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A FPGA Implementation of Adaptive PPM Modulation Schemes for Wireless Optical Communication

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Abstract— Wireless optical communication is the current research topic in high data rate data communication area.It is under research to utilize in under water sensor network communication and free space optical communication. Mainly PPM modulation scheme is used in FSO because of it high power efficiency ,transmission efficiency and strong anti jamming capability. One of the key difficulties of implementing PPM technique is that the receiver must be properly synchronized to align the local clock with the beginning of each symbol. Therefore, it is often implemented differentially as differential pulse-position modulation.

In this paper various PPM modulation schemes like single pulse position modulation, multi pulse position modulation, diffential pulse position modulation schemes are going to implemented in FPGA and its space requirement, time complexity and power consumption are going to analyzed. This implementation is also concern with an adaptive selection of modulation scheme based on channel condition ,for this feed back received from receiver based on bit error rate.

Index Terms— adaptive modulation, wireless optical communication, fuzzy controller

1 INTRODUCTION

Today's information economy depends on the transmission of data, voice and multimedia across telecommunication networks. Optical networks remain the most ideal medium for high-bandwidth communications for true connectivity. There are two distinct types of optical communications: Fiber optics (fiber-optic cable) and optical wireless systems based on free-space optics (FSO) technology. FSO is a line-of-sight technology that uses invisible beams of light to provide optical bandwidth connections that can send and receive voice, video, and data information. Free-space optics (FSO) refers to the transmission of modulated visible or infrared beams through the atmosphere to obtain broadband communications. Most frequently, laser beams are used, although non-lasing sources such as light-emitting diodes or IR-emitting diodes will serve the purpose.

The difference in fiber communication and FSO is that the energy beam is collimated and sent through clear air or space from the source to the destination, rather than guided through an optical fiber much used in the enterprise, mobile communication.

capable of sending up to 1.25 Gbps of data, voice, and video communications Simultaneously through the air enabling fiber-optic connectivity without requiring physical fiber-optic cable.

Light travels through air faster than it does through glass, so it is fair to classify FSO technology as optical communications at the speed of light.

Compared to the radio frequency domain optical wireless communication offers much higher speeds and bit rates per watt

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Modulation techniques have attracted increasing attention in optical wireless communications. Basic schemes such as on off keying (OOK), pulse amplitude modulation (PAM) and pulse position modulation (PPM) have been validated as suitable for the optical wireless channel.

PPM is a well-known orthogonal modulation technique [2].In L -PPM, a block of log2L input bits is mapped to one of L distinct waveforms, each including one "on" chip and L-1 "off" chips. A pulse p(t) is transmitted during the "on" chip.

One of the principal advantages of PPM is that it is an M-ary modulation technique that can be implemented non-coherently, such that the receiver does not need to use a phase-locked loop (PLL) to track the phase of the carrier. This makes it a suitable candidate for optical communications systems, where coherent phase modulation and detection are difficult and extremely expensive. It improves transmission channel anti jamming capability, consumes less transmission power and average energy efficient

The combined power and bandwidth requirements suggest that the basic modulation schemes cannot provide reliability when deployed in a real time channel, resulting in compromised system performance. So an adaptive selection of modulation scheme based on channel condition is the better solution for this. in this paper an adaptive PPM modulation scheme of FPGA implementation is presented

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2 ADAPTIVE PPM MODULATION SCHEME

2.1 system outline

The selection of the modulation scheme is done according to power and bandwidth efficiency and the channel capacity. The power efficiency is a measure of how much signal power should be increased to achieve a particular BER (Bit Error Rate) for a given modulation scheme. Bandwidth efficiency is the ability to accommodate data within a limited bandwidth of a channel. It's also a tradeoff between data rate and pulse width. So in this project three different modulation schemes are implemented for wireless optical communication and based on bandwidth efficiency requirement or power efficient requirement on network side or application side we can configure any modulation scheme as current scheme

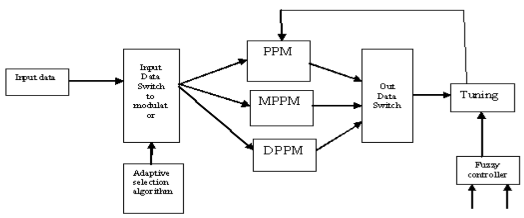

Fig.1 block diagram of adaptive PPM scheme

This scheme selects any one of the modulator dynamically based on mod set that is based on the scenario under which the system works. Various parameter like high band with requirement, constant data rate require and low power level in battery or in the device is used as key for this work.

Here single pulse PPM of the case 8-PPM is used Which will take 3 bit symbol as input and will produce 8-PPM output, Multi pulse PPM of dual pulse system is considered with slot size M=5(slots) which will take three bit input and a DPPM is generated by deleting all of the "off" chips following the "on" chip.

