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Digital-high definition television servicing curriculum for Santa Ana Community College

David Glenn Schmidt

DIGITAL-HIGH DEFINITION TELEVISION SERVICING CURRICULUM FOR SANTA ANA COMMUNITY COLLEGE

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

Education:

Career and Technical Education

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by

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[redacted] 5/6/02

Date

Ronald K. Pendleton, Ph.D., Second Reader

ABSTRACT

This project presents a curriculum for a community college level course in the theory and servicing of digital - high definition television for students in the service technology field of electronics at Santa Ana Community College in Santa Ana, California. In December 1996 the U.S. Federal Communications Commission adopted a new standard that will make the televisions that are in use today obsolete. This new standard known as the Advanced Television Systems Committee (ATSC) replaces the current National Television System Committee (NTSC) standards that have been in use since 1941.

This new standard is a revolutionary change in the way television is transmitted and received. Current television receivers will no longer be able to receive transmitted television signals. The analog transmissions will cease and be replaced by digital signals on a new spectrum of channels. This change of standards will require the retraining of the current electronic service industry workforce and mandate new curriculum for those teaching television servicing as part of an electronics program. Therefore the purpose of this project is to develop the new digital - high definition television curriculum.

The project came to several conclusions and made several recommendations. The project found that current curriculum is not keeping up with the pace of the electronic industry and the emerging technologies. The project also found that when students are exposed to this technology they training and additional information. The project also found that courses need to be developed to meet the requirements of the emerging technologies.

The project also made several recommendations. The role of the advisory committee is crucial to any successful program. The committee needs to seek members from the Consumer Electronics Association, who represent the manufacturers, are current with the industry practices, and familiar with the developments of the emerging technologies. Mini courses need to be developed to improve, update, and refresh the skills of the current service industry workforce. The project made one final recommendation and that was that additional courses need to be developed to meet the requirements of emerging technologies.

ACKNOWLEDGMENTS

I would like to acknowledge the support of my wife Karen who was my soul mate through this process. I would like to thank Mr. Charles Howard who made it possible for me to get much needed technical information from the electronics service industry. I would like to thank Dr. Ronald K. Pendleton, of the California State University Career and Technical Education Program for getting me started with a Bachelor Vocational Education Degree and Dr. Joseph A. Scarcella of the California State University San Bernardino who gave me guidance and support to complete this project.

DEDICATION

To my parents, Fred W. Schmidt and Marie S. Schmidt and Thomas Edward Yost who inspired me to pursue a career in electronics and to my beautiful daughter Breanna Barbara Schmidt, (April 14, 2001-June 13, 2001).

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CHAPTER ONE

BACKGROUND

Introduction

The contents of Chapter One present an overview of the project. The contexts of the problem are discussed followed by the purpose, significance of the project, and assumptions. Next, the limitations and delimitations that apply to the project are reviewed. Finally, definitions of terms are presented.

Purpose of the Project

The purpose of the project was to develop a semester length community college curriculum for a course in the Theory and Servicing of Digital - High Definition Television for the students in the service technology field of electronics at Santa Ana Community College in Santa Ana, California. Additionally, it is designed with the current electronic service industry in mind. This skilled workforce will require new training to meet the challenges and requirements of this new technology.

Context of the Problem

The Federal Communications Commission in December 1996 adopted new standards that will make broadcast television, as we know it today obsolete. The current

National Television System Committee (NTSC) standards were adopted in 1941 and only minor changes have been made to these standards until the adoption of the new Advanced Television Systems Committee (ATSC) standards in December 1996. The NTSC standards are analog and the current required curriculum addresses the theory and servicing of this standard. The new ATSC standard for Digital - High Definition Television is digital and will require new theory of operation and servicing to be taught.

Significance of the Project

The existing television standards adopted and in use since 1953 are now obsolete. A mandated U.S. Federal Communications Commission new Advanced Television System Commission (ATSC) standard replaces the current National Television Systems (NTSC) standard in 2006. When the change over is made the televisions in the United States will no longer be able to receive broadcast television transmitted signals, without a digital to analog converter.

Assumptions

The following assumptions were made regarding the project:

1. It was assumed that the existing curriculum will be obsolete when the new standards come into effect.
2. It was assumed that the Federal Communications Commission would not change the implementation date of the new Advanced Television System Committee standard.

Limitations and Delimitations

During the development of the project, a number of limitations and delimitations were noted. These limitations and delimitations are presented in the next section.

Limitations

The following limitations apply to the project:

1. The Digital - High Definition Course Curriculum was developed for the Santa Ana Community College Electronics Servicing program.
2. The project only addresses broadcast television in the Los Angeles television reception market.
3. The project curriculum is not designed to function as a stand-alone course. Students will need to adhere to the requisites and perquisites

described in the Santa Ana Community College catalog.

4. The project will only address television systems and broadcasting from 1939 to 2000.

Delimitations

The following delimitations apply to the project:

1. The Digital- High Definition Curriculum was designed for use in the Electronics Program at Santa Ana Community College with modifications it could be used in other educational environments.
2. The project only addresses broadcast television in the Los Angeles television reception market with modifications it could be used in other broadcast market areas.
3. The project curriculum is not designed to function as a stand-alone course. With modifications the curriculum could function as a stand-alone course.
4. This project only addresses the television system and broadcast television 1939 to 2000. This period could be expanded to include early television and television after 2000.

Definition of Terms

The following terms are defined as they apply to the project.

Advanced Television Systems Committee - "Is an international, non-profit membership organization developing voluntary standards for the entire spectrum of advanced television systems" (Advanced Television Systems Committee, n.d., para. 1).

Analog - The branch of Electronics dealing with infinitely varying quantities. Often referred to as linear electronics (Malvino, 1999).

Digital - "The branch of electronics dealing in information transfer utilizing binary and other forms of number systems" (Harsany, 2000, p. 513).

Digital to Analog Conversion - (DAC) produces a dc output voltage that corresponds to a binary code and converts digital properties to analog voltages (Ross, 1999).

Digital Television - (DTV) TV that is handled digitally, whether or not it is high or low definition (Utz, 1998).

High Definition Television - (HDTV) The new standard for television transmission and reception; it doubles the luminance definition and displays four times as many pixels as the older NTSC standard (Ross, 1999).

National Television Systems Committee - (NTSC) the designation for the analog TV standard used in the USA (Metzger, 1998).

Organization of the Thesis

The thesis portion of the project was divided into four chapters. Chapter One provides an introduction to the context of the problem, purpose of the project, and significance of the project, limitations and delimitations and definitions of terms. Chapter Two consists of a review of relevant literature. Chapter Three documents the steps used in developing the project. Chapter Four presents the presents conclusions and recommendations drawn from the development of the project. The Appendix: Digital-High Definition Television Servicing Curriculum. Finally, the Project references.

CHAPTER TWO

REVIEW OF THE LITERATURE

Introduction

Chapter Two consists of a discussion of the relevant literature. Specifically, a brief history of broadcast television 1939 - 2000, the technical changes during this period, the NTSC standard, and the new ATSC standard. The chapter concludes with a summary.

A Brief History

Broadcast television was introduced to the public at the New York World Fair in 1939. RCA televised the opening and carried speeches by President Franklin D. Roosevelt and RCA President David Sarnoff (Weiner 1992). According to the Consumer Electronics Manufacturers Association RCA, GE, Dumont and Philco sold the first consumer television sets the same year.

On December 7th 1941 CBS televised news on the attack on Pearl Harbor. The outbreak of hostilities caused the development of television to be placed on hold, commercial production of TV equipment was banned in 1942 for the duration of the war and NBC cancelled its television broadcast schedule (Fisher & Fisher 1996).

The first production line televisions were produces by RCA, these were their model 630-TS, and they were considered the "Model T" of television. RCA sold 10,000 units in 1946 at a cost of $385.00 each (Fisher & Fisher 1996). The first televisions had very small screens compared to today's standards. They were round and less than 10 inches across. These black and white picture tubes or technically referred to as cathode ray tubes produced very poor pictures by today's standards.

During this same period CBS demonstrated color television to the Federal Communications Commission (FCC). The FCC determined that CBS was premature in its introduction of color television. On June 25th 1951 CBS televises a one-hour gala color premier, featuring Ed Sullivan and others but only two-dozen sets in the entire country can pick it up (Fisher & Fisher 1996).

The development of color television was put on hold because of the outbreak of the Korean Conflict this hold lasted until 1953. A technical battle was raging between the two industry giants RCA and CBS as to which color system was best. In December 1953 the FCC adopted the system used by RCA and it became part of the NTSC standard. RCA put on the market its first color televisions, which sold for $1000.00 each and by the end of 1954 they had sold only 5000 sets.

The industry continued to grow and by 1960 RCA had spent more than $130 million in development and marketing and recorded its first profits (Fisher & Fisher 1996). The growth of television continued and so did industry profits. In 1970 there were more than 59 million televisions in US households and more than 691 commercial broadcast stations (US Bureau of the Census 1975). The growth of television continued and by 1998, 98 percent of US households had television (U.S. Bureau of the Census 1999).

In 1996 the FCC adopted the new ATSC standard and digital television not only became a reality but also was mandated by the United States government. The telecommunication act mandated that 30 percent of U.S. television households receive digital signals by May of 1999. This was accomplished by the television networks placing digital equipment in the top 10 markets: New York, Los Angeles, Chicago, Philadelphia, San Francisco, Boston, Washington, DC, Dallas/Ft. Worth, Detroit and Atlanta (DTV Guide 1999). The mandate also required this number be increased to 50% by November 1999. The industry accomplished this by adding an additional twenty cities strategically located throughout the United States. The transition from analog to digital will continue and by May 2002 all television stations must offer digital signals and, and by the end of 2006, analog signals will yield entirely too digital (Nickerson, 1999). The consumer electronics industry has sold more that 120 thousand digital televisions and expects this number to grow to 10 million by 2003, the industry expects this number to grow with more than 30 percent of U.S. households having digital televisions by 2006.

