UNIVERSITY OF WEST LONDON

Communication Systems

Assignment 1

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Abstract

This assignment is composed of 2 tasks. The first is an exercise that requires the performance of the modulation and demodulation of a signal. This was achieved using Matlab code and Simulink simulation following the equation in the lecture notes. The second task was a research-based task of the two topics. Each topic was discussed in detail and proved graphical representations of the methods and mathematical equations were provided. The advantages, disadvantages, and different techniques used to perform the wavelength division method were described as well as the current and future of the technology.

Introduction

This assignment is composed of two main tasks. The first was software and simulation-based task that required one to perform the modulation and demodulation of a signal with a sampling frequency of 1kHz and a run time of 1 second. The second task was a research-based task that required one to research different topics. The first topic consisted of using the cutback method, the second topic discussed wavelength division multiplexing. The purpose of this assignment was to learn and develop the understanding of communication systems through performing the modulation and demodulation of signals. The research was also undertaken on current techniques used to transfer data through fiber optic.

Task 1

The first task consists of simulating the modulation and demodulation of a signal with a sampling frequency of 1khz and run time of 1 second.

Theory

Modulation is used in a communication system to transmit signals through long-distance without losing the original signal to noise caused by transmission lines. To prevent this, the signal is modulated by using a summer amplifier and nonlinear component like a diode to add to the original signal and carrier signal of the same amplitude. This achieves optimal modulation and typically higher frequency hence conveying the original signal to a distant receiver. The signal is then demodulated through the processes of rectifying and filtering using low pass filters resulting in the original signal.

Programming

The first method used to perform the modulation and demodulation of the signal was by using the Matlab code to write the equations and enter the parameters of the signal to perfume the modulation. This code is composed in the first 2 lines by code to clear all previous data before running the code of the signal. Line 3 to 8 of the code are the parameters of the signals displaying sampling frequency, the time variable, the carrier signal frequency, the frequency of the input signal, and the amplitude of the input signal and carrier respectively. Inline 9, the modulation index is calculated. Lines 10 to 13 portrays the calculation of the carrier signal formula and the modulating signal formula. Line 14 shows how the signal is modulated, and lines 15 and 19, the signal demodulated. This is done by first rectifying the signal and then filtering it. Lines 20 to 40 conveys where the plotting of the signals on a graph.

```
1-clc;
2-clear;
3-fs=1000; %sampleling
4-t=linspace(0,1,1000); %or 0:0.001:1 to get a sampeling
frequncy of 1khz with a 1 sec runtime
5-fc=5000; %carrier
6-fm=200;  %signal
7-am=10;    % amplitude of singal
8-ac=10;   % amplitude of carrier
9-m=am/ac; % modulating index
10-wc=2*pi*fc*t;  % carrier frequecy
11-wm=2*pi*fm*t;  % signal frequency
12-ec=ac*sin(wc); % carrier signal
13-em=am*sin(wm); % signal
14-y=ac*(1+m*sin(wm).*sin(wc)); % modulated signal
15-d=y.*ec;
16-d1=conv(d,exp(-t/0.000795));
17-d2=conv(d1,exp(-t/0.000795));
18-d3=conv(d2,exp(-t/0.000795));
19-d4=conv(d3,exp(-t/0.000795));%demodulated signal
```

```
a=1000;

subplot(5,1,1),plot(t(5:a),em(5:a)) % plot of input signal
xlabel('Time(s)');
ylabel('Amplitude(v)');
title('Signal');
subplot(5,1,2),plot(t(5:a),ec(5:a)) % plot og carrier signal
xlabel('Time(s)');
ylabel('Amplitude(v)');
title('Carrier Signal');
subplot(5,1,3),plot(t(5:a),y(5:a)) % plot of modulated signal
xlabel('Time(s)');
ylabel('Amplitude(v)');
title('Modulated Signal');
subplot(5,1,4),plot(t(5:a),d(5:a)) %plot of rectified signal
xlabel('Time(s)');
ylabel('Amplitude(v)');
title('rectified Signal');
subplot(5,1,5),plot(t(5:a),d4(5:a)) %plot of demodulated signal
xlabel('Time(s)');
ylabel('Amplitude(v)');
title('Demodilated Signal');
```

Results

Figure 1 shows all the plotted signals consisting of the carrier signal, the input signal, modulated signal, rectified signal, and the demodulated signal. The modulated signal achieves optimal modulation, this is conveyed by the modulation index equalling 1. The rectified signal can be observed and compared to the final output demodulated signal. It was found that the demodulated signal was similar to the original signal displaying the clarity and its similarity through the filtering of the signal multiple times.

