AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
ECE DEPARTMENT

Thesis Title

Low Power Constellation De-mapping Design for DVB-T2 Standard

A thesis submitted in partial fulfilment of the requirement of the M.Sc. in Electronics and Communication Engineering

by

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BSc. Degree, 2010

Supervised by

Prof. Dr. Salwa Hussein El-Ramly
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STATEMENT

This thesis is submitted as partial fulfillment of M.Sc. degree in Electronics and Communication Engineering, Faculty of Engineering, Ain Shams University.

The Author carried out the work included in this thesis, and no part of it has been submitted for a degree or qualification at any other scientific entity.

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Abstract

Digital video broadcasting for terrestrial transmission is a new trend expanding quickly worldwide. It has been adopted by 150 countries including Egypt where it is planned to be deployed in 2015. The second generation terrestrial digital video broadcasting standard (DVB-T2) is the most advanced digital terrestrial television system, offering significant improvements in spectral efficiency, in addition to more robustness and flexibility compared to any prior system. It also supports SD, HD, UHD, and mobile TV.

This thesis is mainly focused on a new low-power implementation of the DVB-T2 de-mapper. One of the introduced advancements in DVB-T2 is the use of signal space diversity (SSD) to improve system performance in frequency selective terrestrial channels. This concept is implemented through the use of rotated constellation and Q-delay. Yet, the de-mapping proposed in the DVB-T2 standard is based on computing the Log-Likelihood-Ratios (LLRs) for all bits, which does not use the uniqueness of the I and Q components (projections) of the rotated constellation points. Prior-art in DVB-T2 demapper design attempted to reduce power through reduction of the complexity in LLR calculations by limiting the set of points included in LLR calculation and approximating the Euclidean distance calculation. On the other hand, the proposed low-power de-mapper design of this work attempts to employ the introduced SSD to reduce power through replacing LLR calculations by a significantly less complex projection-based demapping whenever possible. It benefits from an algorithm that applies projection-based de-mapping to significantly reduce LLR computations without deteriorating performance. The proposed design also attempts to reduce power through clock-gating, Euclidean distance approximation, statistical approximations, and hardware optimization and pipelining. Two versions are introduced for hard de-mapping and soft de-mapping.

The design prototype is implemented on Vertix-II pro FPGA (XC2VP30). The prototype uses significantly less resources compared to prior-art even with the soft de-mapper version that includes statistical calculations. Simulation results of BER performance clearly indicate better performance compared to prior-art that limited the set of points included LLR calculation. They also indicate significant reduction of calculations as signal to noise ratio increases with no performance degradation. The proposed design will be highly useful in low power DVB-T2 receivers. The power saving techniques can be easily applied to any rotated constellation de-mapper.

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SUMMARY

In this thesis, a new low power implementation design of the DVB-T2 de-mapper is proposed. This design is used to reduce power by seamless calculations. This design uses Signal Space Diversity (SSD) to improve system performance in frequency selective terrestrial channels which implemented through the use of rotated constellation and Q-delay. The proposed low-power de-mapper design of this work attempts to employ the introduced SSD to reduce power through replacing LLR calculations by significantly less complex projection-based de-mapping whenever possible without deteriorating performance. The proposed design also attempts to reduce power through clock-gating, Euclidean distance approximation, statistical approximations, and hardware optimization and pipelining. Two versions are introduced for hard de-mapping and soft de-mapping. The design prototype is implemented on Xilinx Vertix-II pro FPGA (XC2VP30) and Xilinx Spartan-3 FPGA starter kit (XC3S200). This thesis consists of six chapters.

Chapter 1 gives overview on DVB-T2 system and describes its blocks.

Chapter 2 reviews the background to digital modulation specially DVB-T2 modulation, Signal Space Diversity (SSD), importance of rotated constellation, channel coding/decoding for non-rotated constellation and rotated constellation.