Technical Changes 1950-2000

In 1939 all of the televisions in the United States used the technology available at the time. All of the television cathode ray tubes (CRT's) or picture tubes were round and less than 10 inches across. This limitation was due to the use of electrostatic deflection.

Deflection is the method used to produce an image on the screen, the way the picture is made, the NTSC standard dictates that the picture is made of scanned lines. The process of controlling these scanned lines is called deflection. In 1939 the method used was electrostatic. plates were placed in the picture tube and a voltage on the plates caused an electron beam to move across the face of the CRT. When the phosphor on the face of the CRT is struck by this beam it lights up and after 525 lines are completed a picture is produced. Figure 1 shows the construction of the basic CRT using electrostatic deflection plates. The electron gun contains a cathode which is an element that when heated has many free electrons. These electrons are attracted to the phosphor screen by the high voltage applied to the CRT. The screen is struck by the electrons flowing like a beam and lights up. The deflection plates contained in the CRT are used to control the electron beam. Two plates control the beam vertically and two plates control the beam horizontally, the process is called electrostatic deflection.

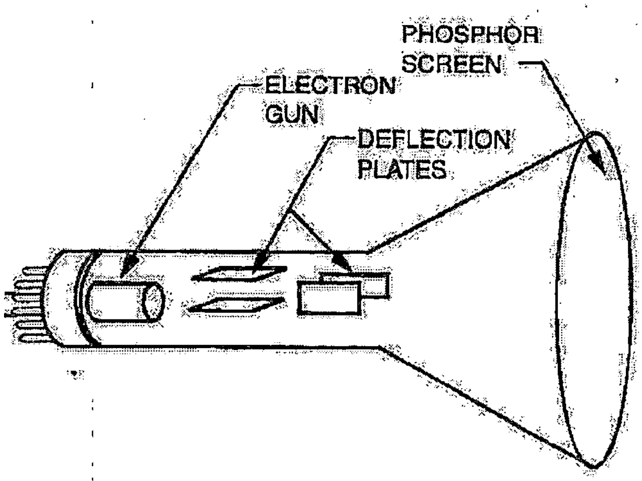

Figure 1.

Basic Cathode Ray Tube

When one thinks of the how a picture is produced in the NTSC standard one must know that the picture is made of 525 horizontal lines placed on the picture tube so fast that they appear to make a picture. In reality they are turning on and off at a rate so fast that the human eye doesn't see when the picture is off.

The use of a new deflection system electromagnetic permitted larger screen sizes. This system placed a coil of wire on the picture tube and used the magnetic field produced when current passed through the coil to control the electron beam. The coil was called a deflection yoke and is still in use today. This system allows for greater control of the electron beam and was easily modified to work with the new rectangular picture tubes that were introduces in the early 1950's. Shown in figure 2 are the coils as they placed on the CRT neck and their arrangement in a deflection yoke. The two coils shown in the schematic drawing labeled V are the two vertical electromagnets. These perform the same function as the two vertical plates in an electrostatic deflection system. The two coils labeled H are the horizontal coils and they perform the same function as the horizontal plates in an electrostatic picture tube or CRT. This new method of deflection and how the coils are placed on the neck of a picture tube is shown in the second drawing in figure 2.

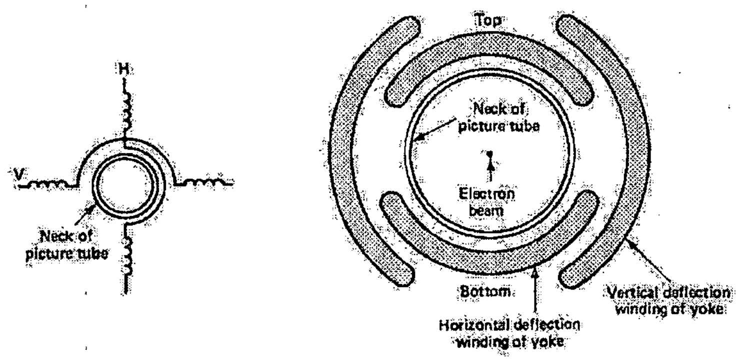

Figure 2.

Electromagnetic Deflection on the Cathode Ray Tube

The technology available at the beginning of the television era relied on the electronic vacuum tube. The vacuum tube had been in use for some time and many of the early television servicemen were able to repair television sets because they had been repairing radio sets that had used this technology for years.

The diode was the first solid-state device introduced into the television and was soon followed by the transistor, These devices were used in signal applications because technology had not advanced them to a state where they could function in power applications. A television receiver that utilized both technologies was referred to as a hybrid set and was the first to present a technical challenge to the service industry, which up to now consented of radio repair shops. Color television was the next big challenge to this industry. The technicians had to be trained on this new product much of the technology was new not just the application.

The first all solid-state televisions were produced and the era of the vacuum tube was over. The new solid state televisions used less energy and were much lighter than the vacuum tube models, the portable was born. The transistor led to the development of the integrated circuit (IC). The integrated circuit could do the same function of many transistors and other electronic components used less energy and a lot less space.

The integrated circuit is still widely used by the electronic industry, however the microprocessor is now used and has become a major component in most consumer electronic products especially the television. Most of the controls the knobs have been replaced by a button and a display on the CRT screen indicating what is happening when you push the button this is one use of what is referred to today as on screen display.

The use of the microprocessor has allowed the manufactures to move into the digital world. The mandated changes by the United States government will force the consumer to do the same. The technicians in the workforce and the students in school today must now train for this new technology.

Overview: The National Television Systems Standards

The FCC approved the NTSC Standards in 1941. These standards with only minor modifications have been in use by the television industry since the approval. The most significant change to the standard was the addition of the signals required to produce a color picture.

The NTSC black and white picture standard calls for a vertical frequency of 60 Hertz and a Horizontal Rate of 15,750 Hertz. The standard also consists of 525 lines to make up a complete picture and the use of interlace scanning. Shown in Figure 3 is the scanning process this process calls for 262.5 lines of information to be placed on the screen followed by a second 262.5 lines. Each set of 262.5 lines is called a frame and two frames make up a field. A field is a complete picture. Figure 3 shows the interlace process. The 262.5 lines are scanned on the face of a CRT; these could represent the odd lines 1,3,5.... The second set of 262.5 lines is scanned immediately after the first these represent lines 2,4,6.... This process repeats every 1/30th of a second and is the way a picture or image is written on the face of a CRT.

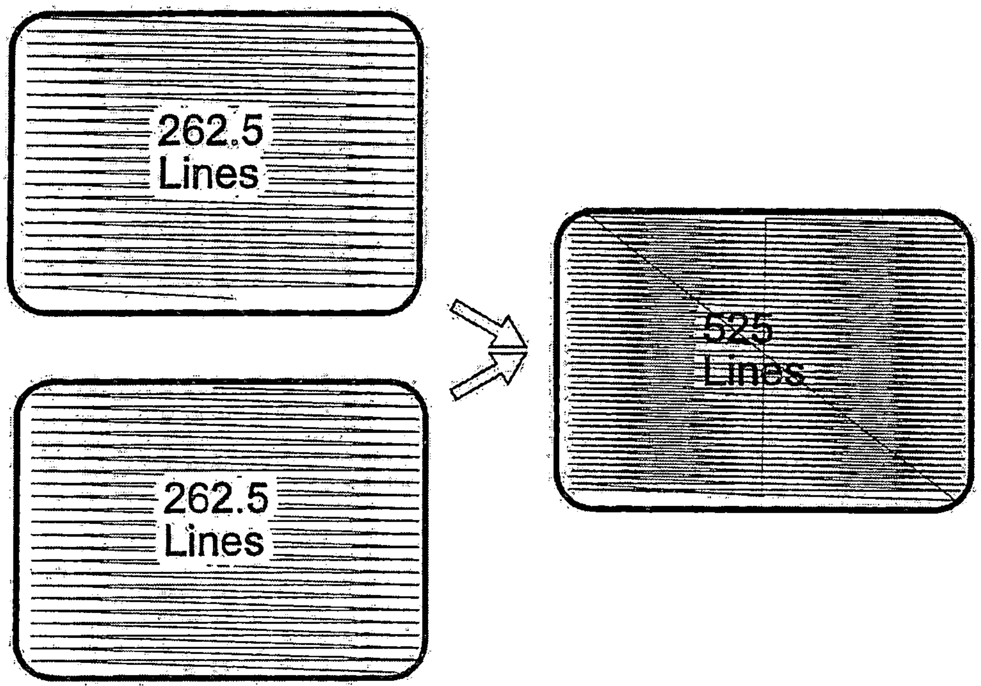

Figure 3.

Interlace Scanning National Television Systems Standard

The standard was modified slightly to accept the color signal. The horizontal scanning rate was slowed to 15,734 Hertz and color information was added. It was a requirement of the FCC that black and white televisions that were in use, without modification, receive the color television signals. The compatibility requirement was met and the new modified standards were adopted in 1953. Table 1. is the current NTSC color television standard. The picture is made up as a field and changes every 30th of a second. The field is made up by the two interlaced frames at a rate just under a 60th of a second. The horizontal or speed of writing each line is 15.734 k Hertz or 15734 Hertz. This frequency or horizontal line rate is also referred to as the line frequency.

Table 1.

National Television Systems Committee Signal Color Television Characteristics

Characteristics	
Number of lines per picture (frame)	= 525
Field frequency (fields/second	= 59.94
Picture (frame) frequency (pictures/second)	= 30
Line frequency (lines/second)	= 15734

The following is the NTSC standard for a video signal. Shown in Figure 4 is a single line of picture information. The first is of a monochrome or black and white stairs step. This pattern would represent shades of gray from black to white. The second figure shows a similar pattern however color information has been added and this represents a single line of the standard NTSC color bar test signal.

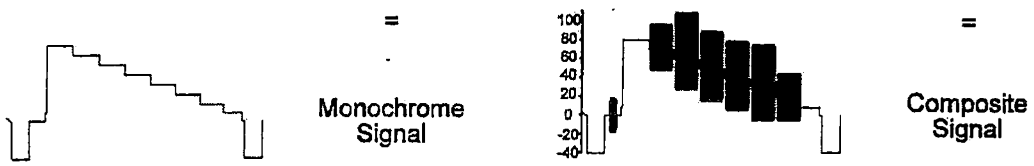

Figure 4.

