of the optical solitons propagation when before travel to 10 km is noted similar to that of the input before travel to 3.9482 km which is 1071.13μW which is obtained from marker C at y-axis as shown in Figure 4.6.

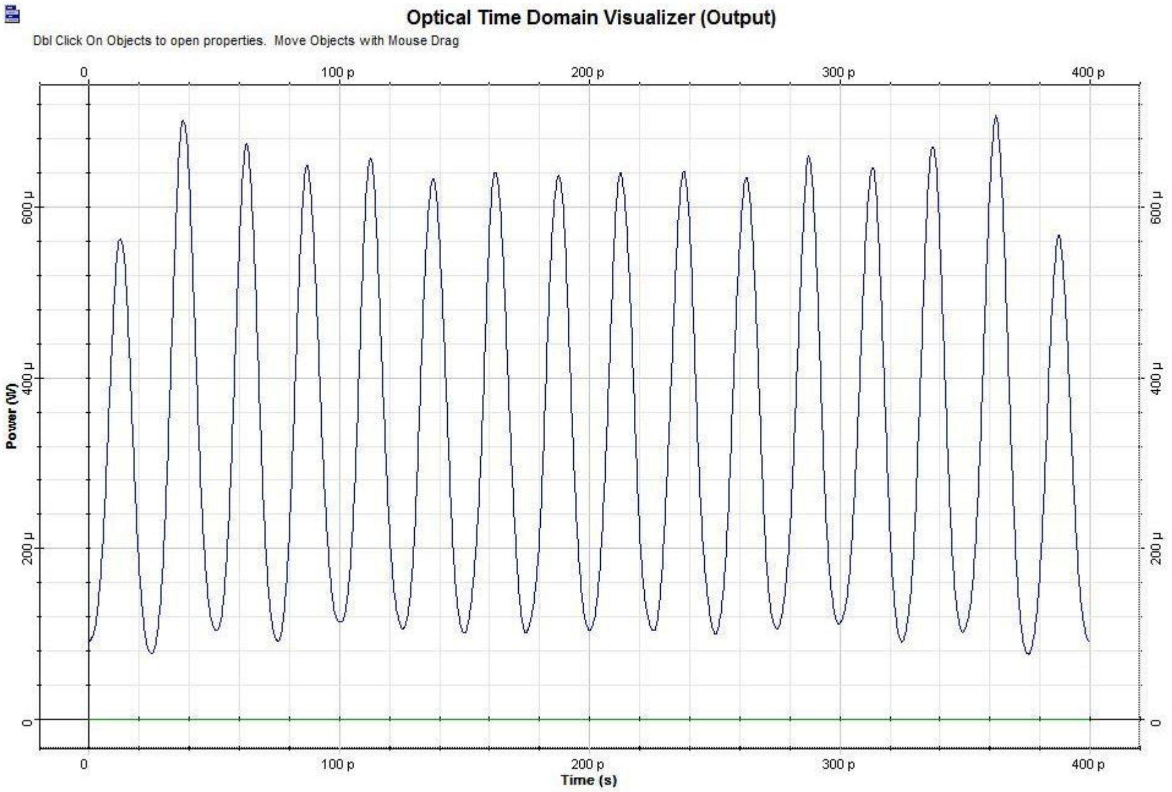
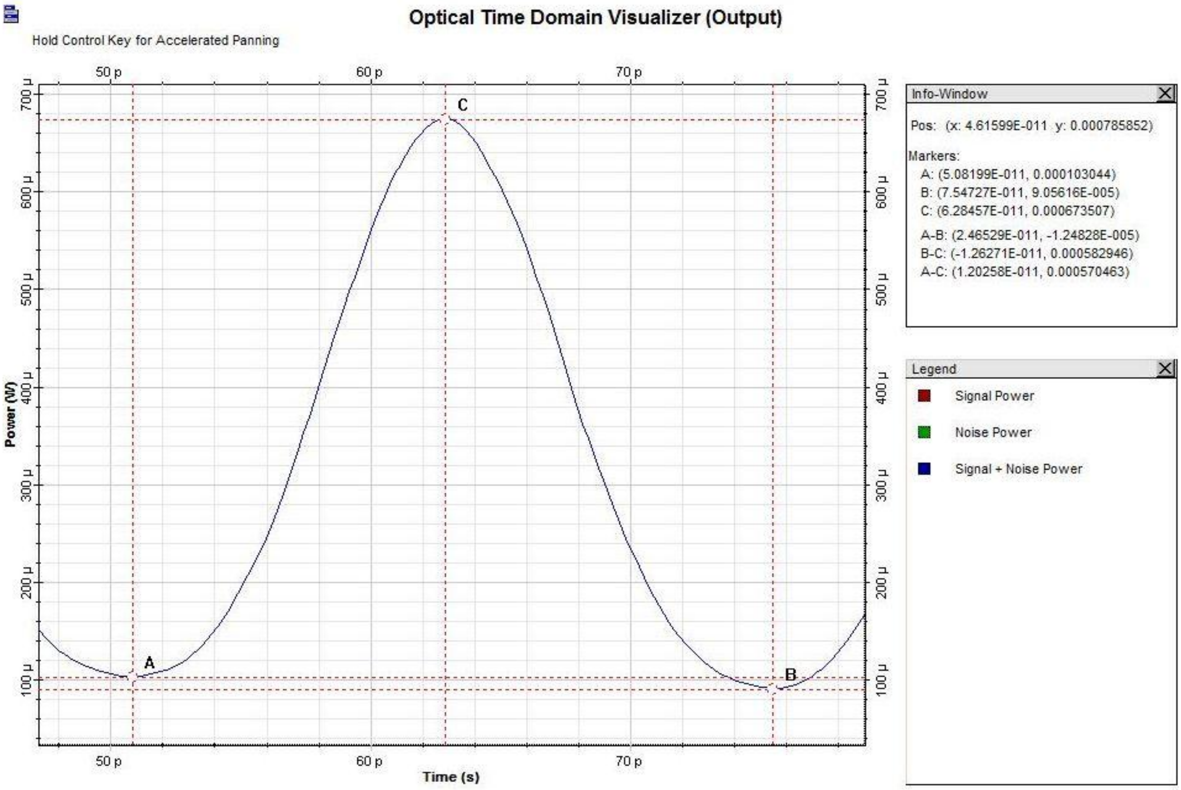


Figure 4.7: Optical solitons overall output propagation after travel over 10 km using optical Gaussian pulse generator

The Figure 4.7 shows the output graph for simulation of the optical solitons when using the optical Gaussian pulse generator after travel at 10 km with the aid of nonlinear dispersive fiber total field. It shows that from the Figure 4.7, the signal are still propagates without changing it shapes but the peak values and periods are slight different now as the length of the nonlinear dispersive fiber total field is increased.



```
Info-Window
Pos:  (x: 4.61599E-011  y: 0.000785852)
Markers:
  A: (5.08199E-011, 0.000103044)
  B: (7.54727E-011, 9.05616E-005)
  C: (6.28457E-011, 0.000673507)
  A-B: (2.46529E-011, -1.24828E-005)
  B-C: (-1.26271E-011, 0.000582946)
  A-C: (1.20258E-011, 0.000570463)
```

Figure 4.8: Optical solitons one cycle output propagation after travel over 10 km using optical Gaussian pulse generator

Figure 4.8 shows one complete cycle of the third pulse from the optical solitons pulses propagation taken from Figure 4.7. It is observed that from the graph, there is no distortion happening at the pulse. The peak value obtained for this optical pulse is 673.506μW obtained from marker C at y-axis and the period for this one cycle pulse is 24.6529 ps thus the bit slot calculated is 12.3264 ps. Then from the bit slot the full width half maximum time, T_{FWHM} is calculated as 6.1632 ps. After that, the relation between T_0 parameter and T_{FWHM} can be find by using the formula of,

$$T_0 = \frac{T_{FWHM}}{1.763} \quad T_0 = \frac{6.1632}{1.763} = 3.4958 \text{ ps}$$

The power value, P_N is then calculated,

$$P_N = N^2 \frac{|\beta^2|}{\gamma {T_0}^2} = N^2 \frac{20}{1.317\ (3.4958)^2} = 1.2426N^2 [\text{W}]$$

Next, the value for the dispersion length, L_D of the optical soliton pulse is calculated,

$$L_D = \frac{{T_0}^2}{|\beta^2|} = \frac{(3.4958)^2}{20} = 0.6110 \text{ km}$$

Later on the solitons period, Z_0 is calculated by using the formula of,

$$Z_0 = \frac{\pi}{2} L_D = \frac{\pi}{2} 0.6110 = 0.9598 \text{ km}$$

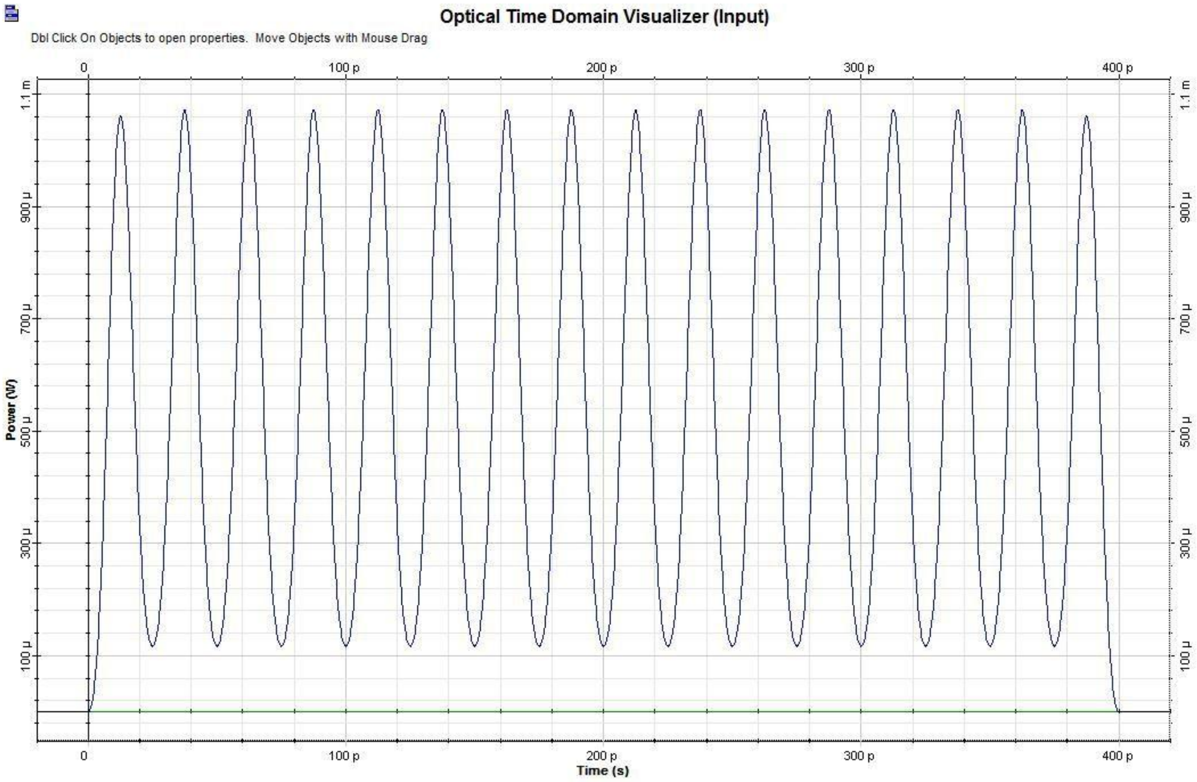
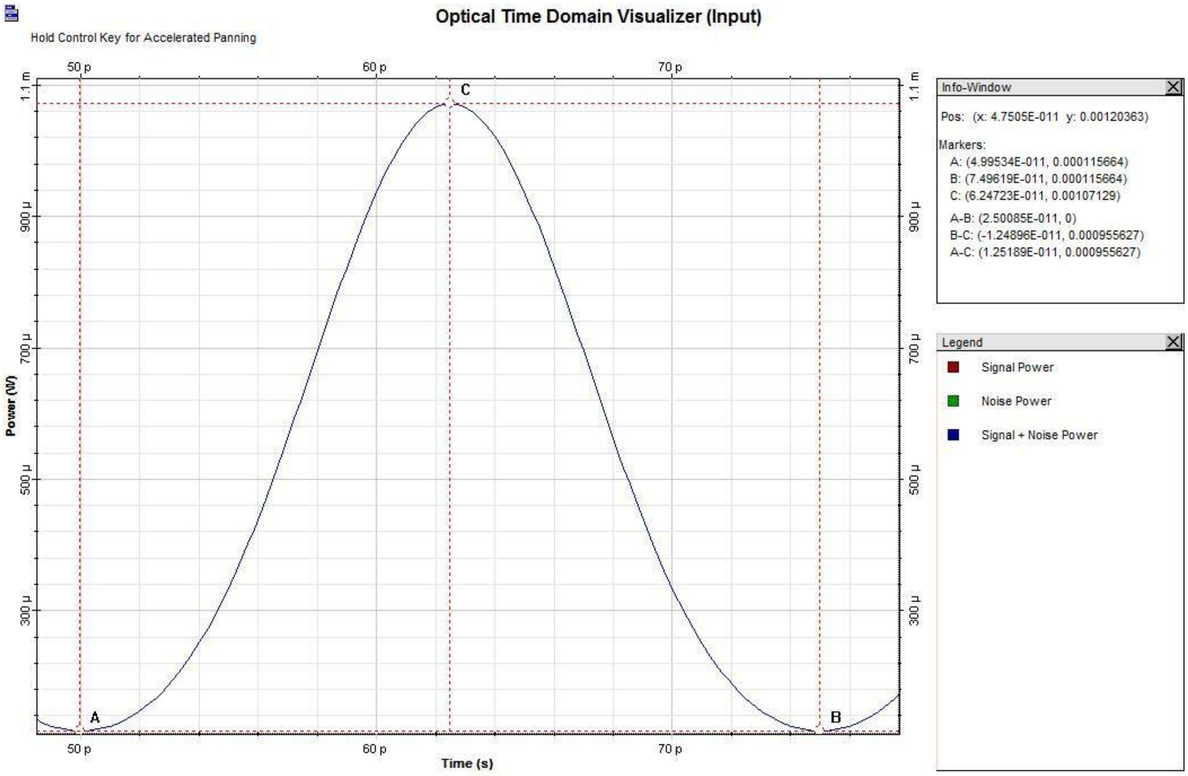