Chapter 3 presents prior work in de-mapper design and the proposed design of DVB-T2 rotated constellation de-mapper. It shows several techniques which used simultaneously in new design to be even more efficient. The proposed design presented, prototyped by VHDL, and the simulation results use Modelsim and Matlab to compare between the performance of the traditional technique and the proposed technique.

Chapter 4 presents modification on new de-mapper design. It presents two algorithms depend on statistical assignment to guarantee the best performance of the LDPC decoder. The modification design presented, prototyped by VHDL and the simulation results use Modelsim.

Chapter 5 presents hardware implementation procedure to build experiment with Xilinx embedded processor called MicroBlaze.

Finally, chapter 6 suggests the future work and introduces the thesis's conclusion.

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Nourhan M. Bahgat
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LIST OF ABBREVIATIONS

AM	Amplitude Modulation
ACE	Active Constellation Extension
ASK	Amplitude Shift Keying
BICM	Bit Interleaved Coding and Modulation
BCH	Bose Chaudhuri Hocquengham
BER	Bit Error Rate
BSB	Base System Builder
DVB	Digital Video Broadcasting
DVB-S	Digital Video Broadcasting Satellite
DVB-C	Digital Video Broadcasting Cable
DVB-T	Digital Video Broadcasting Terrestrial
DVB-T2	Digital Video Broadcasting Terrestrial second generation
E_b/N_0	Energy per bit to Noise power spectral density ratio
EDK	Embedded Development Kit
FFT	Fast Fourier Transform
FEC	Forward Error Correction
FM	Frequency Modulation
FSK	Frequency Shift Keying
F/F	Flip Flop
FPGA	Field Programmable Gate Array
GS	Generic Stream
HD	High Definition
HNM	High Efficiency Mode

I	In-phase component
ISSY	Input Stream Synchronizer
LLR	Log Likelihood Ratio
LUT	Look Up Table
LDPC	Low Density Parity Check
MISO	Multiple Input Single Output
ML	Max Log approximation
M	Mean
NM	Normal Mode
OFDM	Orthogonal Frequency Division Multiplexing
PARP	Peak to Average Power Ratio
PM	Phase Modulation
PSK	Phase Shift Keying
PLP	Physical Layer Pipes
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keying
Q	Quadrature component
RAM	Random Access Memory
RQD	Rotated constellation and Q-Delay
SD	Standard-Definition
SSD	Signal Space Diversity
SNR	Signal to Noise Ratio
TS	Transport Stream
TR	Tone Reservation
UHD	Ultra High Definition

V	Amplitude
XPS	Xilinx Platform Studio

List of Symbols

f	Frequency
c	Empirical scaling factor
θ	Phase
σ^2	Noise variance
σ	Standard deviation

Publications

- Nourhan Bahgat, DiaaEldin Khalil, Salwa El-Ramly. "**Energy Efficient Design of DVB-T2 Constellation Demapper**." IEEE 16th International Symposium on Quality Electronic Design (ISQED), March 2015.

- Nourhan Bahgat, DiaaEldin Khalil, Salwa El-Ramly. “**Modification on Energy Efficient Design of DVB-T2 Constellation Demapper**.“ Journal to be published

Chapter 1

DVB-T2 Overview

The switch from analogue to digital broadcast systems is a trend in Television (TV) broadcast as the technology rapidly evolves. Many countries have started terrestrial digital TV broadcast and plan to end analogue broadcasts after some years. The move to digital broadcast system provides more information capacity, compatibility with digital data services, higher data security, better quality communications and quicker system availability [1].

1.1 DVB-T

The Digital Video Broadcasting (DVB) project has developed digital broadcasting system specifications which have been adopted worldwide. The family of DVB standards include DVB-S for satellite, DVB-C for cable and DVB-T for terrestrial system. The DVB-T system has proven its capability and thus is accepted as the standard for terrestrial system in most countries. DVB-T2 is the enhancement of DVB-T that will overcome the shortcomings of the previous standard and provide additional features.

