STUDIES ON CODING TECHNIQUES AND IT'S APPLICATION TO OTDR

A Project Report
Submitted in partial fulfilment of the requirements for the award of the degree
Of

BACHELOR OF TECHNOLOGY
IN
ELECTRONICS AND COMMUNICATION ENGINEERING

By
V Jaikishen (10509011)
Sudharani Kindo (10509008)
Under the guidance of
Prof. P.K. Sahu

Department of Electronics & Communication Engineering
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CERTIFICATE

This is to certify that the thesis entitled, "Studies on coding techniques and its application to OTDR" submitted by V Jaikishen and Sudharani Kindo in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in Electronics & Communication Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date:

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V Jaikishen (10509011)
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Abstract:

In the following thesis, we will be discussing the different aspects and parameters involving Optical Time Domain Reflectometer (OTDR) as well as different aspects of unipolar coding techniques. The purpose of this thesis is to fully understand the methods by which unipolar codes like the Golay and Simplex codes are created from Hadamard matrices and to understand its application in Optical Time Domain Reflectometry. Furthermore, this thesis also delves into the region of performance enhancement of Optical Time Domain Reflectometer by means of implementation of these coding techniques.

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CHAPTER 1

BASICS OF AN OPTICAL TIME DOMAIN REFLECTOMETER.

1.1 Introduction to OTDR:

OTDR (Optical Time-Domain Reflectometer) is a device that is used to determine the nature and location of faults in optical fibers. In order to determine faults, the OTDR sends a pulse into the fiber and records the reflected light and plots a response graph. When light is sent through a glass fiber link, some of the light is reflected back to the transmitter (this is known as backscattering). When characterizing a fiber link using an OTDR, it is this reflected light that is used to calculate the attenuation of the link, the characteristics of loss and the length of the fibre span. The OTDR software displays the faults and fibre joints on a generated graph that is called trace. Faults and Connections can be determined from display of the OTDR.

A typical OTDR trace is shown in figure 1. As we can see from the figure, there is a table on the display below the trace. This table lists all the faults in the fibre in the form of events, namely connectors, splices, fibre breaks etc. A good quality OTDR should be able to determine faults and display them in such a manner that it is understood by the user.

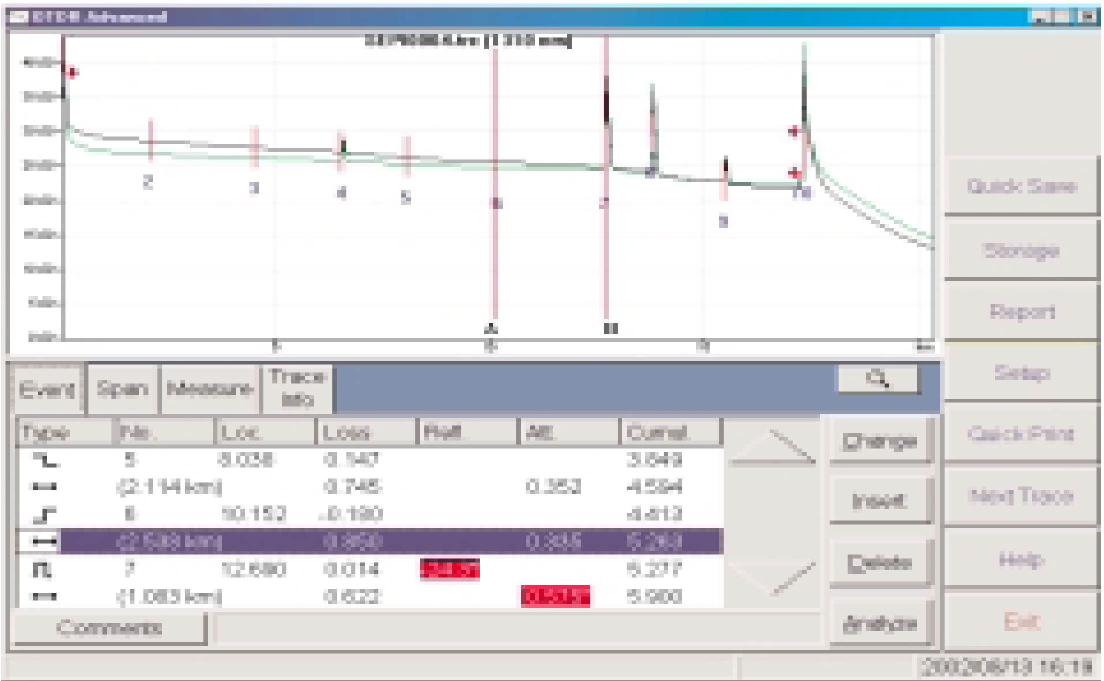

Fig. 1.1: A typical OTDR trace screen. [45]

details so that their design can perform even under difficult circumstances. Next we will see the different coding techniques used in OTDR systems.