Figure 4.9: Optical solitons overall input propagation before travel over 20 km using optical Gaussian pulse generator

Figure 4.9 shows the overall input of optical solitons propagation when using optical Gaussian pulse generator before travel for 20 km with the aid of the nonlinear dispersive fiber total field. It can be seen that from the graph, the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape.



```
Info-Window
Pos:  (x: 4.7505E-011  y: 0.00120363)

Markers:
  A: (4.99534E-011, 0.000115664)
  B: (7.49619E-011, 0.000115664)
  C: (6.24723E-011, 0.00107129)

  A-B: (2.50085E-011, 0)
  B-C: (-1.24896E-011, 0.000955627)
  A-C: (1.25189E-011, 0.000955627)
```

Figure 4.10: Optical solitons one cycle input propagation before travel over 20 km using optical Gaussian pulse generator

Figure 4.10 shows the one cycle input of optical solitons propagation at the 3rd bit pulse when using optical Gaussian pulse generator before travel to 20 km with the aid of the nonlinear dispersive fiber total field. It can be seen clearly from the graph that the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape. Besides that, it doesn’t have any overshoots or undershoots. The input peak power at the 3rd bit pulse of the optical solitons propagation before travel at 20 km is $1071.29\mu W$ that is obtained from the marker C at y-axis as shown in Figure 4.10.

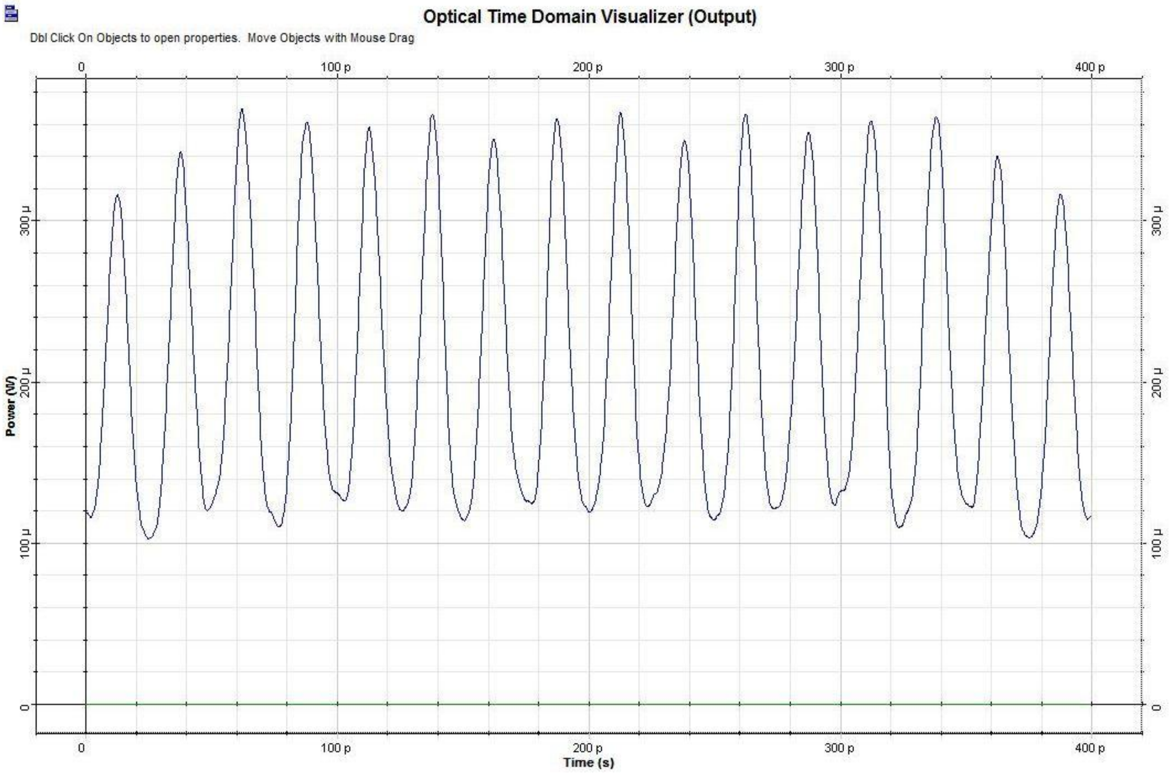
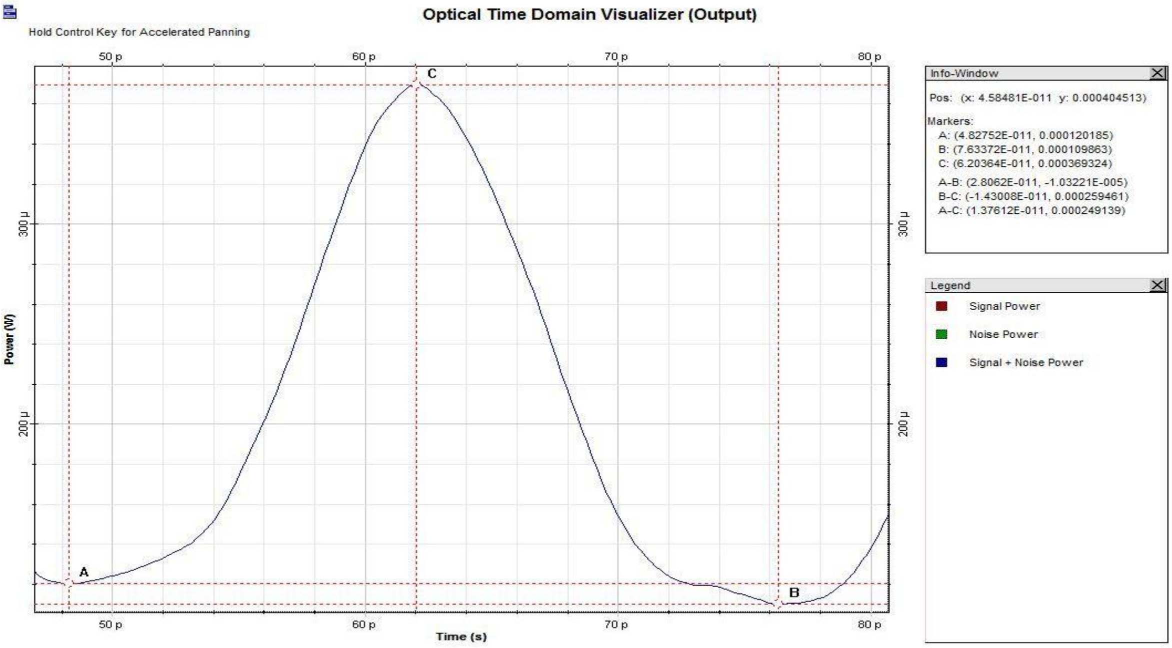


Figure 4.11: Optical solitons overall output propagation after travel at 20 km using optical Gaussian pulse generator

The Figure 4.11 shows the overall output graph for simulation of the optical solitons when using the optical Gaussian pulse generator after travel at 20 km with the aid of nonlinear dispersive fiber total field. It can be seen from the graph that the signal pulses has started to be slightly different in shapes and so as the peak values and periods are different from one pulse to another pulses. Some pulses are noticed to even have undershoots.



```
Pos:  (x: 4.58481E-011  y: 0.000404513)

Markers:
  A: (4.82752E-011, 0.000120185)
  B: (7.63372E-011, 0.000109863)
  C: (6.20364E-011, 0.000369324)
  A-B: (2.8062E-011, -1.03221E-005)
  B-C: (-1.43008E-011, 0.000259461)
  A-C: (1.37612E-011, 0.000249139)
```

Figure 4.12: Optical solitons one cycle output propagation after travel over 20 km using optical Gaussian pulse generator

Figure 4.12 shows one complete cycle of the third pulse from the optical solitons pulses propagation taken from Figure 4.11. It is observed from the graph that there is a slight distortion happening at the pulse. The peak value obtained for this optical pulse is 369.324 μW which means that there are power losses when compared with the input peak power of 1071.29 μW and the period for this one cycle pulse is 28.0620 ps thus the bit slot calculated is 14.0310 ps. Then from the bit slot the full width half maximum time, T_{FWHM} is calculated as 7.0155 ps. After that, the relation between T_0 parameter and T_{FWHM} can be find by using the formula of,

$$T_0 = \frac{T_{FWHM}}{1.763} \quad T_0 = \frac{7.0155}{1.763} = 3.9792 \text{ ps.}$$

The power value, P_N is then calculated as,

$$P_N = N^2 \frac{|\beta^2|}{\gamma {T_0}^2} = N^2 \frac{20}{1.317\ (3.9792)^2} = 1.0561\ N^2 [\text{W}]$$

Next, the value for the dispersion length, L_D of the optical soliton pulse is calculated by using the formula of,