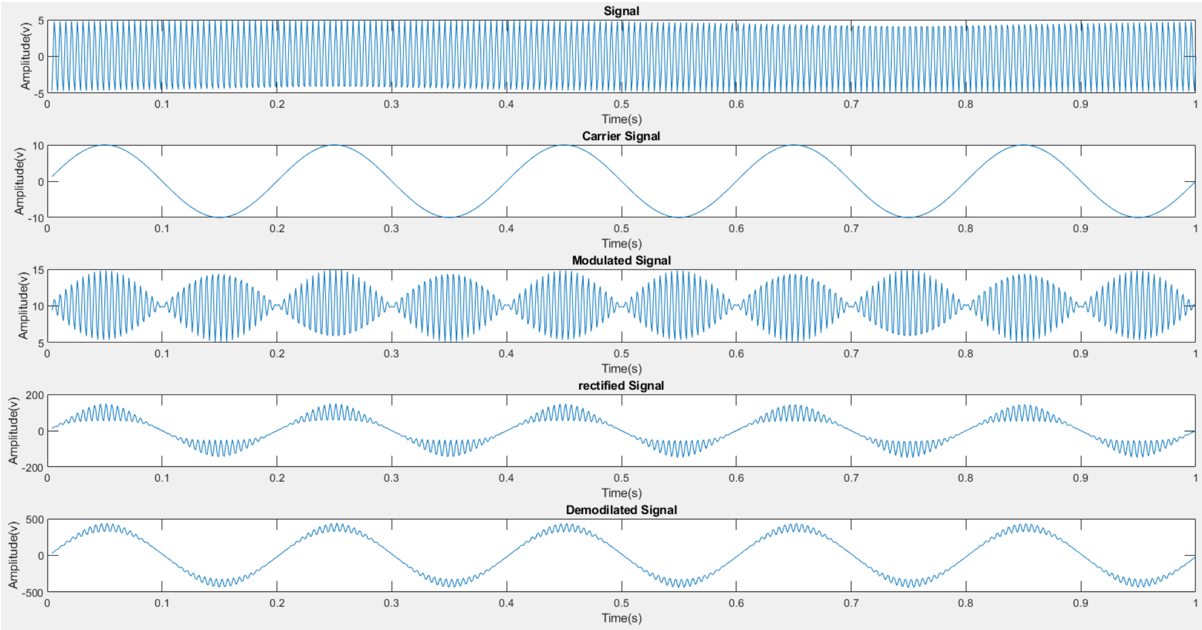

Figure 1: show Matlab code results

Simulation

For the simulation, Simulink was used. Figure 2 shows the Simulink model used for this task which follows the formulas used in the Matlab code forming the code on pages 5 to 6. The same frequency was also used for both signals. In this model the first two block functions are two signal generators which then are multiplied by a product block. The output of the product block is then multiplied by 1/AC. The output of this calculation is then added with AC to get the modulated signal in figure 5. Then the modulated signal is rectified by multiplying it by the carrier signal to achieve the signal in figure 6. The rectified signal is then passed through multiple low pass filters, which in this simulation are represented by transfer functions of values, shown in equation 1, resulting in the demodulated signal in figure 7.

$$\frac{2\pi \times 5000}{s + 2\pi \times 5000}$$

Equation 1: transfer function

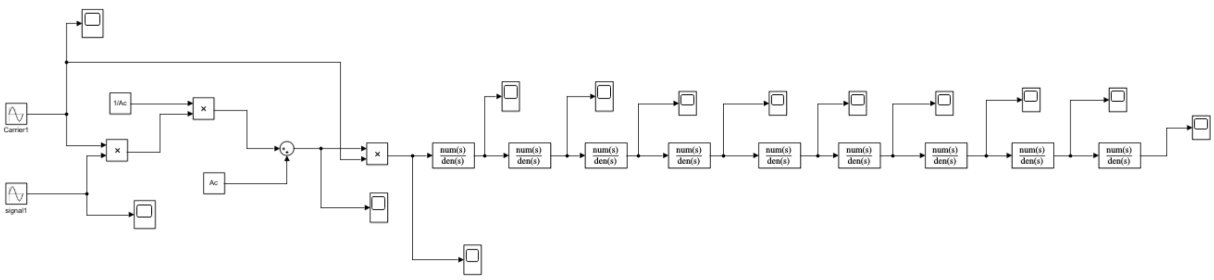

Figure 2: Simulink model

Results

Below, figures 3, 4, 5, 6, and 7 shows that the results achieved in this simulation are similar to the results gathered using the MatLab code. The run time was reduced to better the visualization of the signals.