1.3 Conclusion:

In this chapter we have seen the different aspects of OTDR and what are the different criteria to be considered while designing or selection of one for research or for practical purposes.

HAPTER 2

INTRODUCTION AND MATHEMATICAL ANALYSIS OF DIFFERENT CODING TECHNIQUES

2.1 Introduction to coding:

Coding tackles the two major parameters of an OTDR, namely dead zone and pulse width. As we have seen in the pulse width section, we need more energy in the signal that the OTDR sends in order to detect faults in extremely long fibers. By incorporating a code of a length of, say 64 bits, we are in fact sending that many pulses into the fiber and hence input that much energy into the fiber and hence we can improve the SNR of the OTDR as increasing signal power for the same level of noise results in larger SNR. Also the dead zone problem is also accounted for as in coding the no of pulses are increased and not the pulse width in itself.

OTDR is an important diagnostic tool for the testing of fiber optic transmission system. At present time when optical fiber technology is widely applied not only in building up of optical fiber transmission systems but also in other fields like sensors with distributed parameters “Optical Time-Domain Reflectometry” (OTDR) plays an important role. The basic idea of the conventional OTDR consists in launching a rather short and high power optical impulse into the tested fiber and the consequent detection of the Rayleigh back-scattered or Fresnel reflected light at the input end of the fiber. The measured signal is very weak – typically 40-60 dB under the level of the launched optical power. In OTDR there is also a well-known trade-off between the Signal-Noise Ratio (SNR) and the spatial resolution. Increasing the pulse width of the probe pulse improves the signal-to-noise ratio (SNR) of the detected signal and accordingly improves the dynamic range but degrades the spatial resolution of the OTDR. To overcome this tradeoff between the SNR and the spatial resolution, the use of correlation techniques—commonly used in wireless radars—have been suggested, e.g., employing periodic pseudorandom bit sequences (PRBSs). Still, with the problem resulting from the periodic features of PRBS, this approach was found to be unsuitable for the practical applications. Overcoming the limitations of PRBS-coded OTDR, the complementary correlation OTDR (cc-OTDR) based on the Golay codes was suggested. Following the cc-OTDR, an OTDR based on the simplex codes (scs), Biorthogonal codes, correlated Prometheus orthonormal sequence was then proposed, predicting better SNR performances (over the Golay-code cc-OTDR) without the penalty in the spatial resolution. Still, with the analysis based on simple analogy—compared to that of optical spectrometry the scope of the work was limited to a conjecture on the expected amount of coding gain (SNR increase over conventional

Figure below shows us the code gain obtained while using CCPONS

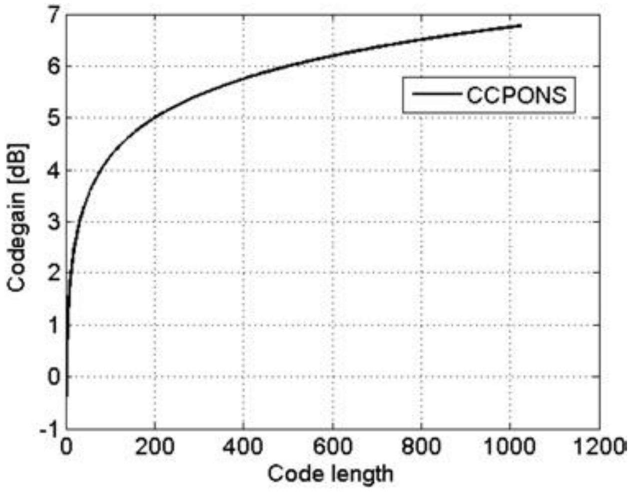

Fig. 2.4: Code gain variation of CCPONS.[5]

2.4 Conclusion:

In this chapter we saw how the application of the codes instead of a single pulse helps in increasing the coding gain of the OTDR without comprising the dynamic range. The code gain of each code is different and it affects an OTDR system in a different manner. Also what is most important in the case of these codes is the PAPR value that determines efficiency of the code. Figure 2.5 gives us a comparative idea of how the code gains of these codes vary with code length.