$$L_D = \frac{{T_0}^2}{|\beta^2|} = \frac{(3.9792)^2}{20} = 0.7917 \text{ km}$$

Later on, the solitons period, Z_0 is calculated by using the formula of,

$$Z_0 = \frac{\pi}{2} L_D = \frac{\pi}{2} 0.7917 = 1.2435 \text{ km}$$

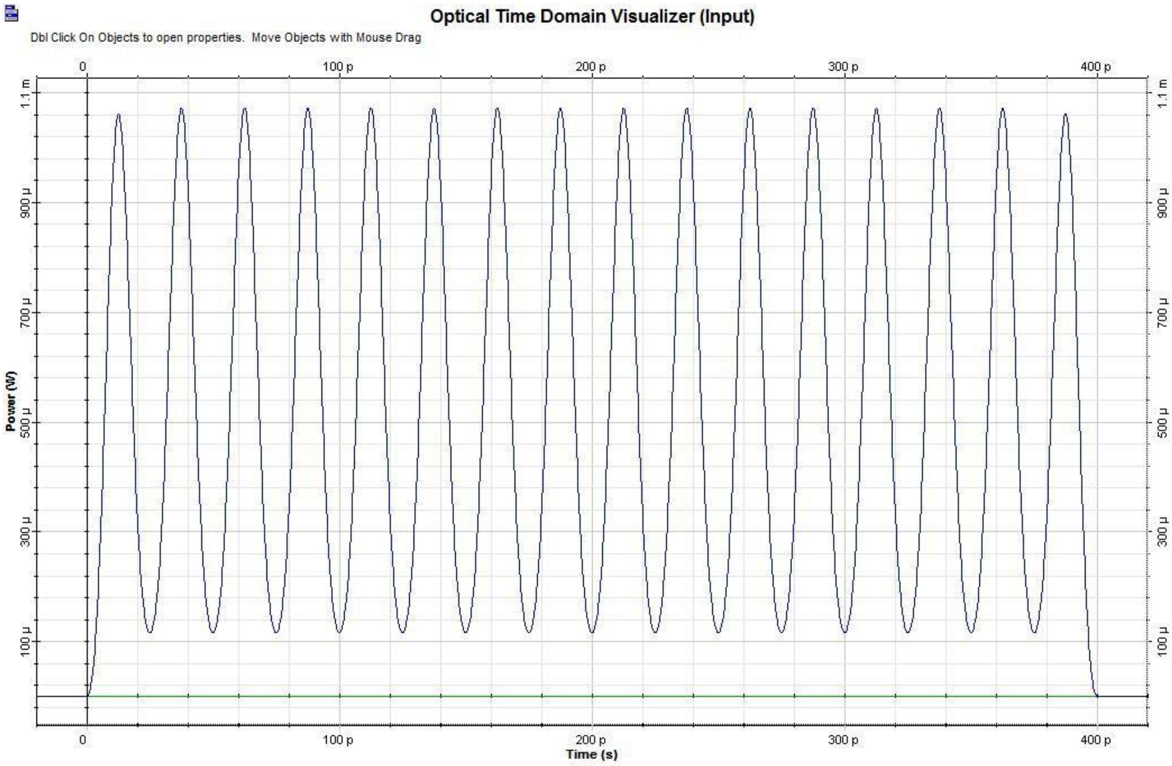
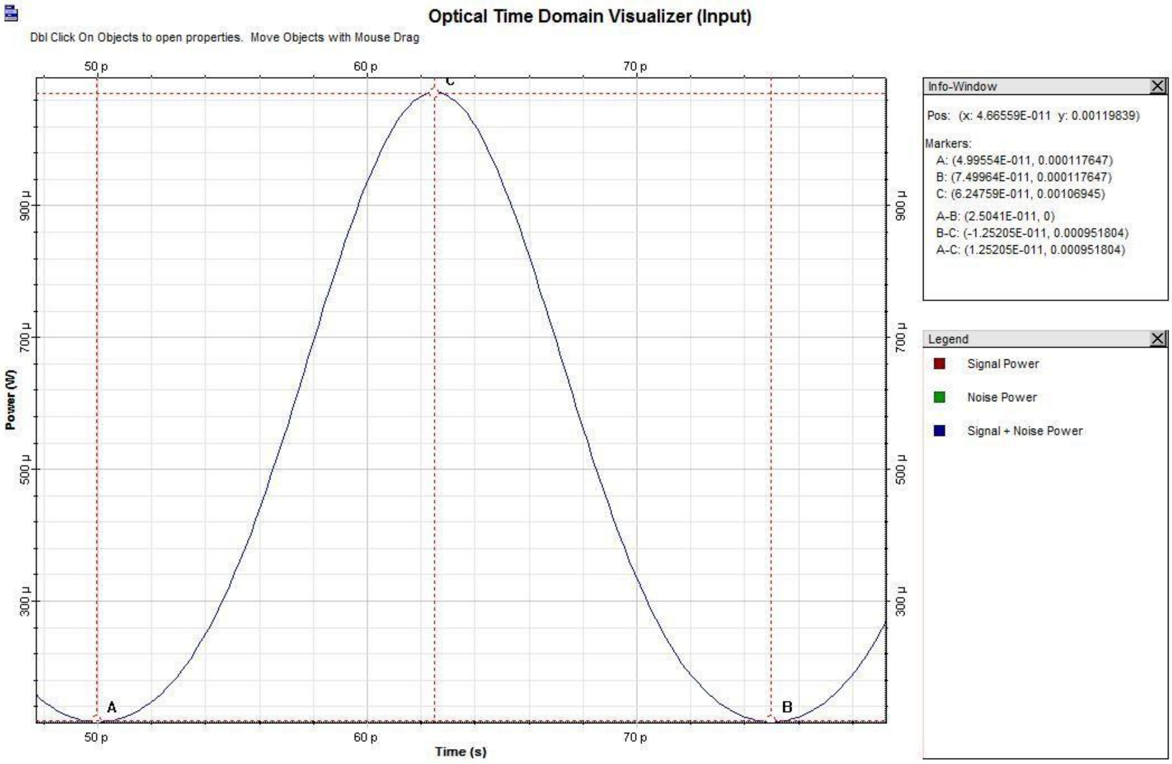


Figure 4.13: Optical solitons overall input propagation before travel over 30 km using optical Gaussian pulse generator

Figure 4.13 shows the overall input of optical solitons propagation when using optical Gaussian pulse generator before travel at 30 km with the aid of the nonlinear dispersive fiber total field. It can be seen from the graph that even though the optical solitons propagation input is before it travel to 30 km, the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape.



```
Pos:  (x: 4.66559E-011  y: 0.00119839)

Markers:
  A: (4.99554E-011, 0.000117647)
  B: (7.49964E-011, 0.000117647)
  C: (6.24759E-011, 0.00106945)

  A-B: (2.5041E-011, 0)
  B-C: (-1.25205E-011, 0.000951804)
  A-C: (1.25205E-011, 0.000951804)
```

Figure 4.14: Optical solitons overall input propagation before travel over 30 km using optical Gaussian pulse generator

Figure 4.14 shows the one cycle input of optical solitons propagation at the 3rd bit pulse when using optical Gaussian pulse generator before travel at 30 km with the aid of the nonlinear dispersive fiber total field. It can be seen from the graph that the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape. Besides that, it doesn't have any overshoots or undershoots. The input peak power at the 3rd bit pulse of the optical solitons propagation before travel at 30 km is $1069.45\mu W$ which is obtained from marker C at y-axis as shown in Figure 4.14.

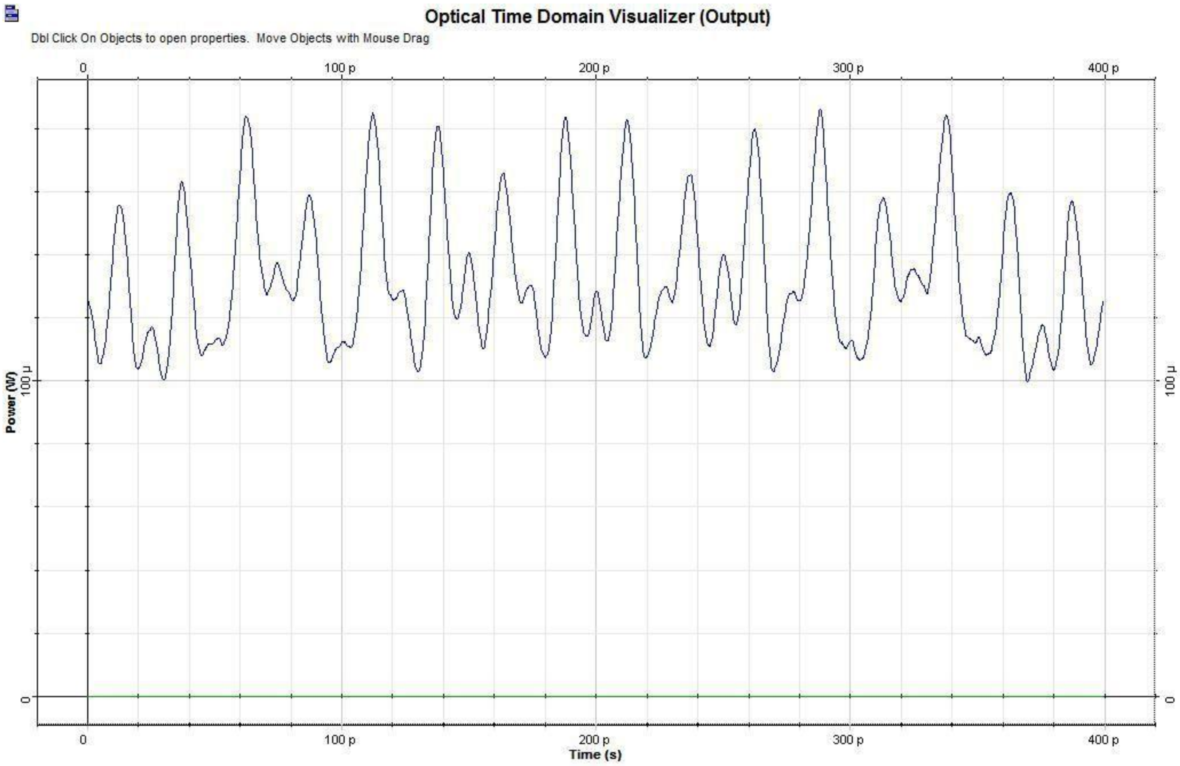


Figure 4.15: Optical solitons overall output propagation after travel at 30 km using optical Gaussian pulse generator

The Figure 4.15 shows the overall output graph for simulation of the optical solitons when using the optical Gaussian pulse generator after travel at 30 km of nonlinear dispersive fiber total field. It can be seen from the graph that the signal pulses are very different in shapes and so as the peak values and periods of the pulses. Most of the pulses are noticed to have undershoots.

4.2 Optical Sech Pulse Generator

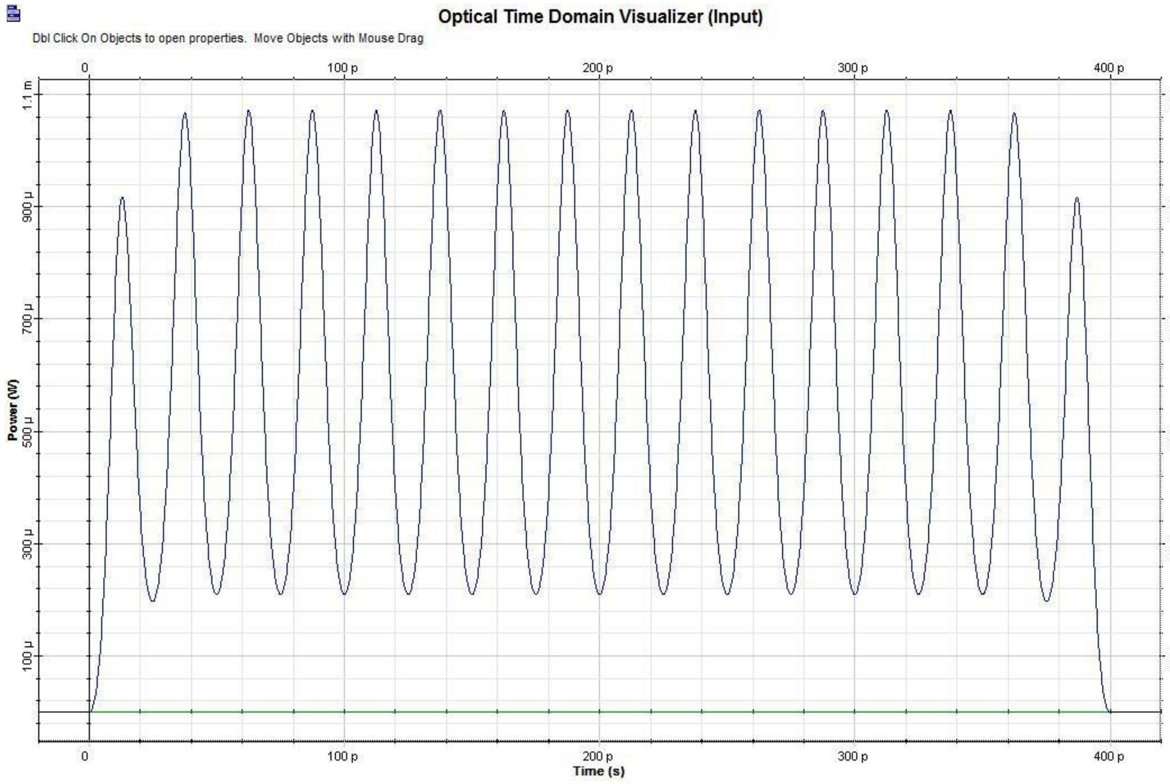
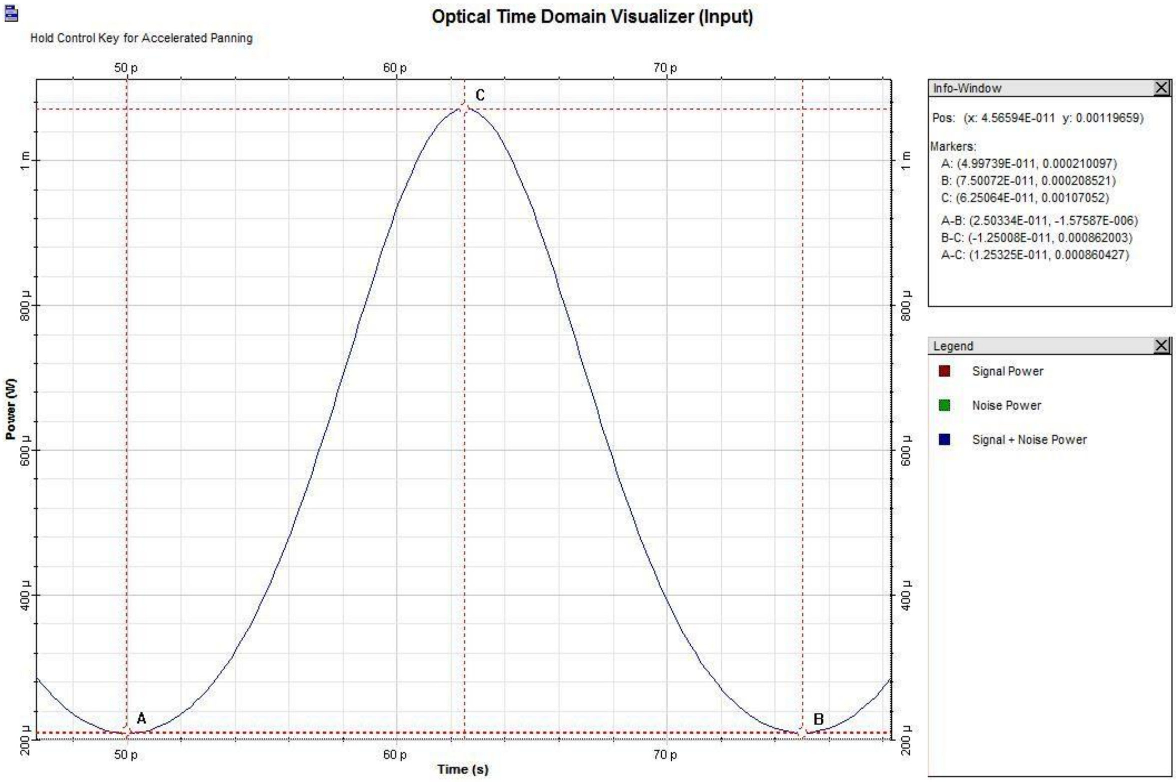


Figure 4.16: Optical solitons overall input propagation before travel over 3.9842 km using optical sech pulse generator

Figure above shows the overall input of optical solitons propagation when using optical sech pulse generator before travel for 3.9482 km with the aid of the nonlinear dispersive fiber total field. It can be seen that from the graph the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape.



```
Info-Window
Pos:  (x: 4.56594E-011  y: 0.00119659)

Markers:
  A: (4.99739E-011, 0.000210097)
  B: (7.50072E-011, 0.000208521)
  C: (6.25064E-011, 0.00107052)
  A-B: (2.50334E-011, -1.57587E-006)
  B-C: (-1.25008E-011, 0.000862003)
  A-C: (1.25325E-011, 0.000860427)
```

Figure 4.17: Optical solitons one cycle input propagation before travel at 3.9842 km using optical sech pulse generator

Figure 4.17 shows the one cycle input of optical solitons propagation at the 3rd bit pulse when using optical sech pulse generator at 3.9482 km with the aid of the nonlinear dispersive fiber total field. It can be seen from the graph that the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape. Besides that, it doesn’t have any overshoots or undershoots. The input peak power at the 3rd bit pulse of the optical solitons propagation when at 3.9482 km is $1070.52\mu W$ that is obtained from marker C at y-axis as shown in Figure 4.17.