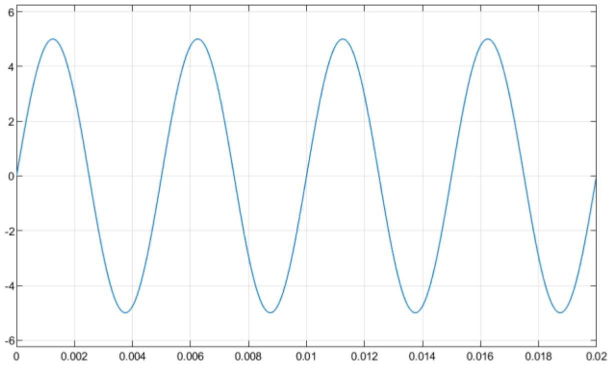

Figure 3: input signal

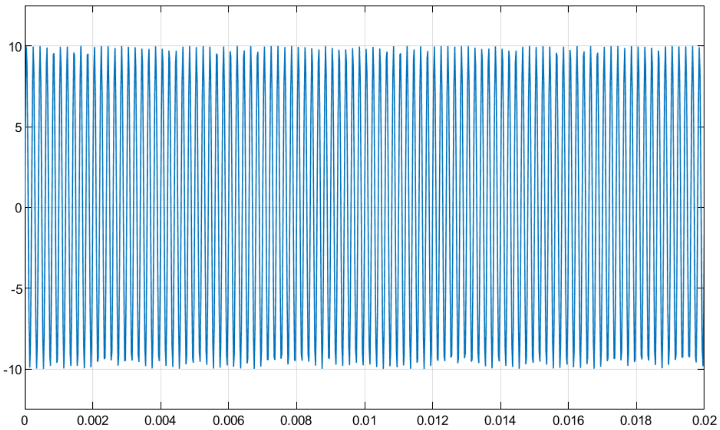

Figure 4: carrier signal

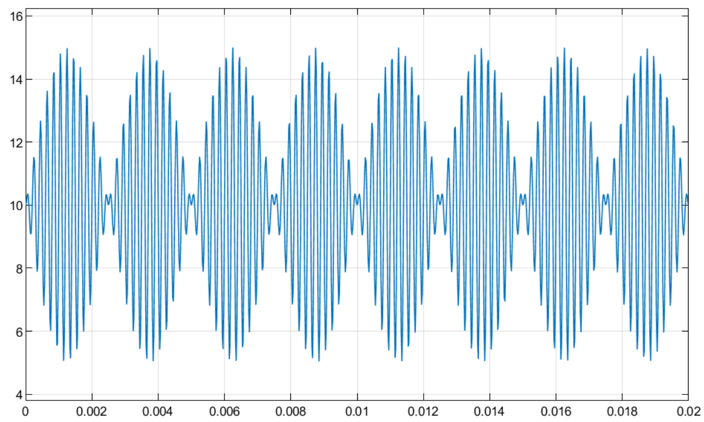

Figure 5: modulated signal

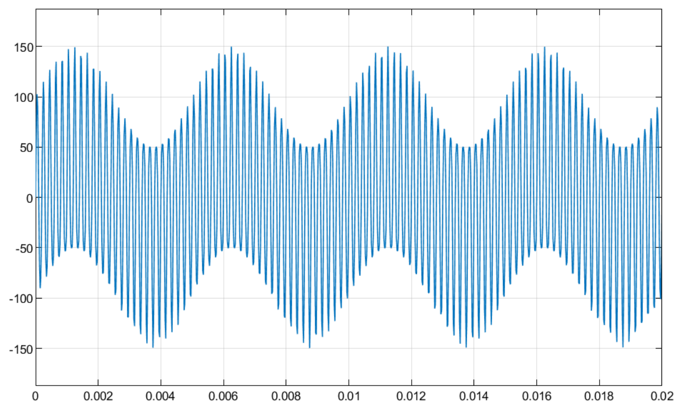

Figure 6: rectified signal

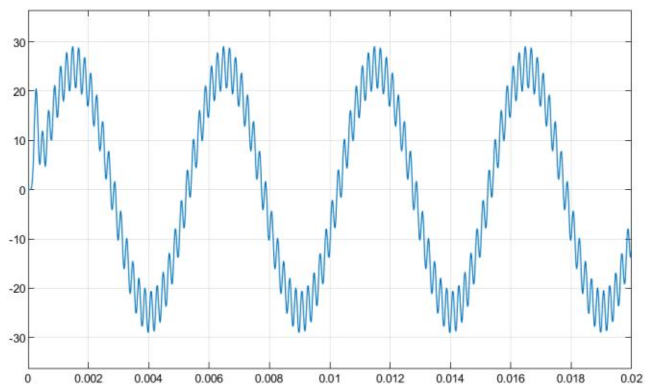

Figure 7: modulated signal

Task 2

The second task is divided into 2 parts which consist of searching for 2 different topics of fiber optics- fiber attenuation and wavelength division multiplexing.

Fiber optic attenuation measurement

In fiber optics, attenuations are the loss of power that affects the light signal caused by absorption and dispersion of the signal whilst traveling through the optic medium every time the signal is refracted or the fiber is bent. This attenuation can be calculated as the measure of power loss of the signal in between 2 arbitrary points as shown in equation 2. Where Pi is the power input of the signal and Po is the power output. And the attenuation rate is calculated by equation 3 which is given by attenuation over distance traveled or length of the optic medium.

$$A = 10\,log\left(\frac{P_i}{P_o}\right)$$

Equation 2: attenuation formula

$$\alpha = \frac{A}{L}$$

Equation 3: attenuation rate

One of the more common methods to measure the attenuation of an optical fiber used is the cut-back method. This method consists of comparing the input and output power of a transmitted light signal through a long segment of an optic fiber wire of a known length. This is done by