The realistic controller to change the state of the tuner block based on dynamic rapid Changing BER of the channel to maintain the constant target BER is implemented by fuzzy logic controller. Utilizing fuzzy systems in a dynamic control environment reduces potential stability problems. So this fuzzy based controller will stabilize the BER

2.2 method of adaptive selection

Adaptive selection scheme to select any one of the available implemented scheme is done here taking the pros and cons of the three PPM schemes. The single pulse PPM is low power efficient one but not bandwidth efficient .so it is not suitable for high bandwidth demand application and networks. It is configured as default type of modulation if there is no specific demand on application side, network side and receiver side.

High data rate demand application and for high data rate network scenario the DPPM is configured as modulation scheme but for constant bit rate receiver and network it is not a suitable scheme because of it's irregular data rate nature.So for such a scenario either PPM or MPPM can be configured as current modulator. When current modulator configured is DPPM and suppose receiver report buffer overflow because of irregular data rate of DPPM, then MPPM is configured as current modulator to avoid the overflow. This selection scheme is given in the form of pseudo code in fig.2

```
If (mode="bandwidth efficient" or "application demand high data rate") then
Modulation=DPPM;
Else if ( mode="low power mode" or mode="uniform data rate requirement or network="fixed through put network") then
Modulation=PPM or MPPM;
    If (modulation=DPPM and receive buffer overflow="yes") then
        Modulation=MPPM;
        Else default:
        Modulation=PPM;
```

Fig.2: psedocode for adaptive selection

2.3. Tuning for BER

Proposed modulation scheme takes the real time channel conditions into account, which is in form of current BER of the channel for tuning. By employing amplitude and position modulation selectively, a guaranteed system performance can be secured, without compromising power and bandwidth efficiency. This is also a new approach to realize reliable optical wireless links. A fuzzy logic control module has been developed to realize the tuning mechanism

2.4. Method of tuning

Fuzzy rule based tuning algorithm is used in this project. Utilizing fuzzy systems in a dynamic control environment reduces potential stability problems, and this is the benefit of applying fuzzy logic control over a modulation channel. Fuzzy logic (FL) is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth, that is truth values between "completely true" and "completely false".FL incorporates a simple, rule-based IF X AND Y THEN Z approach to a solving control problem rather than attempting to model a system mathematically

The standard definitions in fuzzy logic are:

truth (not x) = 1.0 - truth (x)
truth (x and y) = minimum (truth(x), truth(y))
truth (x or y) = maximum (truth(x), truth(y))

Traditional control systems are based on mathematical models to define a relationship that transforms the desired state and observed state of the system into inputs that will alter the future state of that system. Fuzzy machines work the same way, but the decision and the means of choosing that decision are replaced by fuzzy sets and rules. Fuzzy control, which directly uses fuzzy rules, has the purpose of influencing the operation of a system by changing inputs to that system via rules that model how the system operates

2.5. Fuzzy logic control algorithms

The System status can be modeled as membership functions in FL. The rules set in the FL system will come from the requirements of the ideal system. While BER varies across the range, FL can be used to set up rules according to different circumstances such as applications which need prolonged battery power, while the system power consumption is the main concern. In a system where data rate is more vital than others, such as in a bank or government offices, the selection of system status will be weighted more towards Rb to satisfy the need for high performance data transmission

A controller in the system needs to know the current BER level and needs to be able to set the state. Therefore, the controller's input will be the BER level difference (compared to 10-6, expressed in dB) and its output will be the rate, or the trend at which the M or n is changing. Since the BER level tends to oscillate around the desired level, it is also worth considering adding another input, the BER level's rate of change, to slow down the state change when the BER is close to the right level.

2.6 The rules for the fuzzy controller

1. If (BER is ok) then (state is no_change)
2. If (BER is low) then (slot/clock decreased_fast)
3. If (BER is high) then (slot/clock is increased_fast)
4. If (BER is ok) and (rate is negative), then (slot/clock is reduced_slow)
5. If (BER is ok) and (rate is positive), then (slot/cock is increased_slow)

According to the rules set above, the system performs a self-adaptation when BER degrades more than a certain threshold. Since high BER states are usually not acceptable from the communication system design point of view, the system states will be changed based on a calculation within available candidate states.For the tunable PAPM scheme, M can be changed when the fuzzy controller has a positive output, and n changes when the output is negative. The operation could be inverted, dependent on the importance given to M and n.

3 FPGA IMPLEMENTATION

The FPGA is a form of highly configurable hardware. This is the reason why we implemented our modulation scheme in FPGA .More over, when sample rates grow above a few Mhz, a DSP processor or other processor has to work very hard to transfer the data without any loss. This is because the processor must use shared resources like memory busses, or even the processor core which can be prevented from taking interrupts for some time. An FPGA on the other hand with designed dedicates logic for receiving the data, can maintain high rates of I/O. since our modulation scheme of adaptive PPM is target for wireless optical communication which involves Giga bytes/sec data rate support the FPGA implementation will be more appropriate one. the other reason for going to FPGA implementation is FPGAs have product reliability and maintainability. My implementation uses altera Cyclone III EP3C16F484 FPGA.