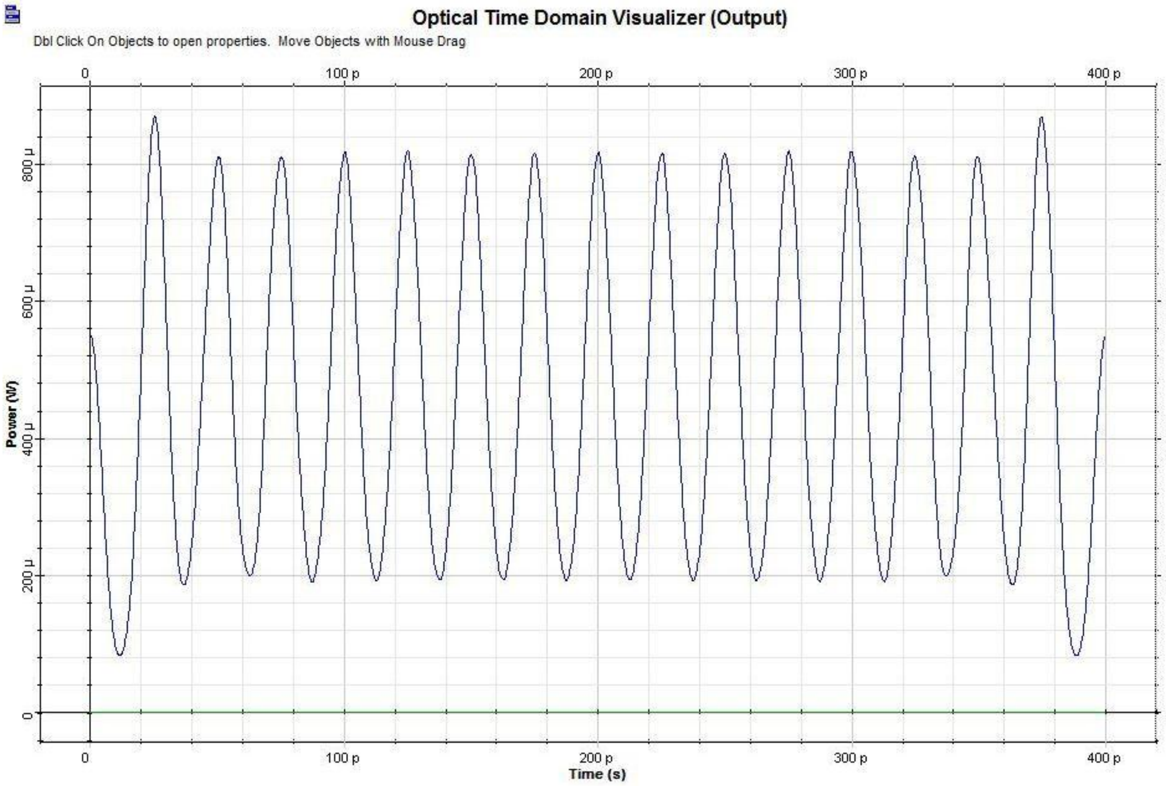
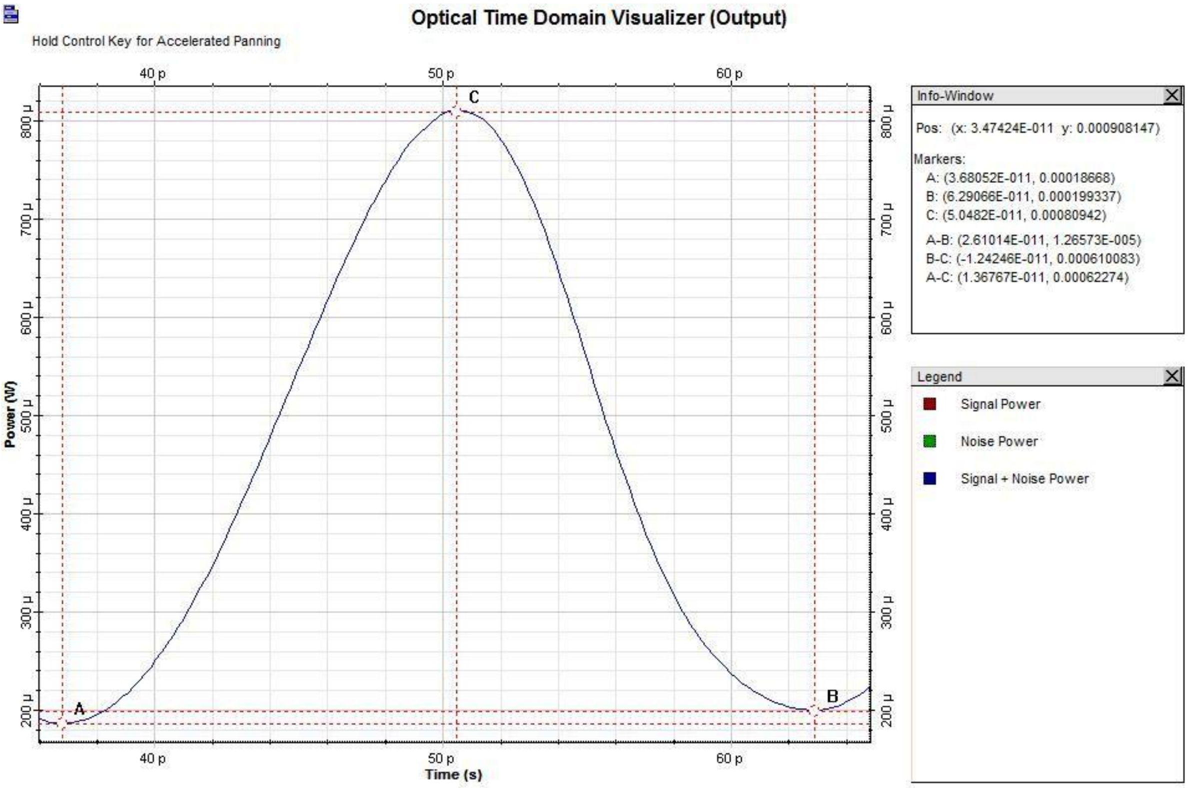


Figure 4.18: Optical solitons overall output propagation after travel over 3.9842 km using optical sech pulse generator

The Figure 4.18 above shows the output graph for simulation of the optical solitons when using the optical sech pulse generator after travel at 3.9482 km with the aid of nonlinear dispersive fiber total field. It can be seen clearly from the graph that the signal propagates without changing it shapes and almost have the same peak value and period except at the starting and ending of the pulses where they could be neglected as they are the pulses affected by noises.



```
Pos:  (x: 3.47424E-011  y: 0.000908147)

Markers:
  A: (3.68052E-011, 0.00018668)
  B: (6.29066E-011, 0.000199337)
  C: (5.0482E-011, 0.00080942)

  A-B: (2.61014E-011, 1.26573E-005)
  B-C: (-1.24246E-011, 0.000610083)
  A-C: (1.36767E-011, 0.00062274)
```

Figure 4.19: Optical solitons one cycle output propagation after travel over 3.9842 km using optical sech pulse generator

Figure 4.19 shows one complete cycle of the third pulse from the optical solitons pulses propagation taken from Figure 4.18. It is observed from the graph that there is no distortion happening at the pulse. The peak value obtained for this optical pulse is 809.420 μW and the period for this one cycle pulse is 26.1014 ps thus the bit slot calculated is 13.0507 ps. Then from the bit slot the full width half maximum time, T_{FWHM} is calculated as 6.5253 ps. Next, the relation between T_0 parameter and T_{FWHM} can be find by using the formula of,

$$T_0 = \frac{T_{FWHM}}{1.763} \quad T_0 = \frac{6.5253}{1.763} = 3.7012 \text{ ps}$$

The power value, P_N is then calculated as,

$$P_N = N^2 \frac{|\beta^2|}{\gamma {T_0}^2} = N^2 \frac{20}{1.317\ (3.74012)^2} = 1.1085\ N^2 [\text{W}].$$

Next, the value for the dispersion length, L_D of the optical soliton pulse is calculated by using the formula of,