acquiring access to both ends of the fiber that is being tested. The fiber is measured to get the length, Li. Then the input signal of power, Pi, is sent through the fiber. The output signal of power, Po, is then measured. The fiber is then cut to a length of around 2m and the input and output signal Pi2 and Po2 are measured for that new length as shown in figure 8. The attenuation rate of that optic fiber is given by equation 4.

$$\alpha = \frac{10^4}{L_0 - L_i} log\frac{P_i}{P_0}$$

Equation 4: cut-back formula

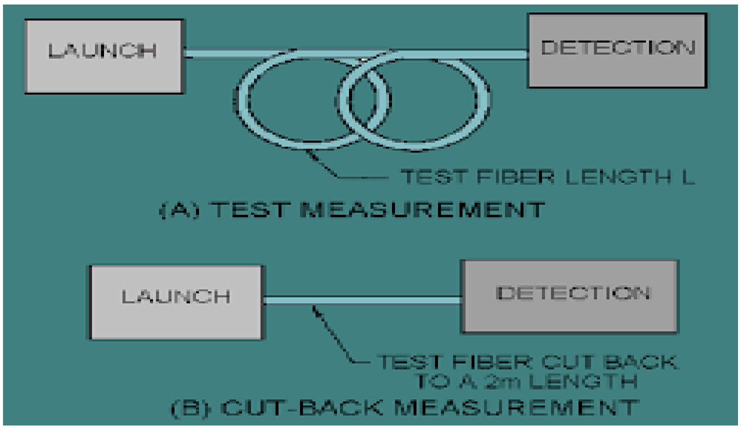

Figure 8: cut-back method

When performing the cut-back method is it is crucial for the result of the test to be as accurate as possible by monitoring the lunch conditions of the signal due to the fact that different lunch conditions lead to different results. The lunch condition is monitored by controlling the lunch spot size and the angular distribution of the light beam. When the spot size is smaller than the area of the fiber face, and the numerical aperture NA of the input radiation is smaller than the NA of the fiber; the fiber is underfilled and most of the signal power is concentrated in the center of the fiber- shown in figure 9. If the contrary is true, the fiber is overfilled and the light signal falls outside the fiber core. Most of the power is lost because the light signal is at an angle greater than the angle of acceptance of the fiber core as shown in figure 10. Hence the optimal lunch conditions for the cut-back method are having an underfilled fiber.