DVB-T uses terrestrial as medium; transmits data using compressed digital audio-video stream, via the entire process, based on the MPEG-2 standard. This is a vast improvement over the ancient analogue signals that required separate streams of transmission. The DVB-T2 standard increases the spectral efficiency and adds new services over DVB-T [2]. Table 1.1 lists the main differences between DVB-T and DVB-T2.

Table 1. 1 The main differences between DVB and DVB-T2 [2]

Features	**DVB-T**	**DVB-T2**
FEC	Convolution Code + RS (1/2, 2/3,3/4 5/6, 7/8)	LDPC + BCH (1/2, 3/5, 2/3, 3/4, 4/5, 5/6)
Modulation	QPSK,16QAM,64QAM	QPSK, 16QAM, 64QAM, 256QAM rotated or non
FFT size	2K, 8K	2K, 8K, 1K, 4K, 16K, 32K
Guard Interval	1/4, 1/8, 1/16, 1/32	1/4, 1/8, 1/16, 1/32, 19/256, 19/128, 1/128
Bandwidth	5, 6, 7, 8 MHz	5, 6, 7, 8, 1.712, 10 MHz
Scattered Pilots	8% of total	1%, 2%, 4%, 8% of total
Continual Pilots	2.6% of total	0.35% of total

1.2 DVB-T2

Fig.1.1 illustrates a block diagram of a DVB-T2 system. The DVB-T2 physical layer introduces new techniques as shown in table 1.1. In order to provide more flexibility in terms of transmission robustness, capacity and more set of configuration options is possible. This system transmits compressed digital audio, video, and other data in "physical layer pipes" (PLPs), using OFDM modulation with concatenated channel coding and interleaving. DVB-T2 introduces the utilization of PLPs in order to achieve per service robustness.

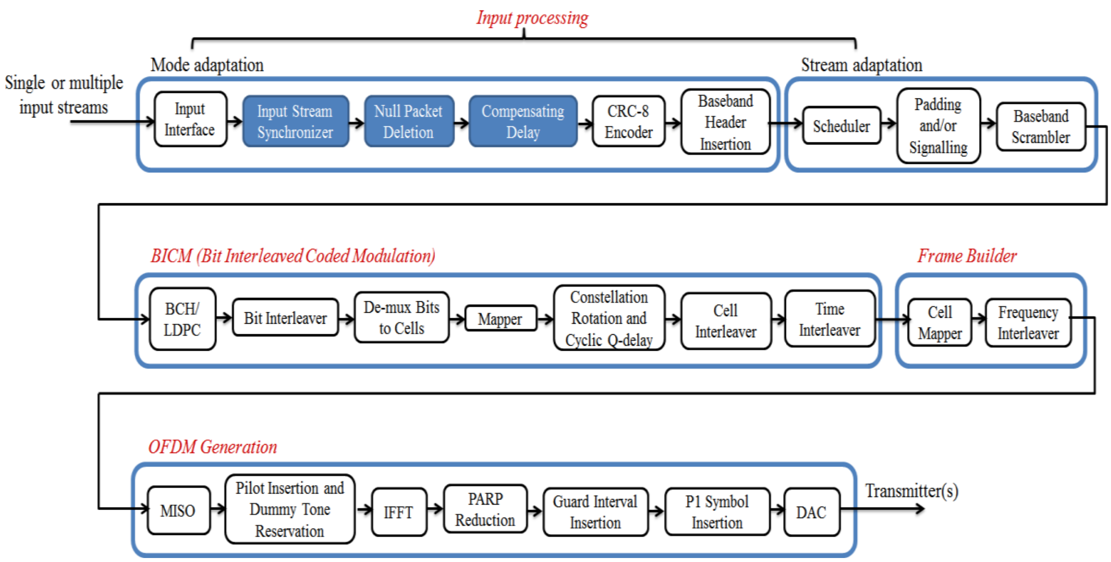

Fig.1. 1 The block diagram of DVB-T2 transmitter [2]