$$L_D = \frac{{T_0}^2}{|\beta^2|} = \frac{(3.7012)^2}{20} = 0.6849 \text{ km}$$

Later on, the solitons period, Z_0 is calculated by using the formula of,

$$Z_0 = \frac{\pi}{2} L_D = \frac{\pi}{2} 0.6849 = 1.0758 \text{ km}$$

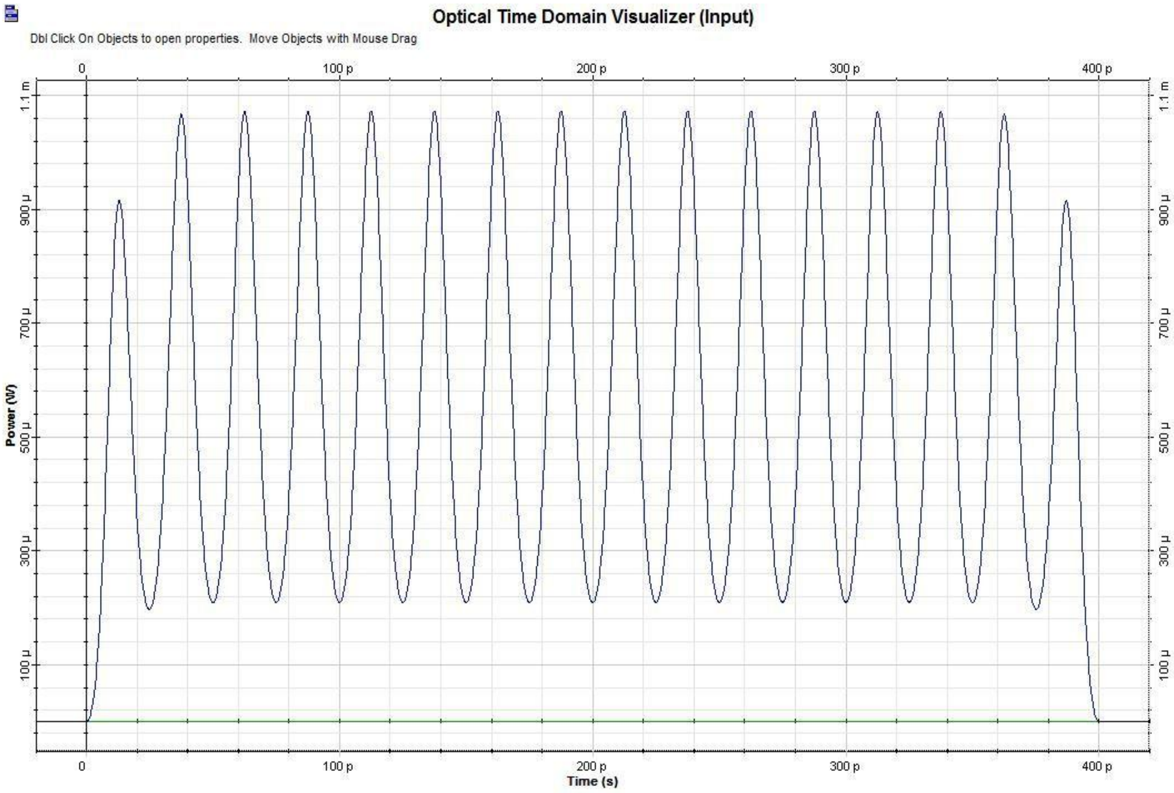
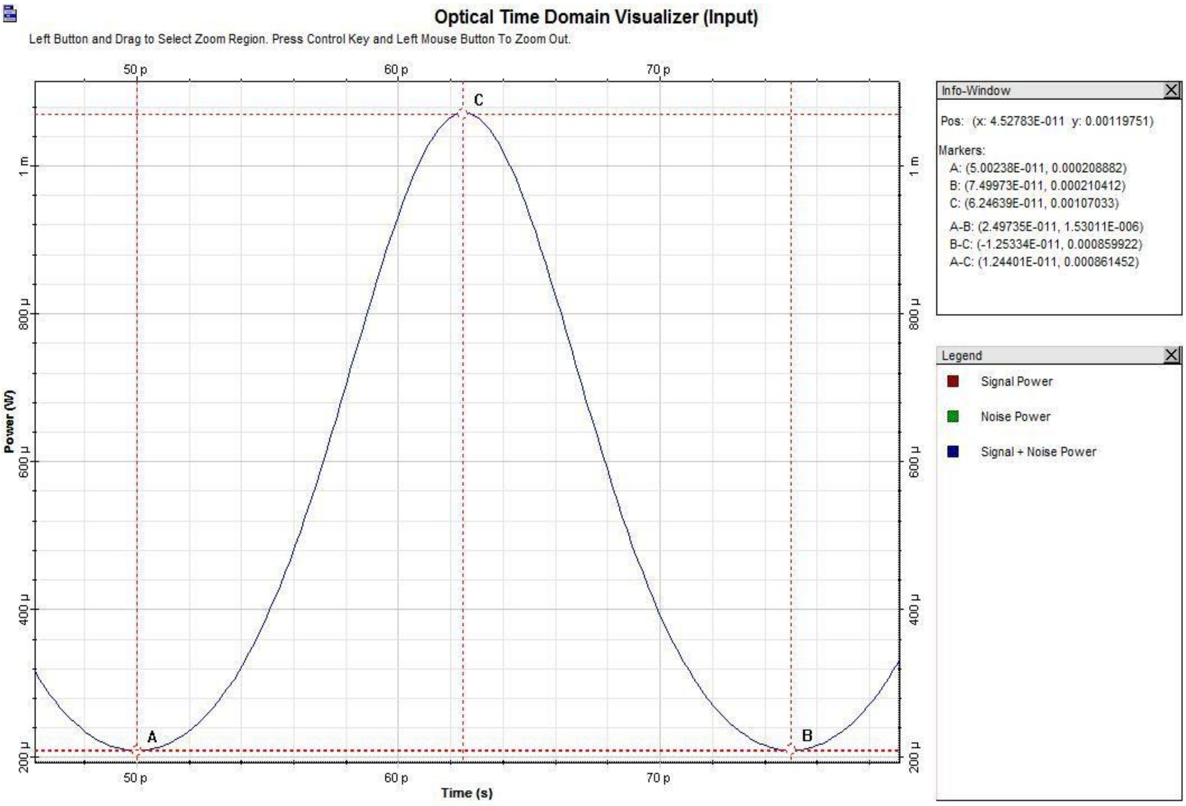


Figure 4.20: Optical solitons overall input propagation before travel over 10 km using optical sech pulse generator

Figure 4.20 shows the overall input of optical solitons propagation when using optical sech pulse generator before travel at 10 km with the aid of the nonlinear dispersive fiber total field. It can be seen from the graph that the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape and the peak power except the first and last bit pulses because they could be neglected as they are affected by noises.



```
Pos:  (x: 4.52783E-011  y: 0.00119751)

Markers:
  A: (5.00238E-011, 0.000208882)
  B: (7.49973E-011, 0.000210412)
  C: (6.24639E-011, 0.00107033)

  A-B: (2.49735E-011, 1.53011E-006)
  B-C: (-1.25334E-011, 0.000859922)
  A-C: (1.24401E-011, 0.000861452)
```

Figure 4.21: Optical solitons one cycle input propagation before travel over 10 km using optical sech pulse generator

Figure 4.21 shows the one cycle input of optical solitons propagation at the 3rd bit pulse when using optical sech pulse generator before travel at 10 km of the nonlinear dispersive fiber total field. It can be seen from the graph that the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape. Besides that, it doesn’t have any overshoots or undershoots. The input peak power at the 3rd bit pulse of the optical solitons propagation when before travel at 10 km is $1070.33 \mu W$ which is determined from the marker C at y-axis as shown in figure 4.21.

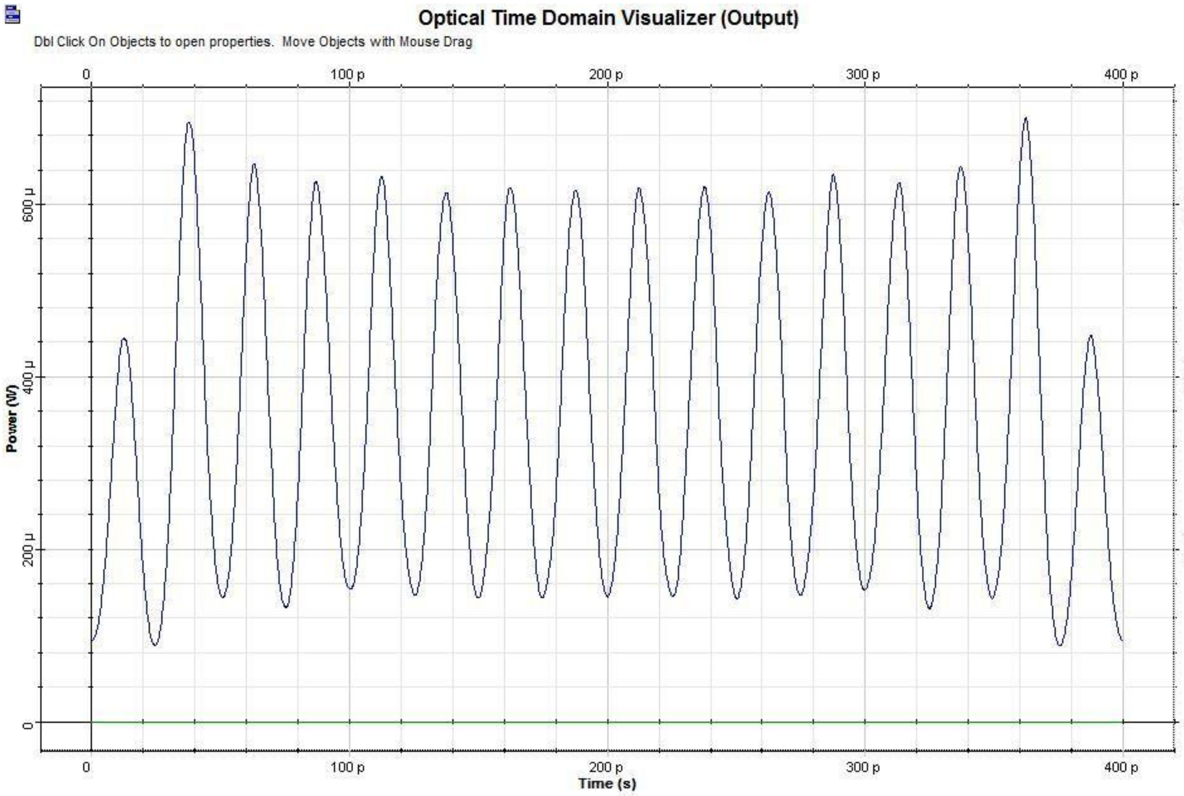
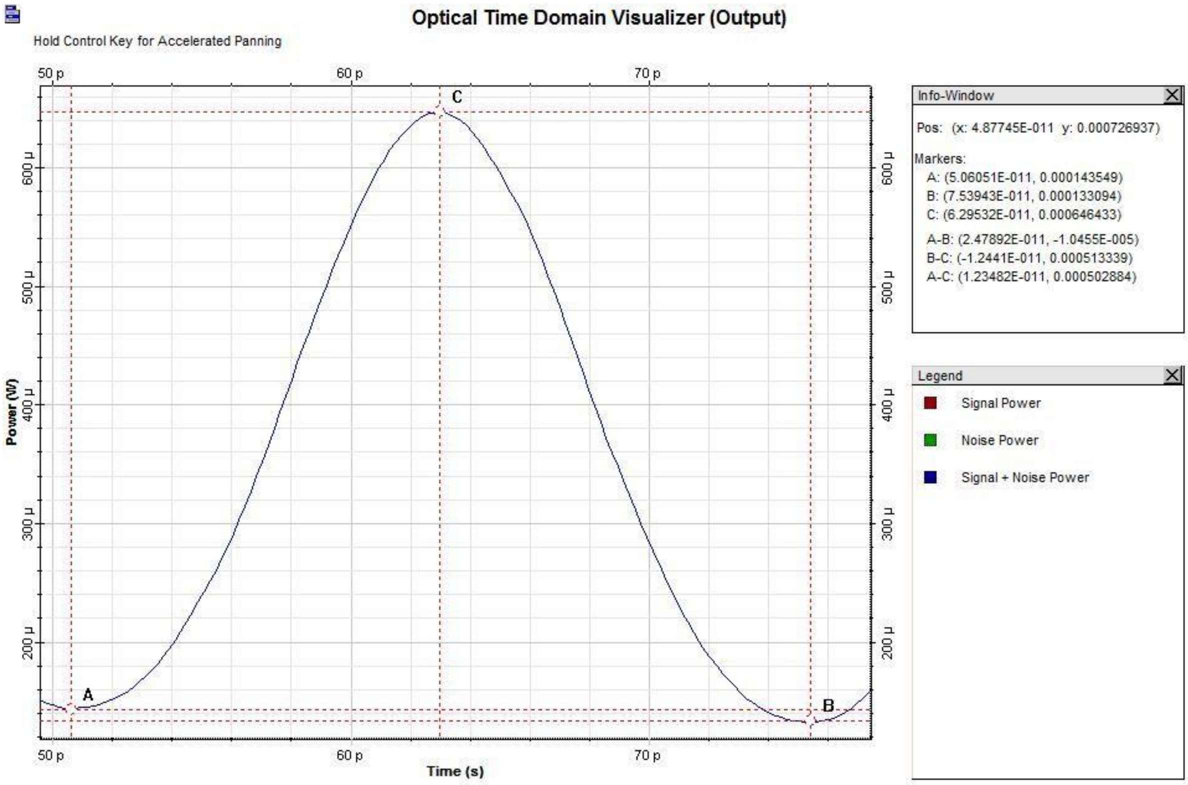


Figure 4.22: Optical solitons overall output propagation after travel over 10 km using optical sech pulse generator

The Figure 4.22 above shows the output graph for simulation of the optical solitons when using the optical sech pulse generator after travel at 10 km of nonlinear dispersive fiber total field. It can be seen from the graph that the signal are still propagates without changing it shapes but the peak values and periods are slightly different now as the length of the nonlinear dispersive fiber total field is increased.



```
Info-Window
Pos:  (x: 4.87745E-011  y: 0.000726937)

Markers:
  A: (5.06051E-011, 0.000143549)
  B: (7.53943E-011, 0.000133094)
  C: (6.29532E-011, 0.000646433)

  A-B: (2.47892E-011, -1.0455E-005)
  B-C: (-1.2441E-011, 0.000513339)
  A-C: (1.23482E-011, 0.000502884)
```

Figure 4.23: Optical solitons one cycle output propagation after travel over 10 km using optical sech pulse generator

Figure 4.23 shows one complete cycle of the third pulse from the optical solitons pulses propagation taken from Figure 4.22. It is observed that there is no distortion happening at the pulse. The peak value obtained for this optical pulse is 646.433μW which means there are power losses when compared with the input peak power of 1070.33 μW and the period for this one cycle pulse is 24.7892 ps thus the bit slot calculated is 12.3946 ps. Then from the bit slot the full width half maximum time, T_{FWHM} is calculated as 6.1973 ps. Next the relation between T_0 parameter and T_{FWHM} can be find by using the formula of,

$$T_0 = \frac{T_{FWHM}}{1.763} \quad T_0 = \frac{6.1973}{1.763} = 3.5152 \text{ ps}$$

The power value, P_N is then calculated as,

$$P_N = N^2 \frac{|\beta^2|}{\gamma {T_0}^2} = N^2 \frac{20}{1.317\ (3.5152)^2} = 1.2289\ N^2 [\text{W}]$$