One Single National Television Systems Horizontal Line

Overview: The Advanced Television Systems Committee Signal

The ATSC signal was adopted in 1996. This new standard is digital and is not compatible with the existing NTSC standard. It provides the broadcasting stations with a variety of formats to choose from, the digital television receiver will be able to receive all of the available formats (Panasonic Services Company 2000).

The new ATSC digital signal consists of two signal categories, Standard Definition Television (SDTV), and High Definition Television (HDTV). Each of the categories offers two different picture resolutions. In Figure 5 all of the formats are shown each exceeds the current NTSC signal standard in both picture and sound quality. Figure 5 is a block representing all the digital television formats. Three standards represent the standard digital television formats. 640X480 is the basic digital television signal; it is a 4x3 ratio and is slightly better than what the NTSC signal can produce. The second 704x480 can be displayed as a 4x3 or a 16:9 aspect ratio. The 16x9 would represent a wide screen format.

Two standards in figure 5 represent the HDTV or high definition format. The first is 1280x720 this would represent a high quality wide screen 16:9 format. The last of the formats is the highest quality with nearly twice the picture information of the current NTSC standard a wide screen 16:9 format and the best that HDTV has to offer.

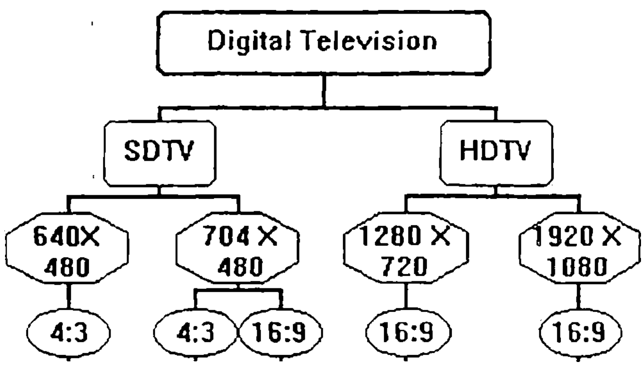

Figure 5.

Digital Television Formats

The new digital signal would not be possible nor would the system work with current broadcast channel allocations if it weren't for the ability to compress the signal. The new digital system utilizes The Motion Pictures Experts Group (MPEG) for video or picture compression and Dolby's AC-3 system for audio compression. The two signals are then sent to the MPEG II transport system encoder. The MPEG II transport system adopted by the industry allows for a very high compression rate nearly 50:1. This compression process allows for an incredibly large amount of information to be placed in a small space. An example of this technology would be a comparison of a Video Home System (VHS) videotape with a digital versatile disk (DVD). Each of these formats could contain the same movie up to 120 minutes of record time but the DVD is much smaller and the end result is of higher quality. The VHS video is an analog recording and the DVD is a digital recording.

The MPEG II system in order to attain the high rate of compression relies on two forms of compression, spatial and temporal. Spatial compression takes advantage of redundancies usually found in a single frame. Temporal compression takes advantage of redundancies that occur between frames. (Panasonic Services Company 2000) Figure 6 shows an example of the spatial and temporal compression method. Elements of the picture are broken down into digital information this information is then compared to other elements of the picture containing the same digital information. The compression is not only a single frame but many frames that contain the same information. In the example used the face and monitor or television screen appear in all of the frames. Compression only requires the information once and reinserts it into the picture or frame as required.

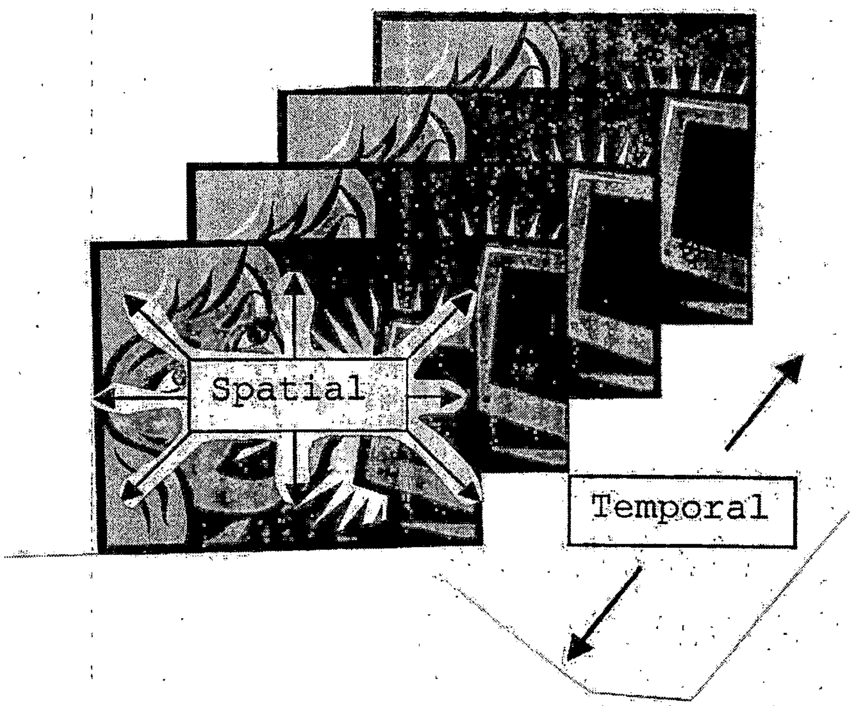

Figure 6.

Spatial and Temporal Compression Method

AC-3 audio compression was selected by the ATSC as the audio compression system for digital television. AC-3 was selected because it is a flexible system with a high compression ratio. The system delivers six discrete channels of high quality audio, five of which are equal to CD in quality and one for Low Frequency Effects (LFE) utilized for low frequencies up to 120 hertz or cycles per second. Shown in Figure 7 is a typical surround sound system speaker location. Each channel has a speaker and the LFE or sub-woofer is placed near or on the floor so the effect is felt anywhere in the room. Figure 7 shows a

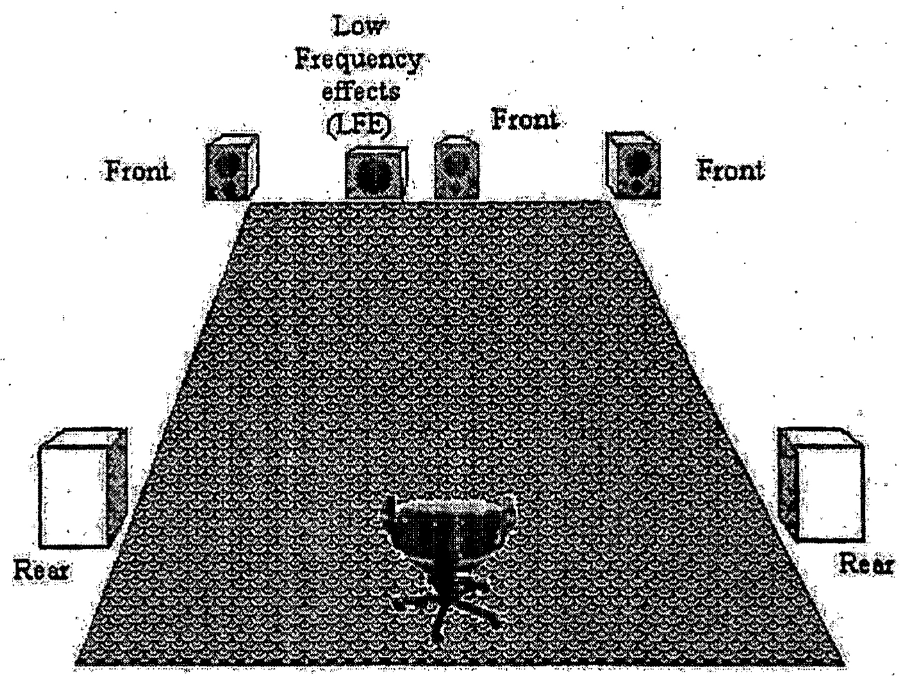

Figure 7.

Typical 5.1 Surround Sound

A typical home theatre audio set up with 5.1 surround sound. Not shown is the HDTV or HDTV projections system that would typically be placed in the front of the room between the right front and left front speakers directly inline with the center speaker.

Summary

In chapter two a brief history of broadcast television 1939 through 2000 was discussed. The technical changes in the television set and electronics for the same period were also presented. The chapter concluded with a review of the current NTSC standard and an introduction to the new ATSC television standard and the compression system that makes the standard possible. The chapter also contained information on the Dolby digital audio system and an introduction to the standards that allow for 5.1 digital sounds.

CHAPTER THREE

METHODOLOGY

Introduction

Chapter Three documents the steps used in developing the project. Specifically, the curriculum development process including curriculum structure and content validation was presented. Next, the population served was discussed. The chapter concludes with a summary.

Development

Resources and Content Validation

Design

The Digital High Definition Curriculum was designed to be the third in a series of four semesters of coursework for a degree in electronics with the emphasis in the area of consumer products servicing. The program at Santa Ana College is deigned to teach students the basics of electronics with the emphasis on servicing consumer electronic products. This course is designed to meet the new the new ATSC broadcast standards.