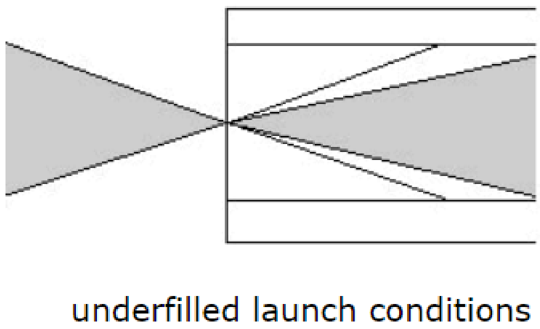

Figure 9: underfilled launch condition

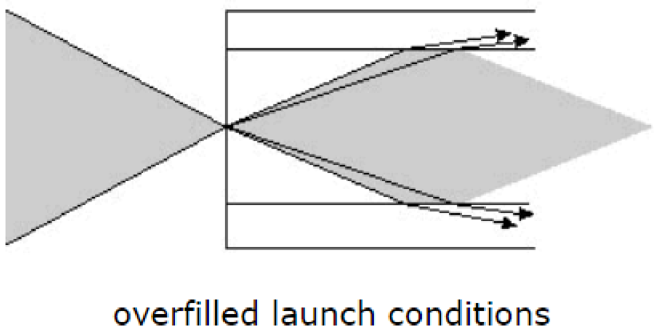

Figure 10: overfilled launch condition

Wavelength Division multiplexing

For fiber optic telecommunications, the implementation of the wavelength division multiplexing was a revolutionary and fundamental step for the success and performance of this technology. This method was first deployed for commercial use in 1996 and has significantly increased the bandwidth by allowing multiple data streams to be sent contemporaneously through a single fiber optic line. This allows for the maximization of every individual fiber-optic line to the fullest thereby reducing the number of fiber optic lines needed for the transfer of data. This method works by gathering several data streams in different light channels and assigning each channel to a specific wavelength. This changes the light color emitted by each data stream into a specific color for each data stream when visible light is used. Then all the signals are combined and sent through a signal optic fiber, which is then separated back into the original signals when received. This allows using a signal fiber to send multiple signals as shown in figure 11, instead of assigning a line to each signal as shown in figure 12.

Figure 11: WDM

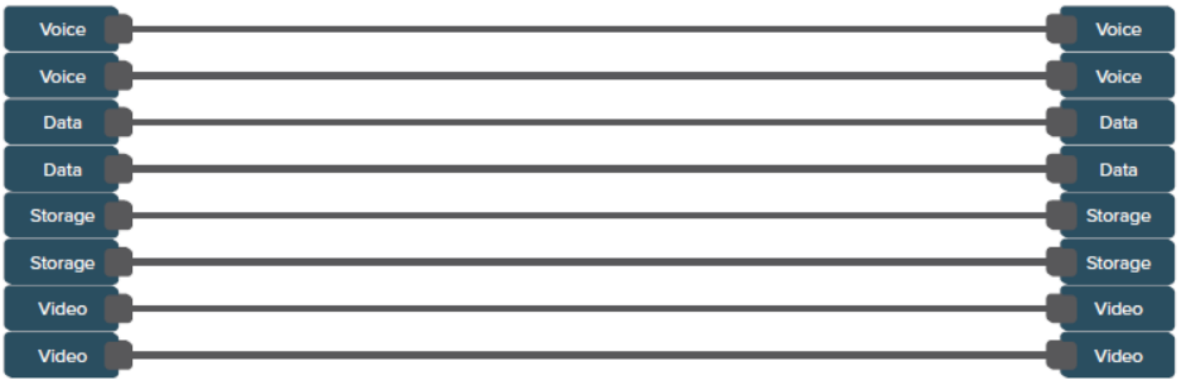

Figure 12: individual line per channel

The system used for wavelength division multiplexing consists of transceivers that are assigned to each data stream channel to convert data into light and transmit and assign a specific wavelength to each line. The patch cord connects the transceiver and the multiplexer, the WDM multiplexer combines all the light signals into one, and the dark fiber transmits the multiplexed signal to the demultiplexer dividing the incoming signal into the originally transmitted signals. This system can be used for pre-existing optic fiber networks and can create more channels needed by demand without disturbing the pre-established channel. This is because they remain unaffected by speed and type of data sent through the line so audio and video signals can all be sent at the same time. To be able to send and receive data simultaneously using this method, 2 techniques are used, the first requires a pair of fiber where one is used for the transmission of data and the other for receiving data- shown in figure 13. The second technique used a single optic fiber for transmission and receiving by assigning a different wavelength to be transmitted and received as shown in figure 14.