Next, the value for the dispersion length, L_D of the optical soliton pulse is calculated by using the formula of,

$$L_D = \frac{{T_0}^2}{|\beta^2|} = \frac{(3.5152)^2}{20} = 0.6178 \text{ km}$$

Later on the solitons period, Z_0 is calculated by using the formula of,

$$Z_0 = \frac{\pi}{2} L_D = \frac{\pi}{2} 0.6178 = 0.9074 \text{ km}$$

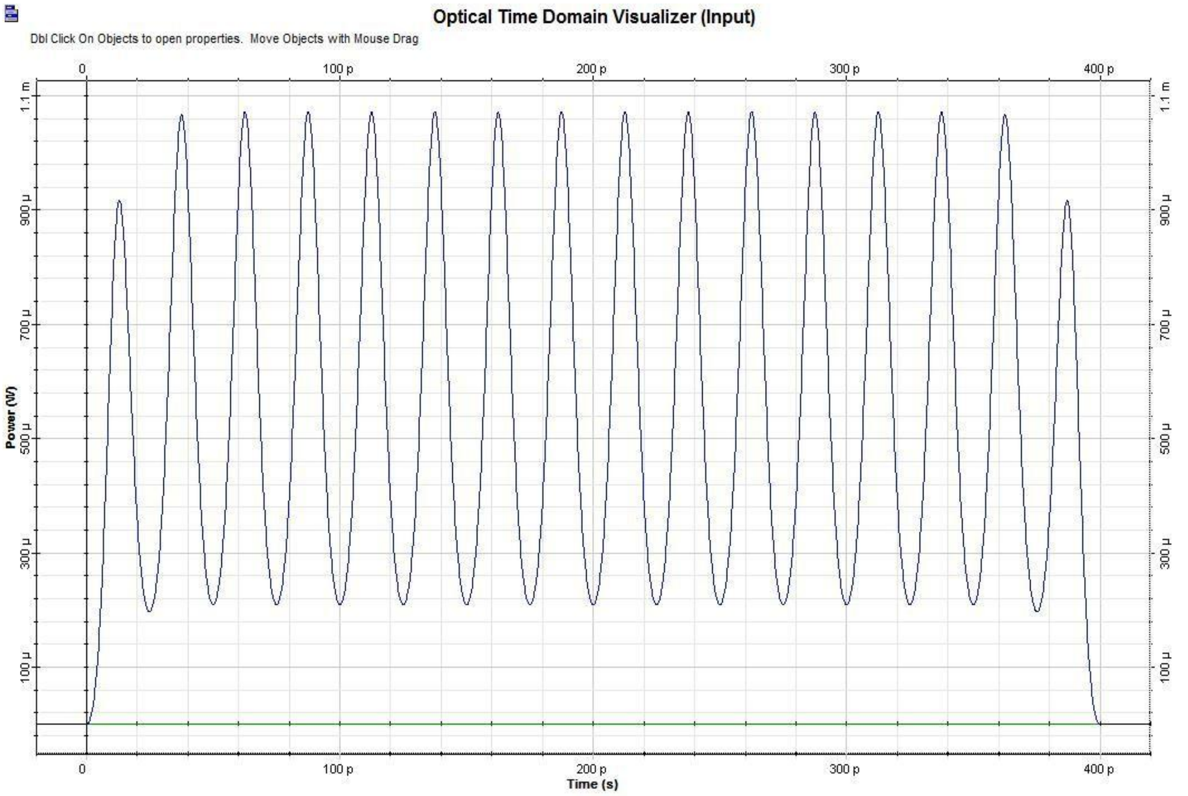
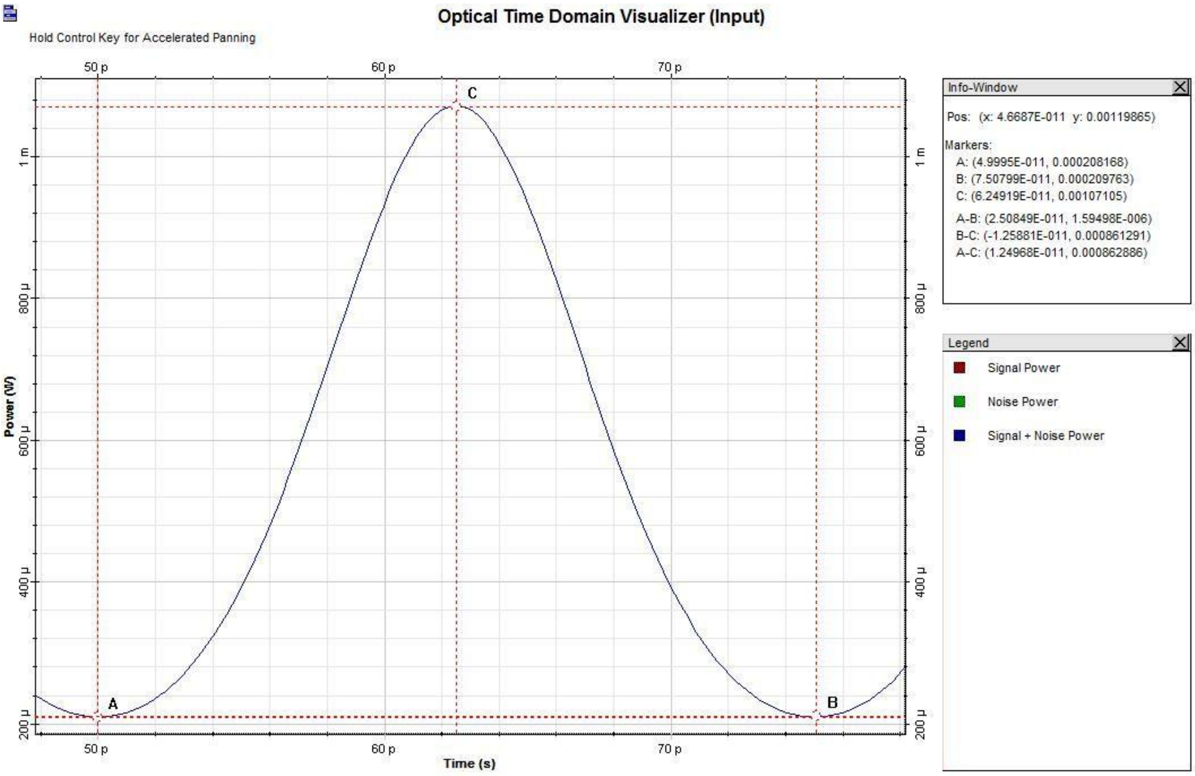


Figure 4.24: Optical solitons overall input propagation before travel over 20 km using optical sech pulse generator

Figure 4.24 shows the overall input of optical solitons propagation when using optical sech pulse generator before travel at 20 km of the nonlinear dispersive fiber total field. It can be seen from the graph that the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape and the peak power except the first and last bit pulses because they could be neglected as they are pulses that are affected by noises.



```
Info-Window
Pos:  (x: 4.6687E-011  y: 0.00119865)

Markers:
  A: (4.9995E-011, 0.000208168)
  B: (7.50799E-011, 0.000209763)
  C: (6.24919E-011, 0.00107105)

  A-B: (2.50849E-011, 1.59498E-006)
  B-C: (-1.25881E-011, 0.000861291)
  A-C: (1.24968E-011, 0.000862886)
```

Figure 4.25: Optical solitons one cycle input propagation before travel over 20 km using optical sech pulse generator

Figure 4.25 shows the one cycle input of optical solitons propagation at the 3rd bit pulse when using optical sech pulse generator before travel at 20 km of the nonlinear dispersive fiber total field. It can be seen from the graph that the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape. Besides that, it doesn't have any overshoots or undershoots. The input peak power at the 3rd bit pulse of the optical solitons propagation when before travel at 20 km is 1071.05μW determined by marker C at y-axis as shown in Figure 4.25.

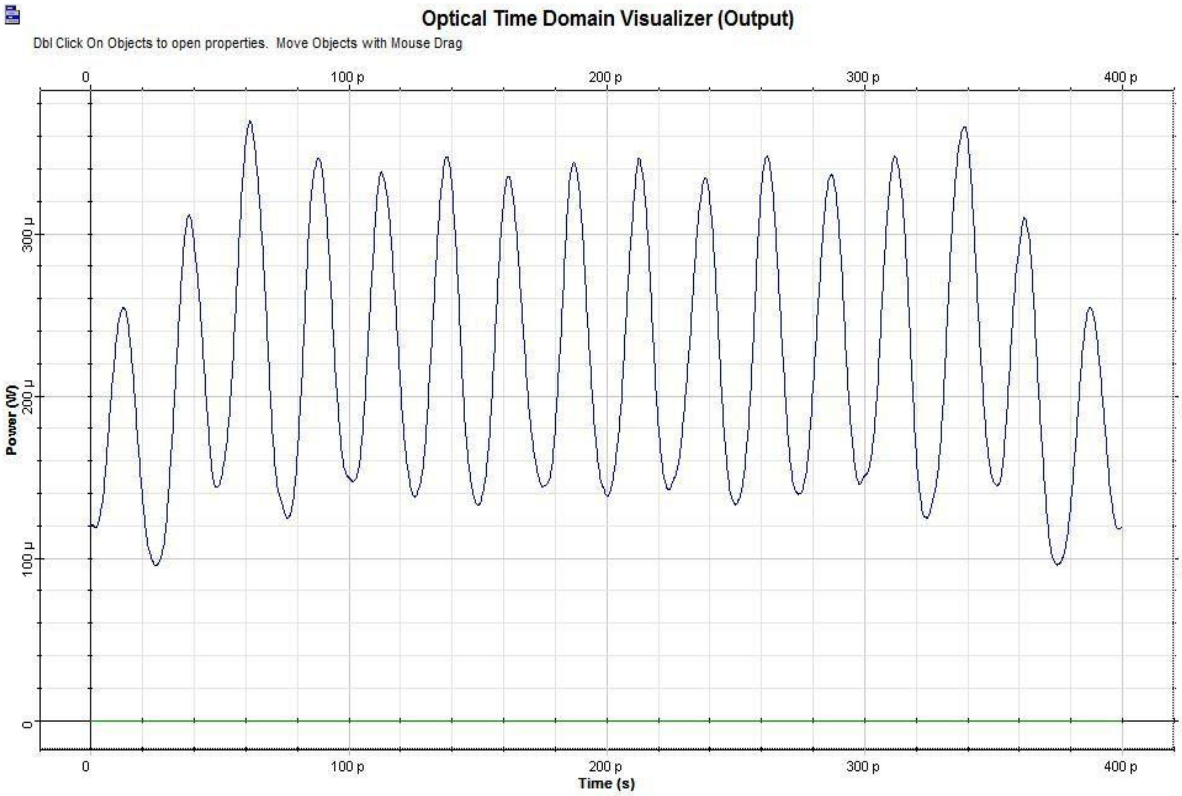
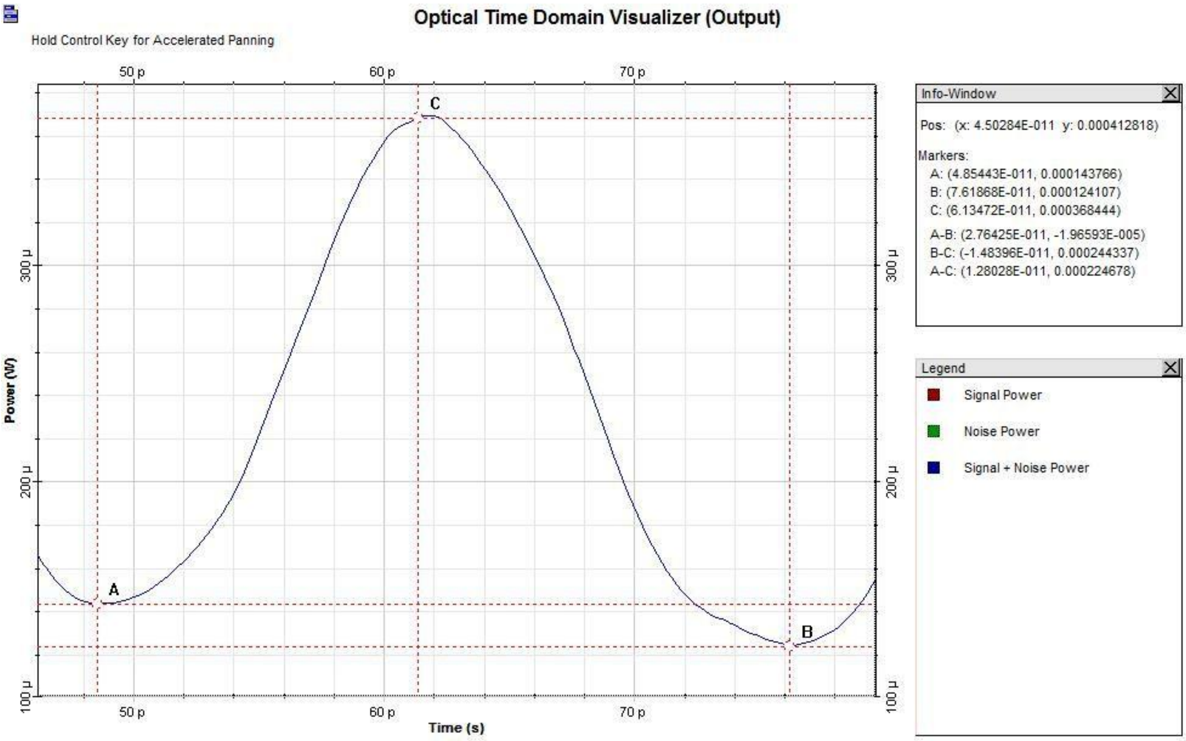


Figure 4.26: Optical solitons overall output propagation after travel over 20 km using optical sech pulse generator