Course Outline

A. Introduction to the NTSC Signal

    1. NTSC Color BARS (EIA Standard)

    2. IEEE Units

3. The NTSC Color Signal

B. Introduction to the ATSC Signal

1. Standard Digital Television Signals

2. High Definition Digital Television Signals

C. Linear Power Supplies

1. Identification

2. Characteristics

3. Measurements

4. Troubleshooting Linear Power Supplies

D. Switch Mode Power Supplies

1. Identification

2. Characteristics

3. Measurements

4. Troubleshooting Switch Mode Power Supplies

E. DTV Tuner Circuits

1. Overview

2. Functional Block Diagrams

3. Troubleshooting

F. Signal Processing Circuits

1. Synchronous Detector

2. Equalizer

3. Decoders

4. Troubleshooting

G. Microprocessors

    1. Overview

    2. Requirements

    3. Testing

    4. Troubleshooting

    5. Handling Precautions

H. Deflection Circuits

    1. Overview

    2. Vertical

    3. Horizontal

    4. Troubleshooting

I. High Voltage Circuits

    1. Overview

    2. High Voltage Safety

    3. High Voltage Transformers

    4. High Voltage Circuits

    5. Measuring High Voltage

    6. Troubleshooting

J. Convergence Circuits

    1. Overview

    2. Customer Adjustments

    3. Service Adjustments

    4. Troubleshooting

K. System Set Up

1. Overview
2. Connections
3. Picture Set Up
4. Additional Connections
5. Troubleshooting

L. 5.1 Sound

1. Overview
2. Connections
3. Testing Software
4. Troubleshooting

M. Audio Circuits

1. Overview
2. Detection Circuits
3. Pre-amplifier Circuits
4. Power Amplification Circuits
5. Troubleshooting

Population Served

The curriculum is designed to serve the need of the students of Santa Ana College as well as members of the community in the electronic service industry seeking additional training on the new technologies. The implementation of this program will serve the needs of the television industry and the community by providing a trained workforce prepared to deal with the new ATSC digital television standard and related technologies.

Summary

The steps used to develop this project were outlined. The curriculum development process including curriculum structure and contend was presented. The target populations for this course are students with information technology experience, wishing to upgrade their skills to enterprise server technologies.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

Introduction

Included in Chapter Four was a presentation of the conclusions gleamed as a result of completing the project. Further, the recommendations extracted from the project are presented. Lastly, the Chapter concludes with a summary

Conclusions

The conclusions extracted from the project follows.

1. That current curriculum is not keeping up with the pace of the electronic industry and emerging technologies.
2. Once Students are exposed to this technology they desire additional training and information on these emerging technologies.
3. Additional courses will need to be developed to meet the requirements of the emerging technologies.

Recommendations

The recommendations resulting from the project follows.

1. The Advisory committee needs to seek members from the Consumer Electronics Association who represent the manufacturers and are current with the industry and familiar with the developments of the emerging technologies.
2. Mini courses need to be developed to improve, update, and refresh the skills of the current service industry workforce.
3. Additional courses need to be developed to meet the requirements of emerging technologies.

Summary

Chapter Four reviewed the conclusions extracted from the project. Lastly, the recommendations derived from the project were presented.

APPENDIX

DIGITAL-HIGH DEFINITION TELEVISION SERVICING CURRICULUM

Overview

This booklet is designed as semester length community college curriculum for a course in the Theory and Servicing of Digital – High Definition Television for the students in the service technology field of electronics at Santa Ana Community College in Santa Ana, California. Additionally, it is designed with the current electronic service industry in mind. This skilled workforce will require new training to meet the challenges and requirements of this new technology.

Introduction

The Federal Communications Commission in December 1996 adopted new standards that will make broadcast television, as we know it today obsolete. The current National Television System Committee (NTSC) standards were adopted in 1941 and only minor changes have been made to these standards until the adoption of the new Advanced Television Systems Committee (ATSC) standards in December 1996. The NTSC standards are analog and the current required curriculum addresses the theory and servicing of this standard. The new ATSC standard for Digital - High Definition Television is digital and will require new theory of operation and servicing to be taught.

The existing television standards adopted and in use since 1953 are now obsolete. A mandated U.S. Federal Communications Commission new Advanced Television System Commission (ATSC) standard replaces the current National Television Systems (NTSC) standard in 2006. When the change over is made the televisions in the United States will no longer be able to receive broadcast television transmitted signals, without a digital to analog converter.

Table of Contents

Lesson Plans

Lesson Title: Introduction, Rules, Regulations, and Safety

Lesson Outline:

1. College Policies
   a. Attendance
   b. Cheating
   c. Plagiarism
2. Course Overview
   a. Schedule
   b. Holidays
   c. Lab Exercises
3. Emergency Procedures
4. Safety
   a. Test Equipment
   b. Product Servicing

Lesson Objectives:

Upon completion of this unit students will:

1. Have an understanding of college policies.
2. Be familiar with the course/ program objectives
3. Understand college and classroom emergency procedures.
4. Demonstrate proper use of an AC voltmeter
5. Demonstrate the ability to perform industry equipment safety checks.
   a. Isolation Check
   b. Dielectric Test
   c. Leakage Current Check

Materials and Equipment:

UL Safety procedures, .15 uf AC capacitor, 1500 ohm 10W resistor, AC Meter, equipment to test.

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will take and pass the college electronics department safety test with 80% accuracy and perform the UL safety check.

Lesson Title: Introduction to the NTSC Signal

Lesson Outline:

1. NTSC Color BARS (EIA Standard)
   a. Color Identification
   b. Chroma Measurement
   c. Luminance Measurement
2. IEEE Units
   a. Applying the NTSC Signal
   b. IEEE Units and Color Bars
3. The NTSC Color Signal
   a. Horizontal Reference
   b. Vertical Reference

Lesson Objectives:

Upon completion of this unit students will:

1. Be familiar with the NTSC EIA Standard Color Bars
2. Understand the Chroma and Luminance Signals
3. Demonstrate the ability to identify colors of The NTSC standard color bars
4. Demonstrate the ability to use the oscilloscope to measure the NTSC signals
   a. At the horizontal rate
   b. At the vertical rate

Materials and Equipment:

NTSC Signal Generator, Color Television Monitor Receiver, Oscilloscope
Isolation Transformer, Measurement Worksheets

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to the NTSC signal and demonstrate the proper use of the oscilloscope.

Lesson Title: Introduction to the ATSC Signal

Lesson Outline:

1. Standard Digital Television Signals
   a. SDTV 640x480
   b. SDTV 704x480 4:3
   c. SDTV 704x480 16:9
2. High Definition Digital Television Signals
   a. HDTV 1280x720 16:9
   b. HDTV 1920x1080 16:9

Lesson Objectives:

Upon completion of this unit students will:

1. Be familiar with the standard digital television signal
2. Be able to identify various SDTV signals
3. Be able to identify various HDTV signals
4. Demonstrate the ability to use the HDTV signal generator

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Digital/HDTV Signal Worksheet

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to the ATSC signal and demonstrate the ability to generate the required DTV test signals using the digital television Signal generator.

Lesson Title: Linear Power Supplies

Lesson Outline:

1. Identification
2. Characteristics
   a. Transformers
   b. Regulation
3. Measurements
   a. AC Voltages
   b. DC Voltages
4. Troubleshooting Linear Power Supplies

Lesson Objectives:

Upon completion of this unit students will:

1. Be able to identify a linear power supplies used in digital televisions
2. Be able to identify major components used in linear power supplies
3. Demonstrate the ability to use a DMM or VOM to make voltage measurements
4. Demonstrate the ability to test a linear power supply though the use of measurements
   a. AC measurements
   b. DC measurements
5. Use schematic diagrams to assist in troubleshooting linear power supplies

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Schematic Diagrams, DMM or VOM

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to the linear power supply. Students will demonstrate the ability to use a DMM or VOM to measure voltages. Students will demonstrate the ability to use schematic diagrams to assist in troubleshooting and repairing power supplies.

Lesson Title: Switch Mode Power Supplies

Lesson Outline:

1. Identification
2. Characteristics
   a. Isolation
   b. Regulation
   c. Switching Devices
3. Measurements
   a. AC Voltages
   b. DC Voltages
   c. Oscilloscope and Waveforms
4. Troubleshooting Switch Mode Power Supplies

Lesson Objectives:

Upon completion of this unit students will:

1. Be able to identify switch mode power supplies used in digital televisions
2. Be able to identify major components used in switch mode power supplies
3. Demonstrate the ability to use a DMM or VOM to make voltage measurements
4. Demonstrate the ability to use an oscilloscope for waveform analysis and measurement
5. Demonstrate the ability to test a switch mode power supply though the use of measurements.
6. Use schematic diagrams to assist in troubleshooting switch mode power supplies

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Schematic Diagrams, DMM or VOM, Oscilloscope

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to the switch mode power supply. Students will demonstrate the ability to use a DMM or VOM to measure voltages. Students will demonstrate the use of the oscilloscope to analyze and measure waveforms. Students will demonstrate the ability to use schematic diagrams to assist in troubleshooting and repairing switch mode power supplies.

Lesson Title: DTV Tuner Circuits

Lesson Outline:

1. Overview
2. Functional Block Diagram
3. Troubleshooting

Lesson Objectives:

Upon completion of this unit students will:

1. Be able to identify a DTV Tuner
2. Be able to identify circuits in the DTV Tuner
3. Demonstrate an understanding of the DTV Tuner
4. Be able to test a DTV Tuner
5. Be able to replace a DTV Tuner

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Schematic Diagrams, DMM or VOM, Oscilloscope

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to the DTV Tuner. Students will demonstrate the ability to use a DMM or VOM to measure voltages. Students will demonstrate the use of the oscilloscope to analyze and measure waveforms. Students will demonstrate the ability to use schematic diagrams to assist in troubleshooting and replacing DTV Tuners.

Lesson Title: Signal Processing Circuits

Lesson Outline:

1. Synchronous Detector Circuits
2. Equalizer Circuits
3. Sync Circuits
4. Decoder Circuits
   a. Trellis
   b. Reed-Solomon
5. Troubleshooting

Lesson Objectives:

Upon completion of this unit students will:

1. Be able to identify the DTV signal processing circuits
2. Be able to trace the signal through the processing circuits
3. Describe the Trellis and Reed-Solomon decoders
4. Use a schematic diagram to aid in the process of troubleshooting signal processing circuits

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Schematic Diagrams, DMM or VOM, Oscilloscope

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to the DTV signal processing circuits.
Students will demonstrate the ability use a DMM or VOM to measure voltages.
Students will demonstrate the ability to use the Oscilloscope to analyze and measure signals
Students will demonstrate the ability to use schematic diagrams to assist in troubleshooting signal processing circuits.