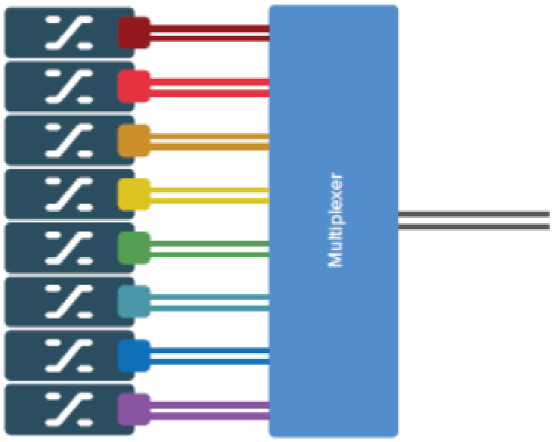

Figure 13: fiber pair

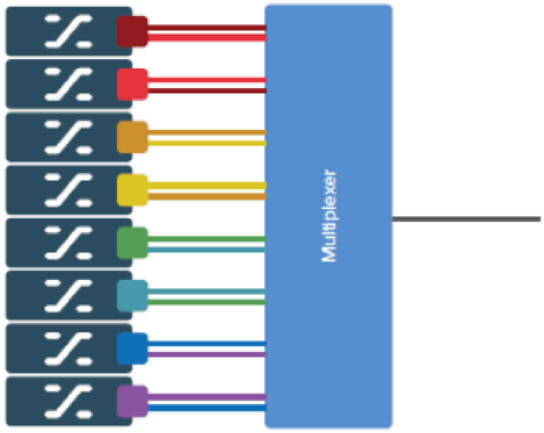

Figure 14: single fiber

Advantages and disadvantages

The primary advantage of this technology as mentioned before is the possibility to reduce the number of optic fiber needed to transfer data. This is important especially under circumstances where the signals have to be transmitted through long distances like 1000km which is usually the distance between a repeater used for the transfer optical signal. Therefore, having one line of dark fiber significantly reduces the cost. This further reduces the costs of manufacturing, deployment, and materials. Since this method allows the sending of multiple signals in a single fiber, the bandwidth of the optic fiber is drastically increased. It also allows for the receiving and transmitting of a signal simultaneously. This technique also increases the carrying capacity of the system. This simple technique requires two extra components which are the multiplexer and the demultiplexer and is a highly secured system since all the optical signals travel through the same line therefore there is just 1 line to monitor. The disadvantages are, that since all the signals have to travel through the same line, distinguishing one signal from the others becomes difficult if there is a lack of proper wavelength distancing between signals. This causes interferences in the signals that are transmitted so proper wavelength distancing is required to optimally use this multiplexing method. This method is also limited to 2 point circuits. This is due to the fact that the multiplexed signal can not be used without demultiplexing first. This leads to all connections to the network being limited by these mandatory two-way connections. This technique is also not viable for short-distance transmissions since the use of optical components increases the cost of the network. Therefore, the benefit of having one line is not as crucial because of the cost of materials, deployment, and manufacturing are relatively small in short distances compared to the cost of the optical components. Scalability is another problem with this method since every data stream must have a specific wavelength and have proper wavelength spacing. The number of lines that are transmittable through this network is limited by the number transceivers provided so adding more signals may create noise in the system.