The Figure 4.26 shows the overall output graph for simulation of the optical solitons when using the optical sech pulse generator after travel at 20 km with the aid of nonlinear dispersive fiber total field. It can be seen from the graph that the signal pulses has started to be slightly different in shapes and so as the peak values and periods are different from one pulse to another pulses. Some pulses are noticed to even have undershoots.



```
Info-Window

Pos:  (x: 4.50284E-011  y: 0.000412818)

Markers:
  A: (4.85443E-011, 0.000143766)
  B: (7.61868E-011, 0.000124107)
  C: (6.13472E-011, 0.000368444)

  A-B: (2.76425E-011, -1.96593E-005)
  B-C: (-1.48396E-011, 0.000244337)
  A-C: (1.28028E-011, 0.000224678)
```

Figure 4.27: Optical solitons one cycle output propagation after travel over 20 km using optical sech pulse generator

Figure 4.27 shows one complete cycle of the third pulse from the optical solitons pulses propagation taken from Figure 4.26. It is observed from the graph that there is a slight distortion happening at the pulse. The peak value obtained for this optical pulse is 368.444 μW which means there are power losses when compared with the input peak power of 1071.05 μW and the period for this one cycle pulse is 27.6425 ps thus the bit slot calculated is 13.8281 ps. Then from the bit slot the full width half maximum time, T_{FWHM} is calculated as 6.9106 ps. Then the relation between T_0 parameter and T_{FWHM} can be find by using the formula of,

$$T_0 = \frac{T_{FWHM}}{1.763} \quad T_0 = \frac{6.9106}{1.763} = 3.9198 \text{ ps.}$$

The power value, P_N is then calculated as,

$$P_N = N^2 \frac{|\beta^2|}{\gamma {T_0}^2} = N^2 \frac{20}{1.317\ (3.9198)^2} = 0.9883\ N^2 [\text{W}]$$

Next, the value for the dispersion length, L_D of the optical soliton pulse is calculated by using the formula of,

$$L_D = \frac{{T_0}^2}{|\beta^2|} = \frac{(3.9198)^2}{20} = 0.7862 \text{ km}$$

Later on, the soliton period Z_0 is calculated by using the formula of,

$$Z_0 = \frac{\pi}{2} L_D = \frac{\pi}{2} 0.7862 = 1.2067 \text{ km}$$

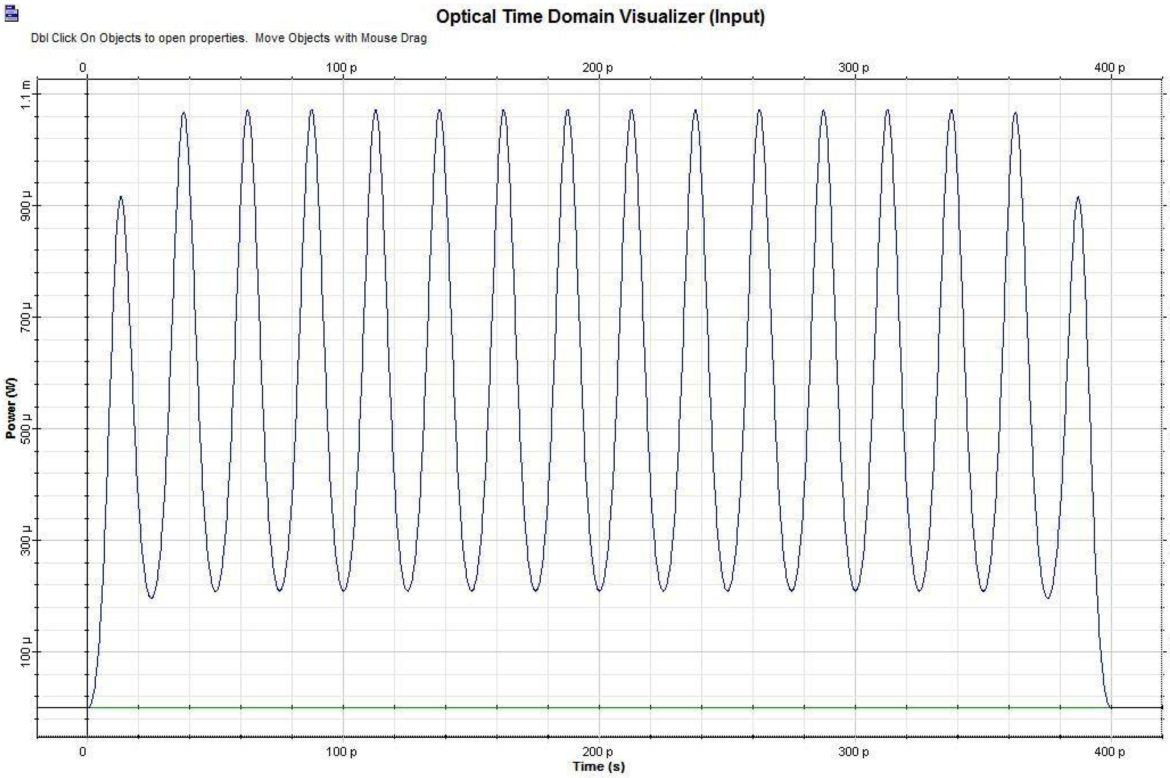
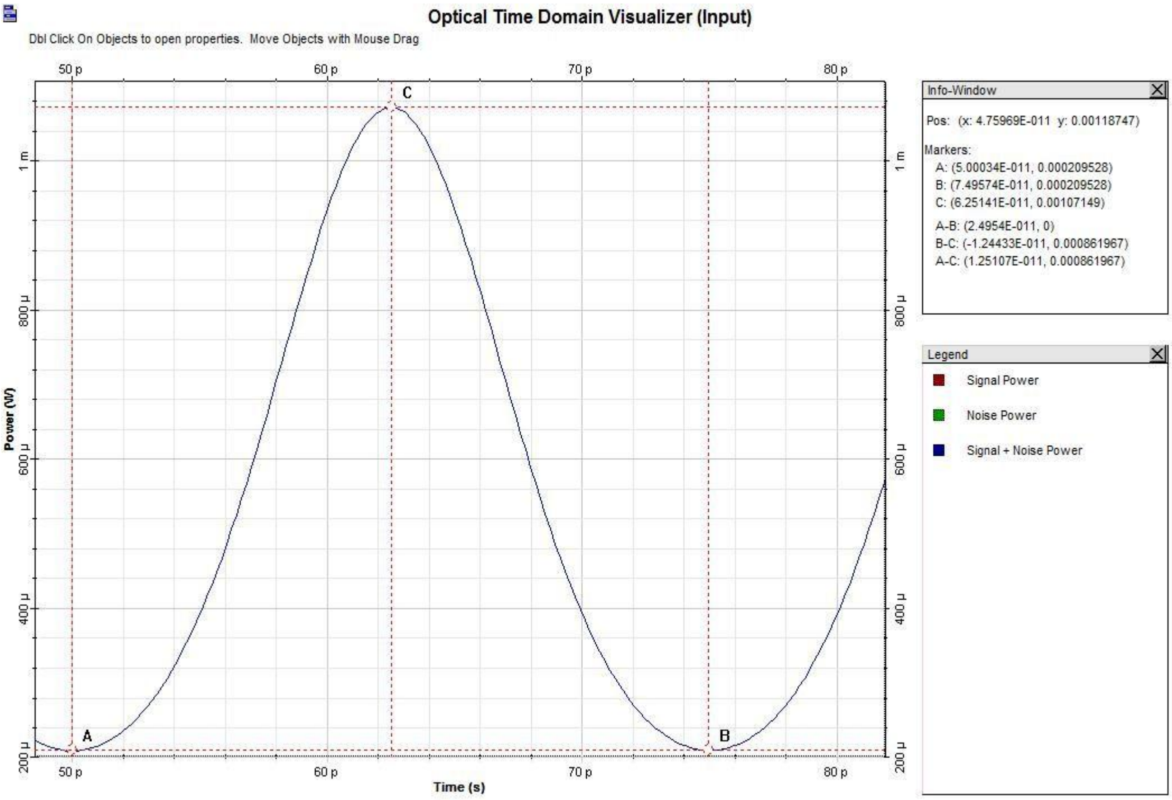


Figure 4.28: Optical solitons overall input propagation before travel over 30 km using optical sech pulse generator

Figure 4.28 shows the overall input of optical solitons propagation when using optical sech pulse generator before travel at 30 km of the nonlinear dispersive fiber total field. It can be seen from the graph that the solitons propagation even though before it travel at 30 km the input travels smoothly without any distortion and could preserve its own shape and the peak power except the first and last bit pulses because they could be neglected as they are the pulses affected by noises.



```
Info-Window
Pos:  (x: 4.75969E-011  y: 0.00118747)

Markers:
  A: (5.00034E-011, 0.000209528)
  B: (7.49574E-011, 0.000209528)
  C: (6.25141E-011, 0.00107149)
  A-B: (2.4954E-011, 0)
  B-C: (-1.24433E-011, 0.000861967)
  A-C: (1.25107E-011, 0.000861967)
```

Figure 4.29: Optical solitons one cycle input propagation before travel over 30 km using optical sech pulse generator

Figure 4.29 shows the one cycle input of optical solitons propagation at the 3rd bit pulse when using optical sech pulse generator before travel at 30 km of the nonlinear dispersive fiber total field. It can be seen from the graph that the solitons propagation when at the input travels smoothly without any distortion and could preserve its own shape. Besides that, it doesn’t have any overshoots or undershoots. The input peak power at the 3rd bit pulse of the optical solitons propagation before travel at 30 km is $1071.49\mu W$ obtained by the marker C at y-axis as shown in Figure 4.29.