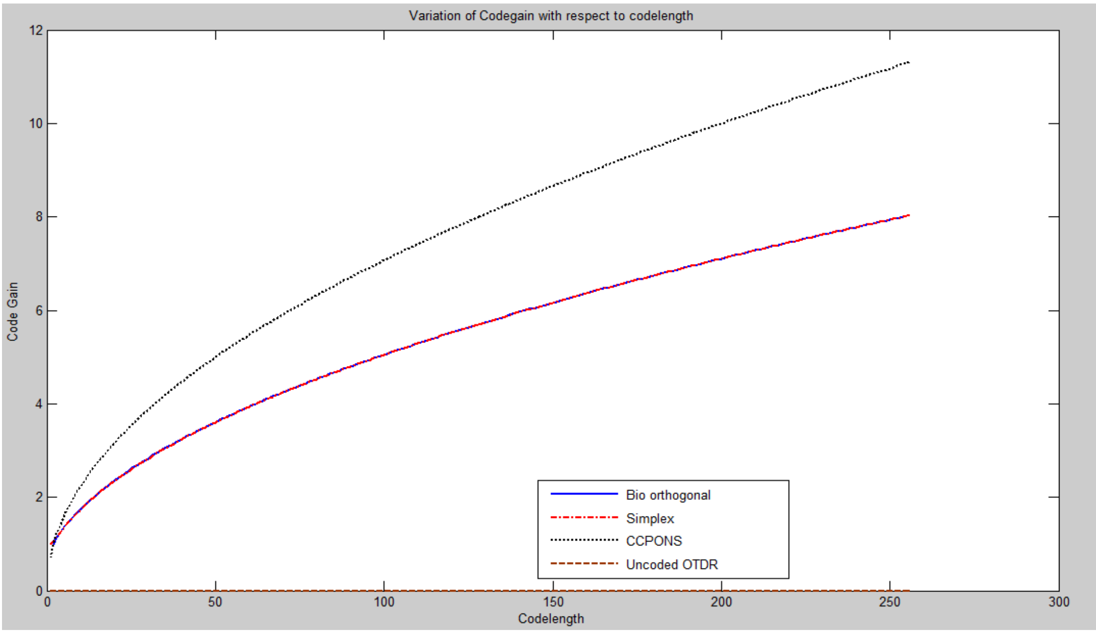

Fig. 2.5: Comparison of Code gain for different code length of different codes.

CHAPTER 3

EXPERIMENTS USING CONVENTIONAL OTDR

3.1 **Experimental Studies on an OTDR**:

The experimental studies were performed on an Agilent 6000 series OTDR at IIT Kharagpur. The details are as follows.

3.1.1 Objective of the experiment:

To understand the workings of an OTDR and to take real-time measurements from single mode and multi mode fibres using the OTDR

3.1.2 Equipment:

1. Agilent E6003A mini-OTDR
2. Optical fibre, singlemode fibre of 500 metres length and two multimode fibres of lengths 1000 metres and 500 metres.
3. Mechanical connectors

3.1.3 Experimental setup

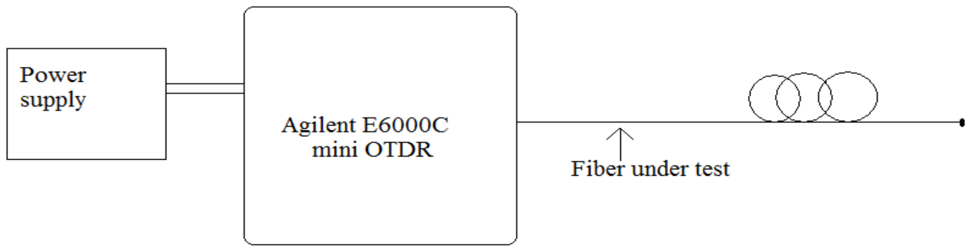

Fig 3.1: Experimental setup used to perform the experiment.