Lesson Title: Microprocessors

Lesson Outline:

1. Overview
2. Voltage Requirements
   a. Power On Reset
   b. Grounding
   c. Voltages
   d. Clock
   e. Programming
3. Testing
4. Troubleshooting
5. Handling Precautions

Lesson Objectives:

Upon completion of this unit students will:

1. Be able to locate and identify the microprocessor
2. Be able to test for the appropriate signals and voltages
3. Understand the Handling precautions related to the microprocessor
4. Use the schematic diagram to troubleshoot the microprocessor

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Schematic Diagrams, DMM or VOM, Oscilloscope

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to the microprocessor. Students will demonstrate the ability to use a DMM or VOM to measure voltages. Students will demonstrate the ability to use the oscilloscope to analyze and measure Waveforms related to the microprocessor.

Lesson Title: Deflection Circuits

Lesson Outline:

1. Overview
2. Vertical
   a. signals
   b. drive
   c. output
3. Horizontal
   a. signals
   b. drive
   c. output
4. Troubleshooting

Lesson Objectives:

Upon completion of this unit students will:

1. Be able to identify the major components in the deflection circuits.
2. Be able to trace vertical signals through the deflection circuits.
3. Be able to trace horizontal signals through the deflection circuits.
4. Be able to measure voltages and signals related to the deflection circuits.
5. Use the schematic diagram to aid in troubleshooting deflection circuits.

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Schematic Diagrams, DMM or VOM, Oscilloscope

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to deflection circuits.
Students will demonstrate the ability to use a DMM or VOM to measure voltages.
Students will demonstrate the ability to use the oscilloscope to analyze and measure Waveforms related to the deflection circuits.
Students will demonstrate the ability to schematic troubleshoot deflection circuits.

Lesson Title: High Voltage Circuits

Lesson Outline:

1. Overview
2. High Voltage Safety
3. High Voltage Transformers
4. High Voltage Circuits
5. Measuring High Voltage
6. Troubleshooting High Voltage Circuits

Lesson Objectives:

Upon completion of this unit students will:

1. Be able to demonstrate the procedures to safely work in high voltage circuits.
2. Be able to identify major high voltage components.
3. Be able to trace the high voltage circuits with the aid of a schematic diagram.
4. Be able to safely perform a high voltage measurement.
5. Be able to troubleshoot high voltage problems with the aid of test equipment.

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Schematic Diagrams, DMM or VOM, High Voltage Probe

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to high voltage circuits.
Students will demonstrate the ability to use a DMM or VOM to measure voltages.
Students will demonstrate the ability to use the high voltage probe to measure high voltage.
Students will demonstrate safety in working around high voltage.

Lesson Title: Convergence Circuits

Lesson Outline:

1. Overview
2. Customer Adjustments
3. Service Adjustments
4. Troubleshooting

Lesson Objectives:

Upon completion of this unit students will:

1. Be able to demonstrate an understanding of convergence circuits.
2. Be able to define customer convergence adjustments.
3. Be able to define service convergence adjustments
4. Be able to perform the adjustments.
5. Be able to locate and troubleshoot convergence problems.

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Schematic Diagrams, DMM or VOM, Oscilloscope

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to convergence circuits.
Students will demonstrate the ability to use a DMM or VOM to measure voltages.
Students will demonstrate the ability to use the oscilloscope to analyze and measure Waveforms related to the convergence circuits.
Students will be able to perform customer and service convergence adjustments.
Students will be able to identify and troubleshoot convergence problems.

Lesson Title: System Set Up

Lesson Outline:

1. Overview
2. Connections
   a. Audio
   b. Video
   c. SVHS
   d. RF
3. Picture Setup
4. Additional Connections
5. Troubleshooting

Lesson Objectives:

Upon completion of this unit students will:

1. Understand the set up procedure of a DTV
2. Understand the connectivity of a DTV
3. Understand DTV Picture Setup
4. Understand connection options
5. Understand the procedure to troubleshoot setup problems

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Service Set Up Manual, DMM or VOM

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to the Setup procedure. Students will demonstrate the ability to follow set up procedures from the manual. Students will demonstrate the ability to troubleshoot setup problems.

Lesson Title: 5.1 Sound

Lesson Outline:

1. Overview
2. Connections
3. Testing Software
4. Troubleshooting

Lesson Objectives:

Upon completion of this unit students will:

1. Understand the setup procedure for 5.1 sound
2. Install related connections for 5.1 sound
3. Use software related to setup 5.1 sound
4. Be able to troubleshoot 5.1 sound problems

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, 5.1 Sound system, Service Set Up Manual, 5.1 Setup software

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to 5.1 sound setup.
Students will demonstrate the ability to use 5.1 software for setup.
Students will demonstrate the ability to troubleshoot 5.1 sound problems.

Lesson Title: Audio Circuits

Lesson Outline:

1. Overview
2. Detection Circuits
3. Pre-amplifier Circuits
4. Power Amplifier Circuits
5. Troubleshooting

Lesson Objectives:

Upon completion of this unit students will:

1. Understand the basic audio circuit in DTV
2. Understand Audio detection circuits
3. Understand Pre-amplifier circuits
4. Understand power amplifier circuits
5. Be able to troubleshoot audio problems

Materials and Equipment:

Digital Television Signal Generator, HDTV Television, Isolation Transformer, Schematic Diagrams, DMM or VOM, Oscilloscope

Evaluation:

Demonstration of the above objectives

Comprehension:

All students will successfully complete the worksheet related to audio circuits.
Students will demonstrate the ability to use a DMM or VOM to measure voltages.
Students will demonstrate the ability to use the oscilloscope to analyze and measure Waveforms related to the audio circuits.
Students will demonstrate the ability to troubleshoot an audio circuit problem.

ATSC Digital Television Standard

1. Scope and documentation structure

The Digital Television Standard describes the system characteristics of the U. S. advanced television (ATV) system. The document and its normative annexes provide detailed specification of the parameters of the system including the video encoder input scanning formats and the pre-processing and compression parameters of the video encoder, the audio encoder input signal format and the pre-processing and compression parameters of the audio encoder, the service multiplex and transport layer characteristics and normative specifications, and the VSB RF/Transmission subsystem.

1.1 Documentation Structure

The documentation of the Digital Television Standard consists of this document which provides a general system overview, a list of reference documents, and sections relating to the system as a whole. The system is modular in concept and the specifications for each of the modules are provided in the appropriate annex.

2. References

Normative references may be found in each normative Annex. The Digital Television Standard is based on the ISO/IEC MPEG-2 Video Standard, the Digital Audio Compression (AC-3) Standard, and the ISO/IEC MPEG-2 Systems Standard. Those references are listed here for the convenience of the reader. In addition, a guide to the use of the Digital Television Standard is listed.

ATSC Standard A/52 (1995), Digital Audio Compression (AC-3).

ATSC Document A/54 (1995), Guide to the Use of the ATSC Digital Television Standard.

ISO/IEC IS 13818-1, International Standard (1996), MPEG-2 Systems.

ISO/IEC 13818-1: 1996/Cor. 1: 1997 (E) Technical Corrigendum 1.

ISO/IEC 13818-1: 1996/Amd. 1: 1997 (E) Amendment 1.

ISO/IEC 13818-1: 1996/Amd. 2: 1997 (E) Amendment 2.

ISO/IEC 13818-1: 1996/Amd. 3: 1997 (E) Amendment 3.

ISO/IEC 13818-1: 1996/Amd. 4: 1997 (E) Amendment 4.

ISO/IEC IS 13818-2, International Standard (1996), MPEG-2 Video.

ISO/IEC 13818-2: 1996/Cor. 1: 1997 (E) MPEG-2 Video Technical Corrigendum 1.

ISO/IEC 13818-2: 1996/Cor. 2: 1997 (E) MPEG-2 Video Technical Corrigendum 2.

3. Definitions

With respect to definition of terms, abbreviations, and units, the practice of the Institute of Electrical and Electronics Engineers (IEEE) as outlined in the Institute's published standards shall be used. Where an abbreviation is not covered by IEEE practice, or industry practice differs from IEEE practice, then the abbreviation in question will be described in Section 3.4 of this document. Many of the definitions included therein are derived from definitions adopted by MPEG.

3.1 Compliance Notation

As used in this document, "shall" or "will" denotes a mandatory provision of the standard. "Should" denotes a provision that is recommended but not mandatory. "May" denotes a feature whose presence does not preclude compliance, that may or may not be present at the option of the implementor.

3.2 Treatment of Syntactic Elements

This document contains symbolic references to syntactic elements used in the audio, video, and transport coding subsystems. These references are typographically distinguished by the use of a different font (e.g., restricted), may contain the underscore character (e.g., sequence_end_code) and may consist of character strings that are not English words (e.g., dynrng).

3.3 Terms Employed

For the purposes of the Digital Television Standard, the following definition of terms apply:

ACATS: Advisory Committee on Advanced Television Service.

access unit: A coded representation of a presentation unit. In the case of audio, an access unit is the coded representation of an audio frame. In the case of video, an access unit includes all the coded data for a picture, and any stuffing that follows it, up to but not including the start of the next access unit. If a picture is not preceded by a group_start_code or a sequence_header_code, the access unit begins with a the picture start code. If a picture is preceded by a group_start_code and/or a sequence_header_code, the access unit begins with the first byte of the first of these start codes. If it is the last picture preceding a sequence_end_code in the bit stream all bytes between the last byte of the coded picture and the sequence_end_code (including the sequence_end_code) belong to the access unit.

A/D: Analog to digital converter.

AES: Audio Engineering Society.

anchor frame: A video frame that is used for prediction. I-frames and P-frames are generally used as anchor frames, but B-frames are never anchor frames.

ANSI: American National Standards Institute.

Asynchronous Transfer Mode (ATM): A digital signal protocol for efficient transport of both constant-rate and bursty information in broadband digital networks. The ATM digital stream consists of fixed-length packets called "cells," each containing 53 8-bit bytes—a 5-byte header and a 48-byte information payload.

ATEL: Advanced Television Evaluation Laboratory.

ATM: See *asynchronous transfer mode*.

ATTC: Advanced Television Test Center.

