Fiber-optic-chirped-pulse-dispersion

This repository contains a few simulations related to the time dispersion of a chirped pulse when it travels along a fiber cable. It is important to understand the frequency dispersion of a pulse when it travel through a fiber cable because when time dispersion increases, the bit rate must decrease in order to avoid pulse interference and information loss.

This simulation was made taking theoretical reference from the book Fiber-Optic Communication Systems by Govind P. Agrawal.

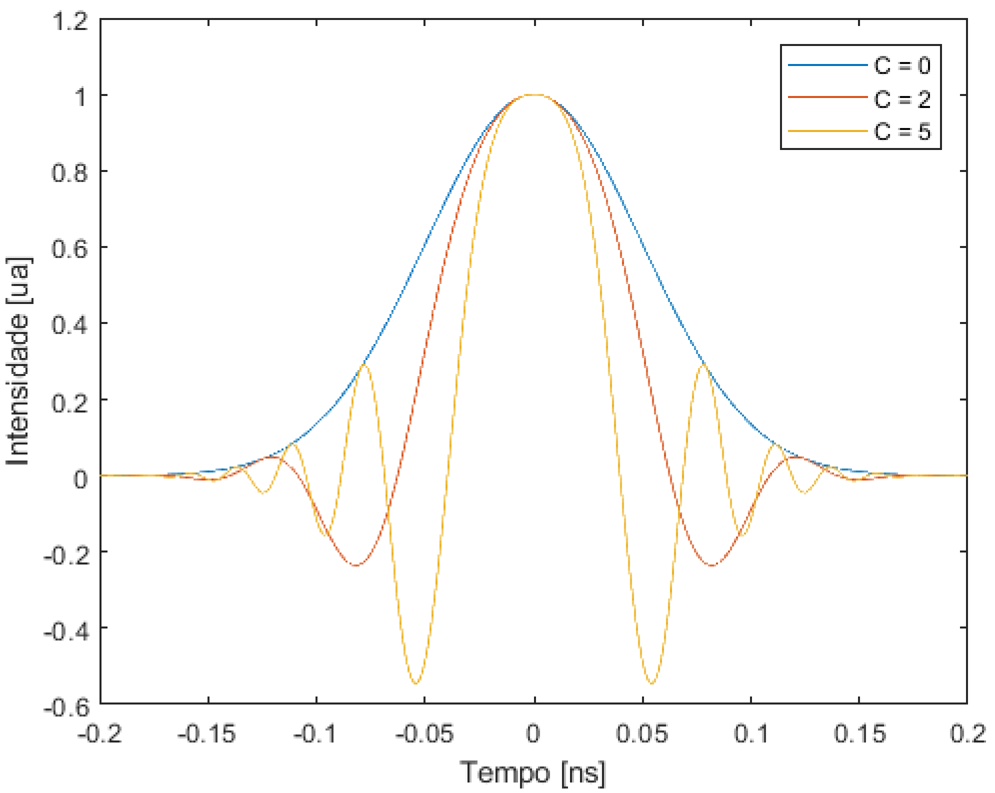
Initial Chirped Pulse

The file **simulation_initial_pulse_form.m** gives a graph of the shape of a chirped gaussian pulse right when it is generated on the fiber. It is interesting to simulate these pulses because the are close to the pulses generated by lasers. The field variation as a function of time of a gaussinan chirped pulse is given by:

$$A(0,t) = A_o exp\left[-\frac{1+jC}{2}\left(\frac{t}{T_0}\right)^2\right]$$

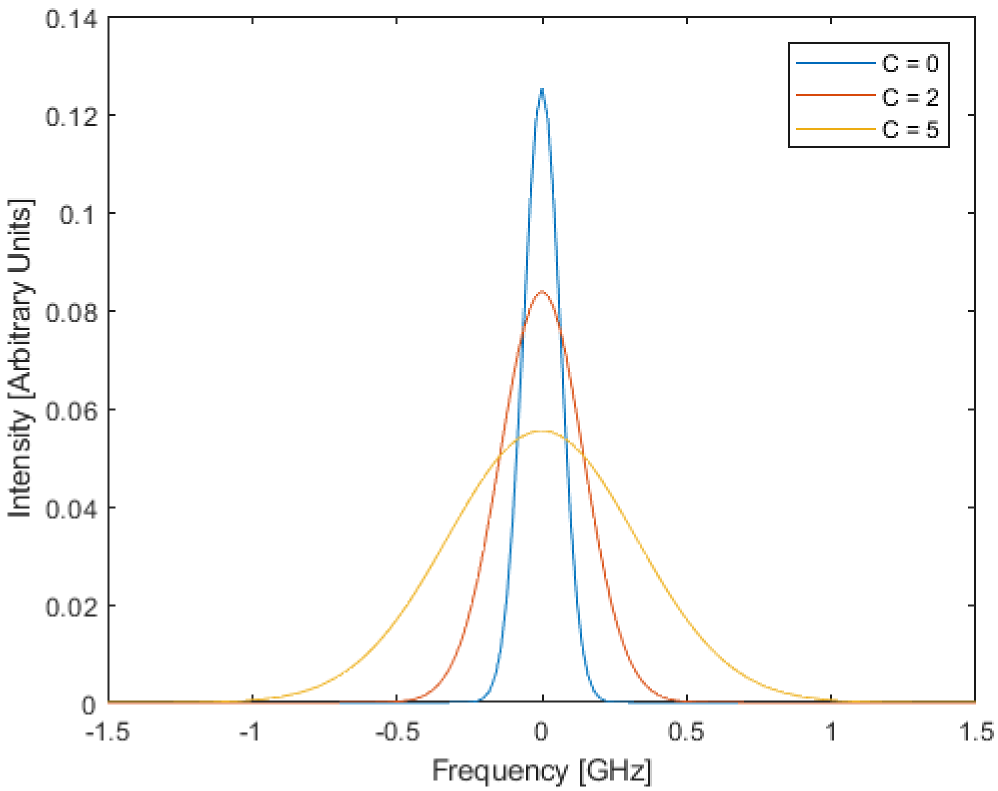
Where A_0 is the pulse amplitude C is the chirp parameter and T_0 is the pulse period.

If we take the real part, we get the following graph:



Frequency Domain Analysis

The file **simulation_fourier.m** provides a frequency analysis of the effects of the frequency chirp by calculating the Fourier transform of the field variations. It is possible to notice that with a greater chirp parameter the field will have more oscillations and the pulse will have a broader frequency spectrum, as it may be seen in the time domain with the initial chirp simulations and in the frequency domain in the next figure.



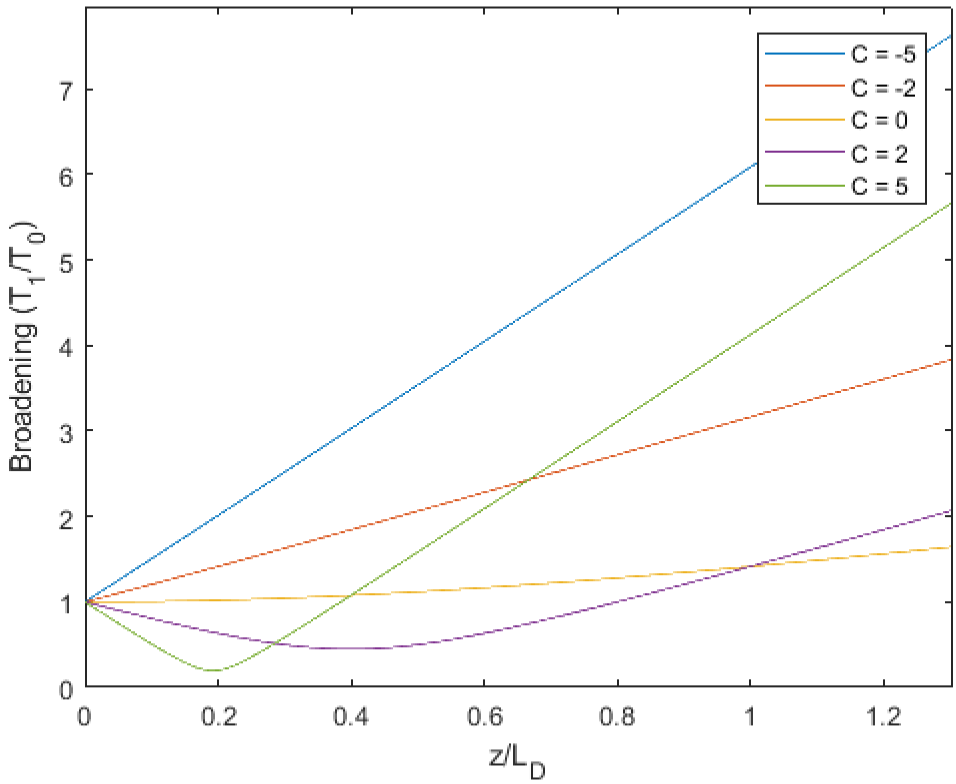
A broader frequency response means more time dispersion when the pulse travel through the fiber since any material has a refraction index dependent on the light frequency. A large time dispersion of a single pulse means that in order to avoid pulse interference the pulses must be transmitted in a lower rate, which degrades the maximum bit rate of the system.