4 RESULT AND ANALYSIS

The adaptive PPM modulation scheme is simulated for three input bit symbol using model sim simulator by setting the mode by means of three bit set as given in table I

TABLE I
MODE SETTING TO SELECT THREE DIFFERENT MODULATION SCHEMES

Mode state	modulation	Bit pattern
Low power mode/low bit rate mode	Single pulse PPM	000
High immune to noise or ISI mode/high power	Multi pulse PPM	001
High data rate/band with effient/non uniform datarate mode	DPPM	010

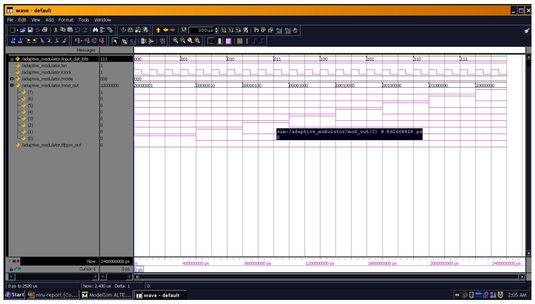

Fig.3 Screen shot out for low power mode modulator PPM

All input date combination is applied by setting mode-000 and the out put is generated. the modulated out signal mod_out is changing the pulse position in slots based on the input data change is shown in fig.1-3 here mod_out(0)-represent slot-0,mod_ou(1) represent slot-1 and so on.

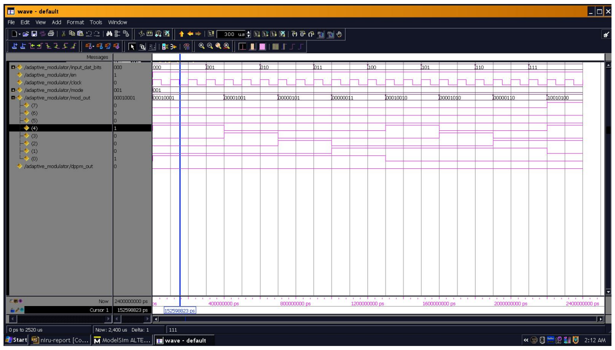

Fig.4 screen shot out for dual pulse PPM modulation

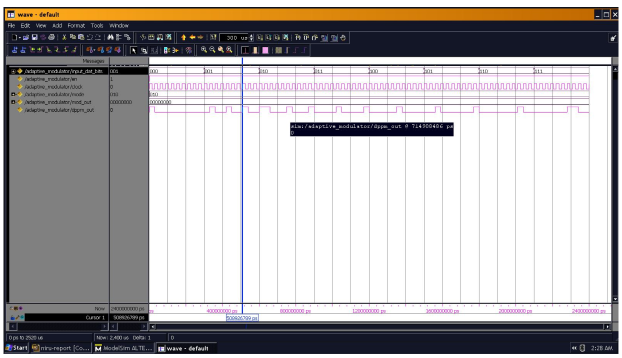

Fig:5 screen shot out for DPPM

4.1 RESORCE USAGE SUMMARY

- total logic element used-122
- total combinational functions-122
- total pin used -23

  Logic elements by mode
  - Normal mode 122
  - Arithmetic mode 0

  - Total registers 0
  - Dedicated logic registers 0
  - I/O registers 0
  - I/O pins 23
  - Maximum fan-out node input_dat_bits[0]~input
  - Maximum fan-out 22
  - Total fan-out 466
  - Average fan-out 2.77

The FPGA kit is programmed by generating the .SOF file by using quadras II software. Before generating .sof file the pin assignment is done by using pin planner tool of quadras II software

5 CONCLUTION

Reliability and multi network communication supports are two important requirements in wireless communication devices. By means of adaptive modulation scheme the multi network support feature can be implemented in communication systems. Reliability can be achieved by fine tuning the modulator parameter to achieve the target bit error rate .
Usually Only one type of modulator used in transmitter that will be suitable for the system that work in single environment with fixed channel condition and fixed data rate system. Recent days the communication device not only communicating in single network but in heterogeneous network environment. So the communication device have to re configure the modulation system that it uses based on the current network environment where it communicate .This multiple modulation system requirement of heterogeneous network environmental communication system leads to adaptive modulator design. This paper presents FPGA implementation of three different PPM modulation schemes of single pulse PPM, dual pulse PPM and DPPM for wireless optical communication that can be selectable by based on environment of communication network .DE0 Altera cyclone III EP3C16F484 FPGA kit used to demonstrate the scheme.
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