ATV: The U. S. advanced television system.

bidirectional pictures or **B-pictures** or **B-frames:** Pictures that use both future and past pictures as a reference. This technique is termed *bidirectional prediction*. B-pictures provide the most compression. B-pictures do not propagate coding errors as they are never used as a reference.

bit rate: The rate at which the compressed bit stream is delivered from the channel to the input of a decoder.

block: A block is an 8-by-8 array of pel values or DCT coefficients representing luminance or chrominance information.

bps: Bits per second.

byte-aligned: A bit in a coded bit stream is byte-aligned if its position is a multiple of 8-bits from the first bit in the stream.

CDTV: See *conventional definition television.*

channel: A digital medium that stores or transports a digital television stream.

coded representation: A data element as represented in its encoded form.

compression: Reduction in the number of bits used to represent an item of data.

constant bit rate: Operation where the bit rate is constant from start to finish of the compressed bit stream.

conventional definition television (CDTV): This term is used to signify the *analog* NTSC television system as defined in ITU-R Recommendation 470. See also *standard definition television* and ITU-R Recommendation 1125.

CRC: The cyclic redundancy check to verify the correctness of the data.

D-frame: Frame coded according to an MPEG-1 mode which uses DC coefficients only.

data element: An item of data as represented before encoding and after decoding.

DCT: See *discrete cosine transform.*

decoded stream: The decoded reconstruction of a compressed bit stream.

decoder: An embodiment of a decoding process.

decoding (process): The process defined in the Digital Television Standard that reads an input coded bit stream and outputs decoded pictures or audio samples.

decoding time-stamp (DTS): A field that may be present in a PES packet header that indicates the time that an access unit is decoded in the system target decoder.

digital storage media (DSM): A digital storage or transmission device or system.

discrete cosine transform: A mathematical transform that can be perfectly undone and which is useful in image compression.

DSM-CC: Digital storage media command and control.

DSM: Digital storage media.

DTS: See *decoding time-stamp.*

DVCR: Digital video cassette recorder

ECM: See *entitlement control message.*

editing: A process by which one or more compressed bit streams are manipulated to produce a new compressed bit stream. Conforming edited bit streams are understood to meet the requirements defined in the Digital Television Standard.

elementary stream (ES): A generic term for one of the coded video, coded audio, or other coded bit streams. One elementary stream is carried in a sequence of PES packets with one and only one stream_id.

elementary stream clock reference (ESCR): A time stamp in the PES stream from which decoders of PES streams may derive timing.

EMM: See *entitlement management message.*

encoder: An embodiment of an encoding process.

encoding (process): A process that reads a stream of input pictures or audio samples and produces a valid coded bit stream as defined in the Digital Television Standard.

entitlement control message (ECM): Entitlement control messages are private conditional access information which specify control words and possibly other stream-specific, scrambling, and/or control parameters.

entitlement management message (EMM): Entitlement management messages are private conditional access information which specify the authorization level or the services of specific decoders. They may be addressed to single decoders or groups of decoders.

entropy coding: Variable length lossless coding of the digital representation of a signal to reduce redundancy.

entry point: Refers to a point in a coded bit stream after which a decoder can become properly initialized and commence syntactically correct decoding. The first transmitted picture after an entry point is either an I-picture or a P-picture. If the first transmitted picture is not an I-picture, the decoder may produce one or more pictures during acquisition.

ES: See *elementary stream.*

ESCR: See *elementary stream clock reference.*

event: An event is defined as a collection of elementary streams with a common time base, an associated start time, and an associated end time.

field: For an interlaced video signal, a "field" is the assembly of alternate lines of a frame. Therefore, an interlaced frame is composed of two fields, a top field and a bottom field.

forbidden: This term, when used in clauses defining the coded bit stream, indicates that the value shall never be used. This is usually to avoid emulation of start codes.

FPLL: Frequency and phase locked loop.

frame: A frame contains lines of spatial information of a video signal. For progressive video, these lines contain samples starting from one time instant and continuing through successive lines to the bottom of the frame. For interlaced video a frame consists of two fields, a top field and a bottom field. One of these fields will commence one field later than the other.

GOP: See *group of pictures.*

Group of pictures (GOP): A group of pictures consists of one or more pictures in sequence.

HDTV: See *high definition television.*

high definition television (HDTV): High definition television has a resolution of approximately twice that of conventional television in both the horizontal (H) and vertical (V) dimensions and a picture aspect ratio (H × V) of 16:9. ITU-R Recommendation 1125 further defines "HDTV quality" as the delivery of a television picture which is subjectively identical with the interlaced HDTV studio standard.

high level: A range of allowed picture parameters defined by the MPEG-2 video coding specification which corresponds to high definition television.

Huffman coding: A type of source coding that uses codes of different lengths to represent symbols which have unequal likelihood of occurrence.

IEC: International Electrotechnical Commission.

intra-coded pictures or **I-pictures** or **I-frames:** Pictures that are coded using information present only in the picture itself and not depending on information from other pictures. I-pictures provide a mechanism for random access into the compressed video data. I-pictures employ transform coding of the pel blocks and provide only moderate compression.

ISO: International Organization for Standardization.

ITU: International Telecommunication Union.

JEC: Joint Engineering Committee of EIA and NCTA.

layer: One of the levels in the data hierarchy of the video and system specification.

level: A range of allowed picture parameters and combinations of picture parameters.

macroblock: In the advanced television system, a macroblock consists of four blocks of luminance and one each C_r and C_b block.

main level: A range of allowed picture parameters defined by the MPEG-2 video coding specification with maximum resolution equivalent to ITU-R Recommendation 601.

main profile: A subset of the syntax of the MPEG-2 video coding specification that is expected to be supported over a large range of applications.

Mbps: 1,000,000 bits per second.

motion vector: A pair of numbers which represent the vertical and horizontal displacement of a region of a reference picture for prediction.

MP@HL: Main profile at high level.

MP@ML: Main profile at main level.

MPEG: Refers to standards developed by the ISO/IEC JTC1/SC29 WG11, *Moving Picture Experts Group.* MPEG may also refer to the Group.

MPEG-1: Refers to ISO/IEC standards 11172-1 (Systems), 11172-2 (Video), 11172-3 (Audio), 11172-4 (Compliance Testing), and 11172-5 (Technical Report).

MPEG-2: Refers to ISO/IEC standards 13818-1 (Systems), 13818-2 (Video), 13818-3 (Audio), 13818-4 (Compliance).

pack: A pack consists of a pack header followed by zero or more packets. It is a layer in the system coding syntax.

packet data: Contiguous bytes of data from an elementary data stream present in the packet.

packet identifier (PID): A unique integer value used to associate elementary streams of a program in a single or multi-program transport stream.

packet: A packet consists of a header followed by a number of contiguous bytes from an elementary data stream. It is a layer in the system coding syntax.

padding: A method to adjust the average length of an audio frame in time to the duration of the corresponding PCM samples, by continuously adding a slot to the audio frame.

payload: Payload refers to the bytes which follow the header byte in a packet. For example, the payload of a transport stream packet includes the PES_packet_header and its PES_packet_data_bytes or pointer_field and PSI sections, or private data. A PES_packet_payload, however, consists only of PES_packet_data_bytes. The transport stream packet header and adaptation fields are not payload.

PCR: See *program clock reference*.

pel: See *pixel*.

PES packet header: The leading fields in a PES packet up to but not including the PES_packet_data_byte fields where the stream is not a padding stream. In the case of a padding stream, the PES packet header is defined as the leading fields in a PES packet up to but not including the padding_byte fields.

PES packet: The data structure used to carry elementary stream data. It consists of a packet header followed by PES packet payload.

PES Stream: A PES stream consists of PES packets, all of whose payloads consist of data from a single elementary stream, and all of which have the same stream_id.

PES: An abbreviation for packetized elementary stream.

picture: Source, coded, or reconstructed image data. A source or reconstructed picture consists of three rectangular matrices representing the luminance and two chrominance signals.

PID: See *packet identifier.*

pixel: "Picture element" or "pel." A pixel is a digital sample of the color intensity values of a picture at a single point.

predicted pictures or **P-pictures** or **P-frames:** Pictures that are coded with respect to the nearest *previous* I or P-picture. This technique is termed *forward prediction*. P-pictures provide more compression than I-pictures and serve as a reference for future P-pictures or B-pictures. P-pictures can propagate coding errors when P-pictures (or B-pictures) are predicted from prior P-pictures where the prediction is flawed.

presentation time-stamp (PTS): A field that may be present in a PES packet header that indicates the time that a presentation unit is presented in the system target decoder.

presentation unit (PU): A decoded audio access unit or a decoded picture.

profile: A defined subset of the syntax specified in the MPEG-2 video coding specification

program clock reference (PCR): A time stamp in the transport stream from which decoder timing is derived.

program element: A generic term for one of the elementary streams or other data streams that may be included in the program.

program specific information (PSI): PSI consists of normative data which is necessary for the demultiplexing of transport streams and the successful regeneration of programs.

program: A program is a collection of program elements. Program elements may be elementary streams. Program elements need not have any defined time base; those that do have a common time base and are intended for synchronized presentation.

PSI: See *program specific information.*

PTS: See *presentation time-stamp.*

PU: See *presentation unit.*

quantizer: A processing step which intentionally reduces the precision of DCT coefficients.

random access: The process of beginning to read and decode the coded bit stream at an arbitrary point.

reserved: This term, when used in clauses defining the coded bit stream, indicates that the value may be used in the future for Digital Television Standard extensions. Unless otherwise specified within this Standard, all reserved bits shall be set to "1".

SCR: See *system clock reference*.

scrambling: The alteration of the characteristics of a video, audio, or coded data stream in order to prevent unauthorized reception of the information in a clear form. This alteration is a specified process under the control of a conditional access system.

SDTV: See *standard definition television.*

slice: A series of consecutive macroblocks.