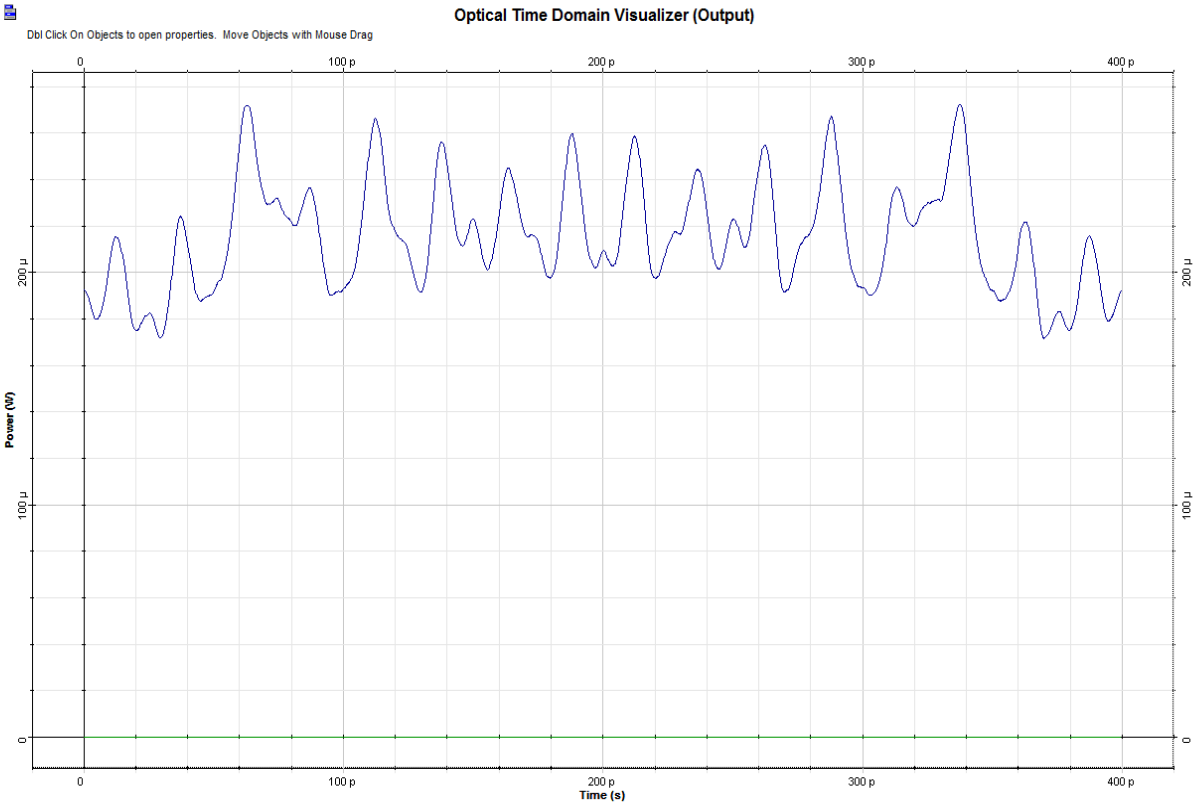
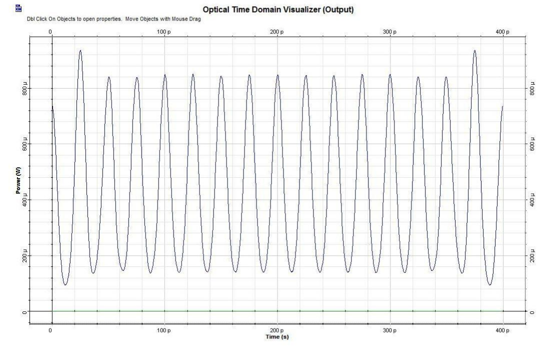
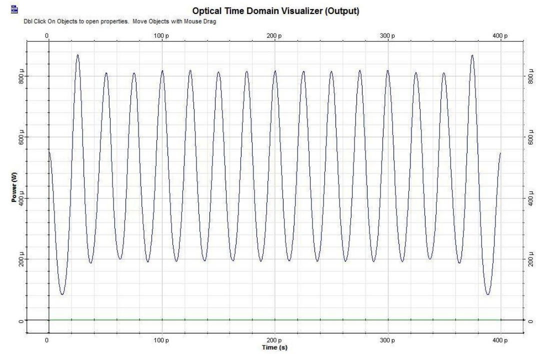
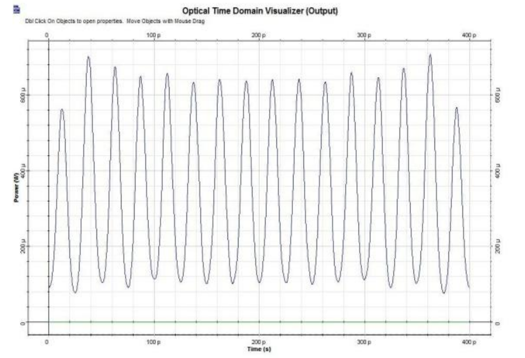
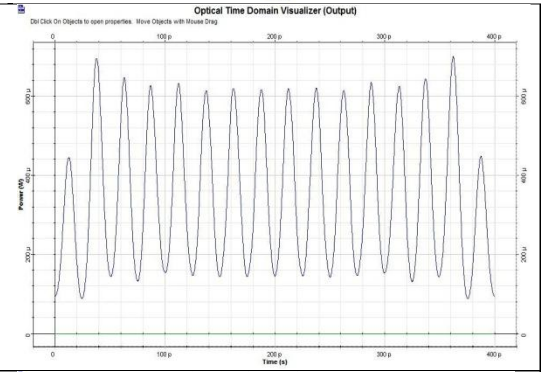
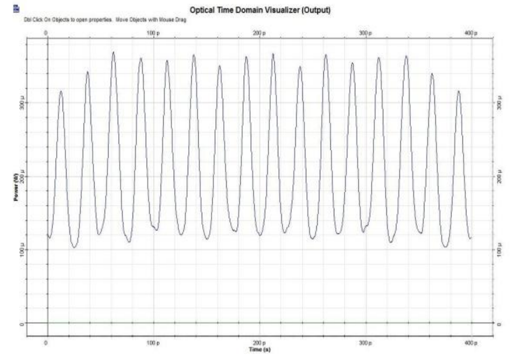
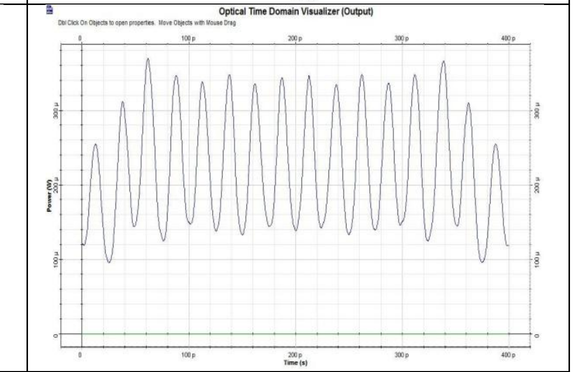
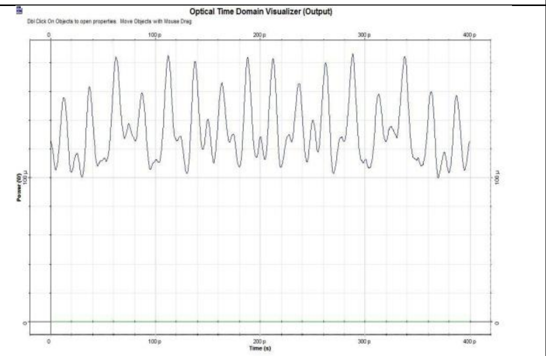
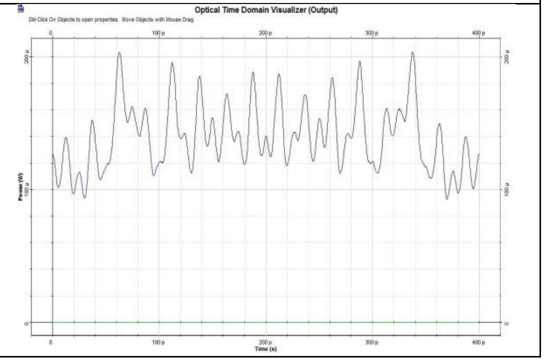


Figure 4.30: Optical solitons overall output propagation after travel at 30 km using optical sech pulse generator

The Figure 4.30 above shows the overall output graph for simulation of the optical solitons when using the optical sech pulse generator after travel at 30 km of nonlinear dispersive fiber total field. It can be seen from the graph that the signal pulses are very different in shapes and so as the peak values and periods of the pulses. Most of the pulses are noticed to have overshoots and undershoots.

From the output of the simulations obtained, the results for the Gaussian pulse and sech pulse could be compared in the table below:

Table 4.1: Comparison of the sech signal and Gaussian Signal on simulation model

Distance	Gaussian Pulse	Sech Pulse
3.9482km		
10km		
20km		
30km		

From the signals in Table 4.1 it is observed that the optical solitons signal when travel over 3.9482 km and 10 km distances either using sech or Gaussian pulse they propagate without changing their shape and even propagate at almost the same peak power undistorted. But then the optical solitons signal started to differ slightly in shape and peak power when they travel over 20 km be it with the sech or Gaussian pulse. However when the optical solitons signal travel at 30 km the signals are could no longer preserve their shape and peak power and at this rate they have overshoots and undershoots.

Table 4.1: Tabulated data for Optical Gaussian Pulse Generator simulation output

Nonlinear Dispersive Fiber Total Field length (km)	T_{FWHM} (ps)	Power Value ($N^2[W]$)	Dispersion length, L_D (km)	Soliton Period, Z_o (km)	Peak Value (μW)
3.9482	6.5846	1.0853	0.6995	1.0988	838.677
10	6.1632	1.2426	0.6110	0.9598	673.507
20	7.0155	1.0561	0.7917	1.2435	369.324
30	-	-	-	-	-

From Table 4.1 it is observed that when using optical Gaussian pulse generator and varying the nonlinear dispersive fiber total field length from 3.9482 km to 10 km, 20 km and 30 km the T_{FWHM} indicates a reduction from 6.5846 ps to 6.1632 ps but then increases back to 7.0155 ps respectively. For the power value initially it is increasing from 1.0853 $N^2[w]$ to 1.2426 $N^2[w]$ and then it decreased to 1.0561 $N^2[w]$. On another note, the dispersion length decreased from 0.6995 km to 0.6110 km and then increased to 0.7917 km. For the solitons period the value decreases from 1.0988 km to 0.9598 km and this means broadening happened but then it increased back to 1.2435 km.

Next, it is noticed that shortening occurred for the solitons as it keep decreasing from 838.677 μW to 673.507 μW and then to 369.324 μW. It is studied that the values obtained excluding peak values didn’t show any fixed pattern and they are either increased at first and then decreased or initially decreased and then increased because of the nonlinearities in optical soliton. When at 30 km, all the values for parametersT_{FWHM}, power value, dispersion length and soliton period couldn’t be traced because the output bit slot couldn’t be determined.

Table 4.2: Tabulated data for Optical Sech Pulse Generator simulation output

Nonlinear Dispersive Fiber Total Field length (km)sech	T_{FWHM} (ps)	Power Value ($N^2[w]$)	Dispersion length, L_D (km)	Soliton Period, Z_o	Peak Value (μW)
3.9482	6.5253	1.1085	0.6849	1.0758	809.420
10	6.1973	1.2289	0.6178	0.9704	646.433
20	6.9106	0.9883	0.7682	1.2067	368.444
30	-	-	-	-	-

From the Table 4.2 it is observed that when using optical sech pulse generator and varying the nonlinear dispersive fiber total field length from 3.9482 km to 10 km, 20 km and 30 km the T_{FWHM} indicates a reduction from 6.5253 ps to 6.1973 ps but then increases back to 6.9106 ps respectively. For the power value initially it is increasing from 1.1085 $N^2[w]$ to 1.2289 $N^2[w]$ and then it decreased to 0.9883 $N^2[w]$.

On another note, the dispersion length decreased from 0.6849 km to 0.6178 km and then increased to 0.7682 km. For the solitons period the value decreases from 1.0758 km to 0.9704 km and this means that broadening happened but then it increased to 1.2067 km. Next, it is noticed that shortening occurred for the solitons as it keep decreasing from 809.420 μW to 646.433 μW and then to 368.444 μW.

It is studied that the values obtained excluding the peak value didn't show any fixed pattern and they are either increased at first and then decreased or initially decreased and then increased because of the nonlinearities in optical solitons. However it shows similarity with that of the optical Gaussian pulse generator in terms of increasing and decreasing of the parameter values.

When at 30 km, all the values for parameters T_{FWHM}, power value, dispersion length and soliton period couldn't be traced because the output bit slot couldn't be determined. At this distance it is obvious that the optical solitons couldn't preserve its own shape anymore. It is also observed that pulses shape obtained for both optical Gaussian pulse generator and optical sech pulse generator is similar to the one expected from the literature review [13].

Besides that, it is also examined that the dispersion length obtained for optical solitons propagation output when using optical Gaussian pulse generator is higher than that of the optical sech pulse generator and when relate to communication system optical solitons that have higher dispersion length will results in higher data losses due to the scattering effect.

Other than that, it is also observed during the simulation that when comparing the input and the output peak power of the optical solitons propagation there are power losses occurred for each simulation process either the optical Gaussian pulse generator or optical sech pulse generator is used at any distances. This is most probably because of the imperfection of the optical fiber.

4.3 Result and Discussion Summary

From the results and discussion in the previous section it is studied that the optical solitons propagation formed due to the simulation are as predicted as in the literature review. On another note, it is also determined that when using optical sech pulse generator data losses could be reduced due to the scattering effect since it have lower dispersion length when compared with the Gaussian pulse. Besides that the nonlinearity effect of the optical solitons are observed when varying the distances of the nonlinear dispersive fiber total field especially when the parameter values obtained are either initially increased and then decreased back or initially decreased and then increased back. Moreover, the power losses from the input to the output peak power of the optical solitons are also identified due to the imperfection of the optical fiber.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As the conclusion, optical solitons could be modeled and simulated by using OptiSytem software whether by using optical Gaussian pulse generator or optical sech pulse generator. Moreover, it could be said that based on the analysis it is better to use optical sech pulse generator compared to optical Gaussian pulse generator as it have lower dispersion length and thus have lower losses in communication system due to the scattering effects. From the simulation the effects of nonlinearity and dispersion are able to be observed due to the shortening and broadening of the optical pulses. Besides that, the use of nonlinear dispersive fiber total field is successfully implemented in this project. This is because by controlling the distance of the nonlinear dispersive fiber total field, the dispersion length and the soliton period could also be control. Last but not least, from this project it is proved that the theoretical aspect and simulation result about the effects of nonlinearity is existed in optical solitons where the result can be compare through theory and simulation.

5.2 Recommendations

The optical solitons simulation could always have a space for improvement, and this project is also included. Since there are still lacks of practical use in optical solitons, a few recommendations had been carried out in order to have more alternatives ways in learning process. These recommendations are based on attractive learning and also observation from the project. Here are some suggestions for the future development;

- ✓ Simulation of optical solitons in single mode optical fiber for over 40Gb/s with the use of multiplexer

- ✓ Optical solitons simulation in multimode optical fiber for over 40Gb/s
- ✓ Implementation of the simulation of the optical solitons in single mode optical fiber (Hardware implementation)

5.3 Project Potential

In communication systems, this project has a potential for being used. This is because this project improvises the speed of the communication system through optical fiber and the optical fiber for communication systems are currently in demand as it is being used for internet connection, phone telecommunication and even internet protocol television. Besides, this project also can produce lower losses and provides stability to the communication system.

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Appendix A: Project Gantt Chart

Project Schedule of Project Activities (Gantt Chart)

No.	Project Activities	2012																2013																							
		Sep				Oct				Nov				Dec				Jan				Feb				Mar				Apr				May				June			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1.	Optical Solitons concept & theory study	■	■	■	■	■	■	■	■																																
2.	Continuous literature review	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
3.	Optical solitons modeling circuit									■	■	■	■	■	■	■	■																								
4.	Optical solitons simulation for both generators																	■	■	■	■	■	■	■	■																
5.	Result comparison from both generators																					■	■	■	■	■	■	■	■												
6.	Result analysis																									■	■	■	■	■	■	■	■								
7.	Report writing preparation and submission																																	■	■	■	■	■	■	■	■