3.1.4 OTDR specifications:

The Agilent E6003A mini-OTDR comes equipped with an exhaustive user manual. Due to the fragility of the OTDR equipment, it was vital that the instructions in the manual were accurately followed. The manual also held specifications for the instrument. Specifications are as follows,

Laser Type	FP – InGaAsP
Laser class	3A/Class 1 (Europe/US
std) O/P power (pulse max)	50 mW

End to end length as per OTDR trace:

1^{st} fiber: 510.11 m

2^{nd} fiber: 1503.23 m

Front end reflection: -10.60 dB

Rear end reflection: -12.56 dB

Reflection at connector: -45.67 dB

2-point attenuation: 20.722 dB/Km

2-point loss: 31.350 dB

Range setting of OTDR: 0-2 Km

Optical return loss: 10.59 dB/Km

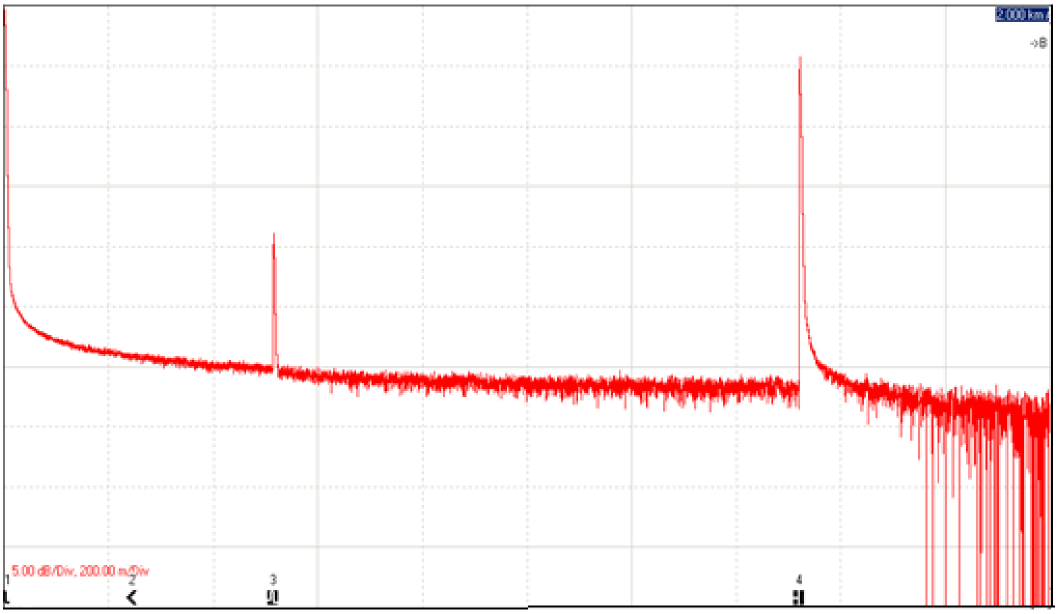

Fig 3.5: OTDR trace of MMF at 1550 nm wavelength

The above trace was obtained on the mini-OTDR monitor during the course of the experiment using a multimode fiber at 1550 nm wavelength.

3.2 Conclusion:

This chapter deals with the experiment involving a conventional OTDR and the traces observed on the OTDR screen are found to be matching with the theoretically predicted values.

CHAPTER 4

RESULTS AND FUTURE SCOPE OF WORK

4.1 Results:

The following table shows the code gains and associated PAPR values of the different codes we have dealt with in the previous chapters.

Coding technique	**Code Gain for a code length of 64**	**PAPR**
Golay Code	3.01 db	4
Simplex Code	4.06 dB	≤2
Bi-Orthogonal Code	4.00 dB	2
Complementary Correlated Prometheus Ortho-Normal Sequence	5.66 dB	2

Table 4.1: Coding gains and PAPRs of the codes concerned.

From this data and the experimental results obtained from the experiment performed at IIT Kharagpur using a conventional OTDR, we are able to draw some important conclusions.