SMPTE: Society of Motion Picture and Television Engineers.

source stream: A single, non-multiplexed stream of samples before compression coding.

splicing: The concatenation performed on the system level or two different elementary streams. It is understood that the resulting stream must conform totally to the Digital Television Standard.

standard definition television (SDTV): This term is used to signify a *digital* television system in which the quality is approximately equivalent to that of NTSC. This equivalent quality may be achieved from pictures sourced at the 4:2:2 level of ITU-R Recommendation 601 and subjected to processing as part of the bit rate compression. The results should be such that when judged across a representative sample of program material, subjective equivalence with NTSC is achieved. Also called standard digital television. See also *conventional definition television* and ITU-R Recommendation 1125.

start codes: 32-bit codes embedded in the coded bit stream that are unique. They are used for several purposes including identifying some of the layers in the coding syntax. Start codes consist of a 24 bit prefix (0x000001) and an 8 bit stream_id.

STD input buffer: A first-in, first-out buffer at the input of a system target decoder for storage of compressed data from elementary streams before decoding.

STD: See *system target decoder.*

still picture: A coded still picture consists of a video sequence containing exactly one coded picture which is intra-coded. This picture has an associated PTS and the presentation time of succeeding pictures, if any, is later than that of the still picture by at least two picture periods.

system clock reference (SCR): A time stamp in the program stream from which decoder timing is derived.

system header: The system header is a data structure that carries information summarizing the system characteristics of the Digital Television Standard multiplexed bit stream.

system target decoder (STD): A hypothetical reference model of a decoding process used to describe the semantics of the Digital Television Standard multiplexed bit stream.

time-stamp: A term that indicates the time of a specific action such as the arrival of a byte or the presentation of a presentation unit.

TOV: Threshold of visibility.

Transport Stream packet header: The leading fields in a Transport Stream packet up to and including the continuity_counter field.

variable bit rate: Operation where the bit rate varies with time during the decoding of a compressed bit stream.

VBV: See *video buffering verifier.*

Video buffering verifier (VBV): A hypothetical decoder that is conceptually connected to the output of an encoder. Its purpose is to provide a constraint on the variability of the data rate that an encoder can produce.

video sequence: A video sequence is represented by a sequence header, one or more groups of pictures, and an end_of_sequence code in the data stream.

8 VSB: Vestigial sideband modulation with 8 discrete amplitude levels.

16 VSB: Vestigial sideband modulation with 16 discrete amplitude levels.

3.4 Symbols, Abbreviations, and Mathematical Operators

The symbols, abbreviations, and mathematical operators used to describe the Digital Television Standard are those adopted for use in describing MPEG-2 and are similar to those used in the "C" programming language. However, integer division with truncation and rounding are specifically defined. The bitwise operators are defined assuming two's-complement representation of integers. Numbering and counting loops generally begin from 0.

3.4.1 Arithmetic Operators

+	Addition.
–	Subtraction (as a binary operator) or negation (as a unary operator).
++	Increment.
- -	Decrement.
* or ×	Multiplication.
^	Power.

/ Integer division with truncation of the result toward 0. For example, 7/4 and –7/–4 are truncated to 1 and –7/4 and 7/–4 are truncated to –1.

// Integer division with rounding to the nearest integer. Half-integer values are rounded away from 0 unless otherwise specified. For example 3//2 is rounded to 2, and –3//2 is rounded to –2.

DIV Integer division with truncation of the result towards $-\infty$.

% Modulus operator. Defined only for positive numbers.

Sign( ) Sign(x) = 1 x > 0
= 0 x == 0
= –1 x < 0

NINT ( ) Nearest integer operator. Returns the nearest integer value to the real-valued argument. Half-integer values are rounded away from 0.

sin	Sine.
cos	Cosine.
exp	Exponential.
√	Square root.
log10	Logarithm to base ten.
loge	Logarithm to base e.

3.4.2 Logical Operators

||	Logical OR.
&&	Logical AND.
!	Logical NOT.

3.4.3 Relational Operators

>	Greater than.
≥	Greater than or equal to.
<	Less than.

≤ Less than or equal to.

== Equal to.

!= Not equal to.

max [,...,] The maximum value in the argument list.

min [,...,] The minimum value in the argument list.

3.4.4 Bitwise Operators

& AND.

| OR.

>> Shift right with sign extension.

<< Shift left with 0 fill.

3.4.5 Assignment

= Assignment operator.

3.4.6 Mnemonics

The following mnemonics are defined to describe the different data types used in the coded bit stream.

bslbf	Bit string, left bit first, where "left" is the order in which bit strings are written in the Standard. Bit strings are written as a string of 1s and 0s within single quote marks, e.g. '1000 0001'. Blanks within a bit string are for ease of reading and have no significance.
uimsbf	Unsigned integer, most significant bit first.

The byte order of multi-byte words is most significant byte first.

3.4.7 Constants

π 3.14159265359...

e 2.71828182845...

3.4.8 Method of Describing Bit Stream Syntax

Each data item in the coded bit stream described below is in bold type. It is described by its name, its length in bits, and a mnemonic for its type and order of transmission.

The action caused by a decoded data element in a bit stream depends on the value of that data element and on data elements previously decoded. The decoding of the data elements and definition of the state variables used in their decoding are described in the clauses containing the semantic description of the syntax. The following constructs are used to express the conditions when data elements are present, and are in normal type.

Note this syntax uses the "C" code convention that a variable or expression evaluating to a non-zero value is equivalent to a condition that is true.

while (condition) {
    data_element
    . . .
}
	If the condition is true, then the group of data elements occurs next in the data stream. This repeats until the condition is not true.

do {
    data_element
    . . . }
while (condition)
	The data element always occurs at least once. The data element is repeated until the condition is not true.

if (condition) {
    data_element
    . . .
}
	If the condition is true, then the first group of data elements occurs next in the data stream.

else {
    data_element
    . . .
}
	If the condition is not true, then the second group of data elements occurs next in the data stream.

for (i = 0;i<n;i++) {
    data_element
    . . .
}
	The group of data elements occurs n times. Conditional constructs within the group of data elements may depend on the value of the loop control variable i, which is set to zero for the first occurrence, incremented to 1 for the second occurrence, and so forth.

As noted, the group of data elements may contain nested conditional constructs. For compactness, the {} are omitted when only one data element follows.

data_element [ ]	data_element [ ] is an array of data. The number of data elements is indicated by the context.
data_element [n]	data_element [n] is the n+1th element of an array of data.
data_element [m] [n]	data_element [m] [n] is the m+1,n+1 th element of a two-dimensional array of data.
data_element [l] [m] [n]	data_element [l] [m] [n] is the l+1,m+1,n+1 th element of a three-dimensional array of data.
data_element [m..n]	data_element [m..n] is the inclusive range of bits between bit m and bit n in the data_element.

Decoders must include a means to look for start codes and sync bytes (transport stream) in order to begin decoding correctly, and to identify errors, erasures or insertions while decoding. The methods to identify these situations, and the actions to be taken, are not standardized.

3.4.8.1 Definition of bytealigned function

The function bytealigned( ) returns 1 if the current position is on a byte boundary; that is, the next bit in the bit stream is the first bit in a byte. Otherwise it returns 0.

3.4.8.2 Definition of nextbits function

The function nextbits( ) permits comparison of a bit string with the next bits to be decoded in the bit stream.

3.4.8.3 Definition of next_start_code function

The next_start_code( ) function removes any zero bit and zero byte stuffing and locates the next start code.

This function checks whether the current position is byte-aligned. If it is not, 0 stuffing bits are present. After that any number of 0 bytes may be present before the start-code. Therefore start-codes are always byte-aligned and may be preceded by any number of 0 stuffing bits.

Table 3.1 Next Start Code

Syntax	No. of bits	Mnemonic
next_start_code( ) {		
while (!bytealigned( ))		
zero_bit	1	'0'
while (nextbits( )!='0000 0000 0000 0000 0000 0001')		
zero_byte	8	'00000000'
}		

4. Background

The Advanced Television Systems Committee, chaired by James C. McKinney, was formed by the member organizations of the Joint Committee on InterSociety Coordination (JCIC) for the purpose of exploring the need for and, where appropriate, to coordinate development of the documentation of Advanced Television Systems. Documentation is understood to include voluntary technical standards, recommended practices, and engineering guidelines.

Proposed documentation may be developed by the ATSC, by member organizations of the JCIC, or by existing standards committees. The ATSC was established recognizing that the prompt, efficient and effective development of a coordinated set of national standards is essential to the future development of domestic television services.

On June 5, 1992, ATSC provided information to the Federal Communications Commission (FCC) outlining proposed industry actions to fully document the advanced television system standard. The FCC has recognized the importance of prompt disclosure of the system technical specifications to the mass production of advanced television system professional and consumer equipment in a timely fashion. The FCC has further noted its appreciation of the diligence with which the ATSC and the other groups participating in the standardization are pursuing these matters.

Supporting this activity, the ATSC Executive Committee requested that the T3/S1 Specialist Group on Macro Systems Approach meet and suggest which portions of an advanced television system broadcasting standard might require action by the FCC and which portions should be voluntary.

1) Subsequently, T3/S1 held meetings and developed recommendations in two areas:

2) Principles upon which documentation of the advanced television system should be based

A list of characteristics of an advanced television system that should be documented

The list tentatively identified the industry group(s) that would provide the documentation information and the document where the information would likely appear.

The recommendations developed by the T3/S1 Specialist Group were modified by T3 to accommodate information and knowledge about advanced television systems developed in the period since June 1992. Some of the modifications to the recommendations ensued from the formation of the Grand Alliance. The modified guidelines were approved at the March 31, 1994, meeting of the T3 Technology Group on Distribution and are described in Section 4.4.

4.1 Advisory Committee on Advanced Television Service (ACATS)
A "Petition for Notice of Inquiry" was filed with the FCC on February 21, 1987, by 58 broadcasting organizations and companies requesting that the Commission initiate a proceeding to explore the issues arising from the introduction of advanced television technologies and their possible impact on the television broadcasting service. At that time, it was generally believed that high-definition television (HDTV) could not be broadcast using 6 MHz terrestrial broadcasting channels. The broadcasting organizations were concerned that alternative media would be able to deliver HDTV to the viewing public, placing terrestrial broadcasting at a severe disadvantage.