Different techniques

The 2 most commonly used techniques for wavelength division multiplexing are coarse wavelength division multiplexing (CWDM) and dense wavelength division multiplexing (DWDM). They mainly differ by the number of channels they transmit through into a single fiber. CWDM allows 18 channels and DWDM allows 88. They also differ in how individual streams are spaced in the electromagnetic spectrum. Both techniques are independent of protocol meaning they can transfer any type of data simultaneously without causing interference. The CWDM method tends to separate its signals at a wavelength of around 20 nm apart from each other, and the wavelength of its 18 channels tend to range around 1300 nm to 1550 nm of which nine between the range of 1270 nm and 1450nm and the other nine 1470 nm to 1610 nm. This range is selected because it is the range at which the signal suffers from the lowest amount of attenuation allowing the signal to travel the furthest. This method is usually used for distances between 40 km and 70 km. This is the maximum distance at which this method can effectively transfer data without the signal being heavily affected by attenuation as CWDM signals are not amplifiable. At this distance this method is also limited to 8 channels due to the water peak phenomenon. This is an area of high loss in the 1300nm wavelength region in which the attenuation rate is 1 dB/km affecting the lower 9 channels at longer distances compared to the higher channels that are in low attenuation of 0.25 dB/km. This thereby limits the distance at which this technique is effective. On the other hand, the DWDM technique can send up to 88 signals because its signals are spaced 0.8 nm apart instead of 20 nm of spacing used in the CWDM technique. This also allows this technique to be able to receive data at higher speeds of up to 100 Gbps per channel. This technique works with the same principles of the CWDM technique but with increased channel capacity. It is also able to produce signals that are amplifiable allowing this method to be effective at longer distances of up to 1000 km with 80 usable channels from which it can effectively transfer data. This is possible due to an interleaver which is a component commonly used in this technique to double the number of channels that are in a higher band by multiplexing 50 GHz into 100 GHz spaced channels. This allows for an increase in the number of channels and the maximum distance of transmission of DWDM signals.

Current and future of this technology

Currently, the way this technology is used in telecom communication systems is by using a hybrid network of DWDM for the core network that sends data over long distances including different cities and countries. The DWDM allows for the sending of large amounts of data over 1000 km and can be amplified for intercontinental transmission by using multiple optical amplifiers to boost the signal along the way without losing the signal due to attenuation and allow to send 100 Gbps signals. In metropolitan areas, CWDM is more commonly used since the distance in this sector for the network is around 50 to 80 km which is the range that the CWDM technique excels at. This technique is currently more cost-effective around this distance because no amplifiers are needed and the wider channel spacing allows for the use of inexpensive components such as uncooled transmitter laser diodes with large wavelength variation, simpler less sensitive multiplexes and demultiplexers with more relaxed wavelength spacing. Usually, the amount of data needed to be transmitted in this section of the network is less demanding making the 8 channels at the maximum distance less of a limitation. The last part of the telecom communication network which is the access network rarely uses WDM since the distances are extremely short when compared to other networks. This section ranges from 10 to 20 m and the data capacity needed is much less. Therefore, the last section is usually connected using copper wire instead of fiber optics to reduce cost and complexity. This is starting to change since it is expected that by 2025, the UK will switch to a telecom communication network that is fully fiber optic-based [1]. The future of this technology lies in finding a better substitute material for silica-based fiber since, at higher light intensities, the signal starts becoming affected by non-linear effects like Raman and Brillouin light scattering. These effects would normally be unnoticed at lower intensity signals but higher intensities can cause signals transmitted through silica fibers to have an increased attenuation than the norm. The signal is then shifted into a different wavelength which causes signal scrambling. This inherent property of silica-based is limiting the performance of current fiber optics causing their performance to plateau. So most of the research being performed is based on the need for a new type of fiber that can transmit high-intensity light [2]. The new materials proposed are composite materials made by the mixture of multiple elements such as fluoride, aluminum, barium, strontium, and phosphorus.

Conclusion

In conclusion, all tasks required were completed. The first task consisted of the modulation and demodulation of a signal of 1kHz sampling frequency and a runtime of 1 second. This task was completed using 2 methods. The first used the Matlab code that works to generate the signal. It can perform modulation by following the formulas provided and the demodulation, by using code that works as a low pass filter. The process was undertaken multiple times to improve the shape of the signal. Shown in the results in figure 1, all of the steps of modulation and demodulation were performed successfully with a modulation index of 1 for optimal modulation. The stimulation followed the formulas but used a different runtime showing a similar signal. For the second task, both topics were discussed in depth. The methods of both topics were introduced providing the equational and graphical representations of the mentioned techniques. The application, advantages, disadvantages, and current and future technology were explored for the second topic in addition to the different techniques used.

Reference

[1] *financial times article, BT switch from copper upgrades to full-fiber broadband:* *https://www.ft.com/content/05c1dade-9bd6-11e8-ab77-f854c65a4465*

[2] *J. Ballato and P. Dragic, Invited Paper, "Rethinking optical Fiber: New Demands, Old Glasses," Journal of the American Ceramic Society, vol. 96, no. 9, pp. 2675 - 2692, 2013.*