PAPR technically gives us information about the amount of power that is sent in the signal. Remember that the signal sent is not sinusoidal but rather a series of pulses modulated according to an unipolar coding sequence. Low PAPR is essentially the requirement for all systems involving digital communication and the above coding techniques seem to help reduce PAPR. PAPR can increase in conventional OTDR because sometimes the pulse may spike causing the maximum power to become much larger than the average power of the pulse causing PAPR to increase. Also unipolar coding has the advantage over standard coding and modulating techniques as in unipolar coding, the average signal power is always greater than zero, where as in standard modulating techniques the carrier signal used is sinusoidal and the average signal power is zero in such cases causing infinite PAPR. From the coding techniques discussed, PAPR of CCPONS and Simplex is found to be the lowest and hence most suited for the required applications.

4.2 Advantages of Coding over Conventional OTDR:

The basic principle in OTDR is to send a small signal through an optical fibre and observe the reflected light. The intensity of the reflected light depends upon many parameters like nature of the fibre, wavelength of light etc. One of the parameters influencing this is the power of the input signal. Larger the input power, larger will be the distance it covers within the fibre. The easiest way of increasing input power would be to send n number of pulses one after the other. But this method has a drawback because u cannot just send pulses like that as it will result in the receiver getting saturated very quickly and it will result in a permanent dead zone that renders the analysis ineffective.

This is where the concept of coding shows its advantage. By using unipolar coding techniques, one is able to send a large amount of input power by using less number of pulses. This way we are able to avoid the scenario of receiver getting saturated.

The other advantages of coding techniques over conventional OTDR include better dynamic range and greater spatial resolution with a definite amount of noise present in the system.

4.3 Future scope and prospects:

Throughout this thesis, we have been discussing the different parameters of an OTDR and how external factors can affect them. In the different chapters we have seen how coding is one of the ways to improve the SNR of an OTDR system and also through different coding methods a better dynamic range and spatial resolution trade off can be achieved.

The experiment performed using the Agilent Mini-OTDR at IIT Kharagpur helped us understand the tracing phenomenon of the OTDR. It is crucial to understand the fact each OTDR manufacturer chooses the different characteristics to be included in their OTDR design. The feature not so commonly found though is the ability to integrate a PC based OTDR into a single kit. Most practical experiments involving the testing of coding revolves around a circuit that is similar to the one shown below.

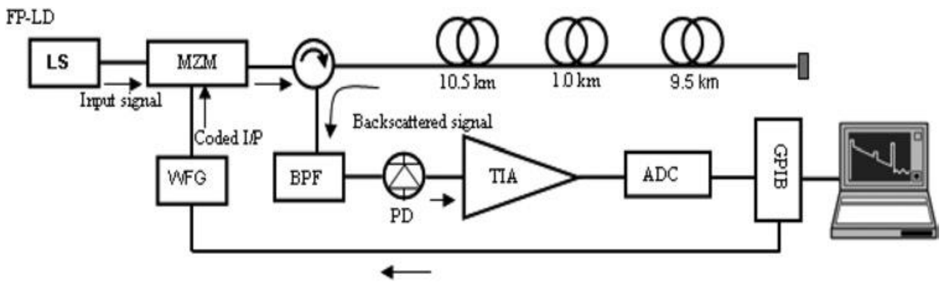

Fig 4.1: The excessive equipment required to integrate coding into an OTDR.[5]

This figure is the experimental setup that was used to implement CCPONS code in an OTDR. The entire circuitry except for the waveform generator (WFG) and the modulator (MZM) is integrated into the current available models of OTDR. The waveform generator and the modulator are the two components of this setup that allow the CCPONS code to be integrated in the testing mechanism.

Throughout the years, the process of implementing various codes and sequences in an OTDR has involved extensive setups like the ones above. But the results of the implementing these codes has been obvious each time a new code is developed. The results of the various experiments performed can be used to facilitate research into design of new OTDR machines which implement these coding techniques in their probing mechanisms. This will result in better fault analysis and the ability of the OTDR to analyze extremely long fibres.

The different experiments and its results that have been studied in this thesis can be used in future to design highly efficient OTDR systems that will be able to provide a better SNR, lower PAPR and in affect improve the dynamic range of the OTDR to a far greater degree.

4.4 Conclusion:

From this chapter it can be concluded that OTDR systems implementing various unipolar codes out perform a conventional OTDR system and by implementation of such codes, PAPR of the signal can be reduced that helps to add to the efficiency of the OTDR system

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