Broadening Factor x Propagation Distance

The file **simulation_broadening.m** provides a simulation of the broadening factor if a pulse in function of the propagation distance, a normalized version of the distance given by z/L_D, where z is the distance traveled by the pulse in kilometers and L_D is the dispersion length, a parameter tha relates the pulse period T_0 and the GVD (Group Dispersion Parameter) of the fiber, denoted by β_2. The broadening factor represents the reason between the final and initial pulse widths T_1 and T_0, and is calculated by the formula:

$$fracT_1T_0 = \left[\left(1 + \frac{C\beta_2 z}{T_0^2}\right)^2 + \left(\frac{\beta_2 z}{T_0^2}\right)^2\right]^2$$

Applying this formula one may see that for some chirp parameters there is a given optimal distance where the pulses actually get a negative broadening factor, as shown on the following image:



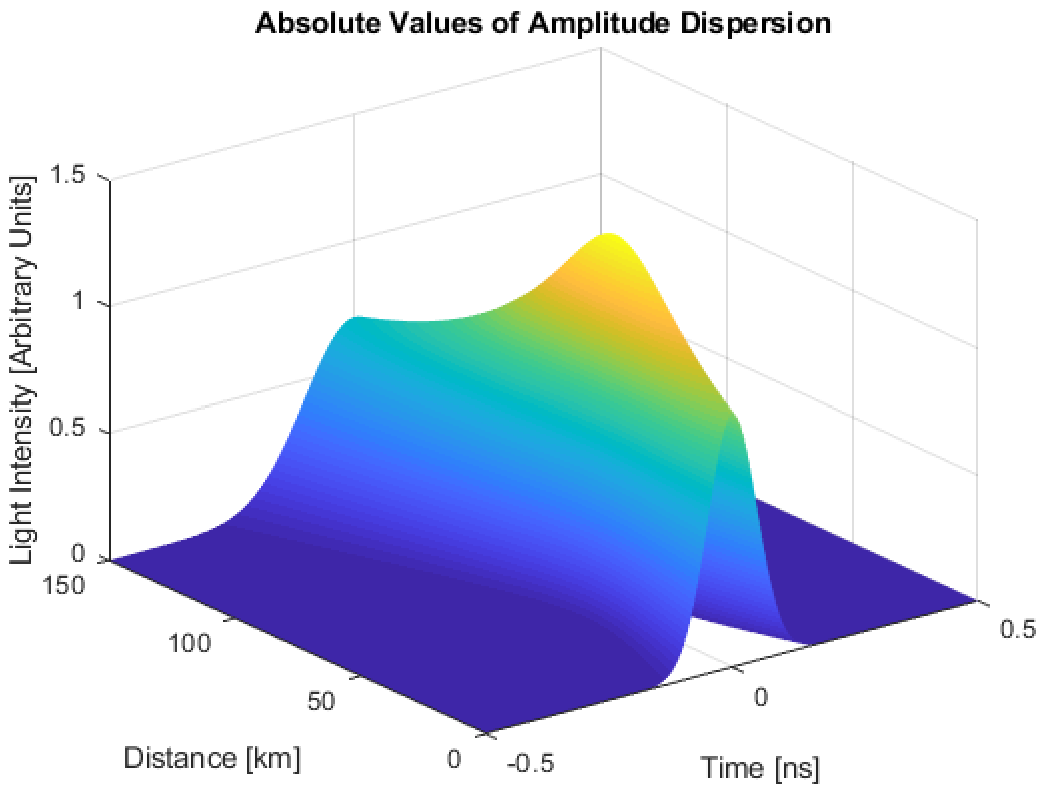
Pulse Broadening x Distance

Finally, the file **simulation_broadening_x_distance.m** provides a simulation of the pulse amplitude evolution as it travels on the fiber. The equation for the propagation of a gaussian chirped pulse as a function of the traveled distance z is given by the following Equation:

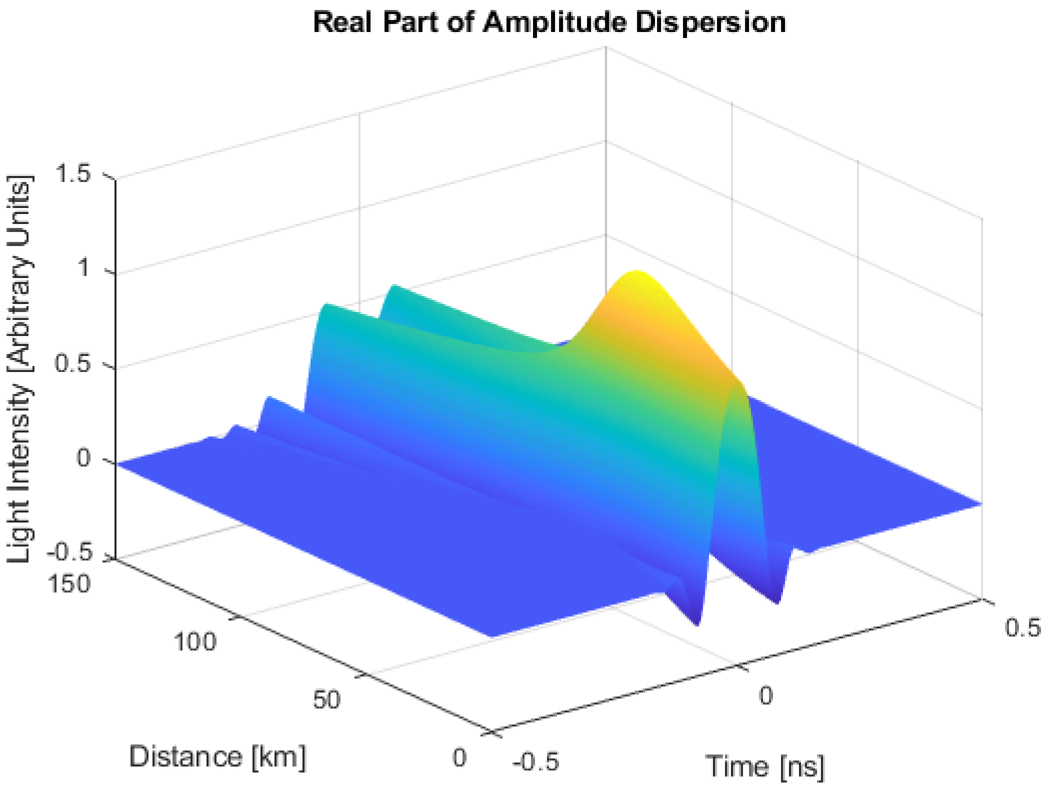
$$A(z,t) = \frac{A_o}{\sqrt{Q(z)}} exp\left[-\frac{1+jC}{2}\left(\frac{t}{T_0}\right)^2 \frac{1}{Q(z)}\right]$$

Which is the general case of the first Equation for the initial pulse introducing the term $Q(z) = 1 + (C - j)\beta_2 z / T_0^2$

The following image illustrates the obtained pulse amplitude absolute value evolution. It is possible to see a peek corresponding to the optimal distance where the pulse has a negative broadening.



This final simulation also shows the pulse amplitude real part evolution, as seen on the following Figure:



Reference Material

A discussion in far grater detail about the chirped pulse evolution and many other themes on fiber optics is found on the book Fiber-Optic Communication Systems by Govind P. Agrawal:

https://www.amazon.com/Fiber-Optic-Communication-Systems-Govind-Agrawal/dp/0470505117