The FCC agreed that this was a subject of utmost importance and initiated a proceeding (MM Docket No. 87-268) to consider the technical and public policy issues of advanced television systems. The Advisory Committee on

Advanced Television Service was empaneled by the Federal Communications Commission in 1987, with Richard E. Wiley as chairman, to develop information that would assist the FCC in establishing an advanced television standard for the United States. The objective given to the Advisory Committee in its Charter by the FCC was:

> "The Committee will advise the Federal Communications Commission on the facts and circumstances regarding advanced television systems for Commission consideration of technical and public policy issues. In the event that the Commission decides that adoption of some form of advanced broadcast television is in the public interest, the Committee would also recommend policies, standards, and regulations that would facilitate the orderly and timely introduction of advanced television services in the United States."

The Advisory Committee established a series of subgroups to study the various issues concerning services, technical parameters, and testing mechanisms required to establish an advanced television system standard. The Advisory Committee also established a system evaluation, test, and analysis process that began with over twenty proposed systems, reducing them to four final systems for consideration.

4.2 Digital HDTV Grand Alliance (Grand Alliance)
On May 24, 1993, the three groups that had developed the four final digital systems agreed to produce a single, best-of-the best system to propose as the standard. The three groups (AT&T and Zenith Electronics Corporation; General Instrument Corporation and the Massachusetts Institute of Technology; and Philips Consumer Electronics, Thomson Consumer Electronics, and the David Sarnoff Research Center) have been working together as the "Digital HDTV Grand Alliance." The system described in this Standard is based on the Digital HDTV Grand Alliance proposal to the Advisory Committee.

4.3 Organization for Documenting the Digital Television Standard
The ATSC Executive Committee assigned the work of documenting the advanced television system standards to T3 specialist groups, dividing the work into five areas of interest:

- Video, including input signal format and source coding
- Audio, including input signal format and source coding
- Transport, including data multiplex and channel coding
- RF/Transmission, including the modulation subsystem

- Receiver characteristics

A steering committee consisting of the chairs of the five specialist groups, the chair and vice-chairs of T3, and liaison among the ATSC, the FCC, and ACATS was established to coordinate the development of the documents. The members of the steering committee and areas of interest were as follows:

Stanley Baron	T3 chair
Jules Cohen	T3 vice-chair
Brian James	T3 vice-chair
Larry Pearlstein	T3/S6 (video systems characteristics), chair
Graham S. Stubbs	T3/S7 (audio systems characteristics), chair
Bernard J. Lechner	T3/S8 (service multiplex and transport systems characteristics), chair
Lynn D. Claudy	T3/S9 (RF/transmission systems characteristics), chair
Werner F. Wedam	T3/S10 (receiver characteristics), chair
Robert M. Rast	Grand Alliance facilitator
Robert Hopkins	ATSC
Robert M. Bromery	FCC Office of Engineering and Technology
Gordon Godfrey	FCC Mass Media Bureau
Paul E. Misener	ACATS

4.4 Principles for Documenting the Digital Television Standard

T3 adopted the following principles for documenting the advanced television system standard:

1) The Grand Alliance was recognized as the principal supplier of information for documenting the advanced television system, supported by the ATSC and others. Other organizations seen as suppliers of information were EIA, FCC, IEEE, MPEG, NCTA, and SMPTE.

2) The Grand Alliance was encouraged to begin drafting the essential elements of system details as soon as possible to avoid delays in producing the advanced television system documentation.

3) FCC requirements for the advanced television system standard were to be obtained as soon as possible.

4) Complete functional system details (permitting those skilled in the art to construct a working system) were to be made publicly available.

5) Protection of any intellectual property made public must be by patent or copyright as appropriate.

6) The advanced television system documentation shall include the necessary system information such that audio and video encoders may be manufactured to deliver the system's full demonstrated performance quality.

7) The advanced television system documentation shall point to existing standards, recommended practices, or guideline documents. These documents shall be referenced in one of two ways as deemed appropriate for the application. In the first instance, a specific revision shall be specified where review of changes to the referenced document is required before changes might be incorporated into the advanced television system document. The second instance references the document without specificity to revision and allows any changes to the referenced documents to be automatically incorporated.

8) System specifications shall explain how future, compatible improvements may be achieved.

9) As ongoing improvements take place in the advanced television system, manufacturers of encoders and decoders should coordinate their efforts to insure compatibility.

10) The advanced television system standard must support backward compatibility of future improvements with all generations of advanced television system receivers and inherently support production of low cost receivers (not withstanding that cost reduction through reduced performance quality may also be used to achieve inexpensive products).

11) The advanced television system standard should not foreclose flexibility in implementing advanced television system receivers at different price and performance levels.

12) The advanced television system standard should not foreclose flexibility in implementing program services or in data stream modification or insertion of data packets by down-stream (local) service providers.

13) The advanced television system documentation shall address interoperability with non-broadcast delivery systems including cable.

14) The advanced television system standard shall identify critical system parameters and shall provide information as to the range of acceptable values, the method of measurement, and the location in the system where measurement takes place.

5. SYSTEM OVERVIEW

The Digital Television Standard describes a system designed to transmit high quality video and audio and ancillary data over a single 6 MHz channel. The system can deliver reliably about 19 Mbps of throughput in a 6 MHz terrestrial broadcasting channel and about 38 Mbps of throughput in a 6 MHz cable television channel. This means that encoding a video source whose resolution can be as high as five times that of conventional television (NTSC) resolution requires a bit rate reduction by a factor of 50 or higher. To achieve this bit rate reduction, the system is designed to be efficient in utilizing available channel capacity by exploiting complex video and audio compression technology.

The objective is to maximize the information passed through the data channel by minimizing the amount of data required to represent the video image sequence and its associated audio. The objective is to represent the video, audio, and data sources with as few bits as possible while preserving the level of quality required for the given application.

Although the RF/transmission subsystems described in this Standard are designed specifically for terrestrial and cable applications, the objective is that the video, audio, and service multiplex/transport subsystems be useful in other applications.

5.1 System Block Diagram

A basic block diagram representation of the system is shown in Figure 5.1. This representation is based on one adopted by the International Telecommunication Union, Radiocommunication Sector (ITU-R), Task Group 11/3 (Digital Terrestrial Television Broadcasting). According to this model, the digital television system can be seen to consist of three subsystems.

- Source coding and compression
- Service multiplex and transport
- RF/transmission

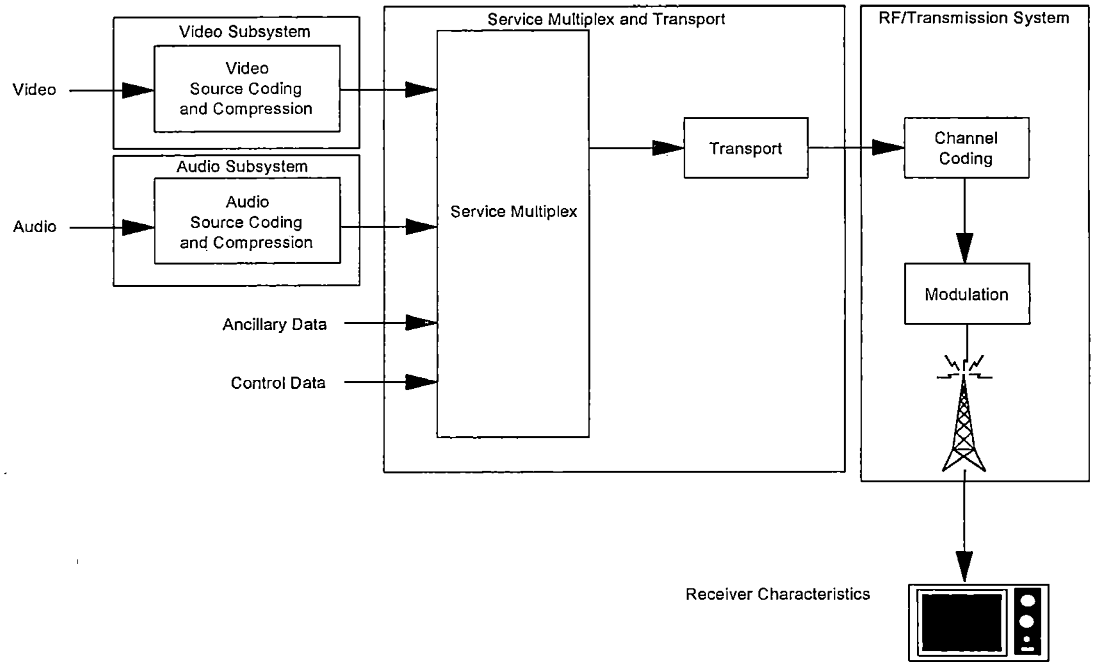

Figure 5.1 ITU-R digital terrestrial television broadcasting model.

"Source coding and compression" refers to the bit rate reduction methods, also known as data compression, appropriate for application to the video, audio, and ancillary digital data streams. The term "ancillary data" includes control data, conditional access control data, and data associated with the program audio and video services, such as closed captioning. "Ancillary data" can also refer to independent program services. The purpose of the coder is to minimize the number of bits needed to represent the audio and video information. The digital television system employs the MPEG-2 video stream syntax for the coding of video and the Digital Audio Compression (AC-3) Standard for the coding of audio.

"Service multiplex and transport" refers to the means of dividing the digital data stream into "packets" of information, the means of uniquely identifying each packet or packet type, and the appropriate methods of multiplexing video data stream packets, audio data stream packets, and ancillary data stream packets into a single data stream. In developing the transport mechanism, interoperability among digital media, such as terrestrial broadcasting, cable distribution, satellite distribution, recording media, and computer interfaces, was a prime consideration. The digital television system employs the MPEG-2 transport stream syntax for the packetization and multiplexing of video, audio, and data signals for digital broadcasting systems. The MPEG-2 transport stream syntax was developed for applications where channel bandwidth or recording media capacity is limited and the requirement for an efficient transport mechanism is paramount. It was designed also to facilitate interoperability with the ATM transport mechanism.

"RF/transmission" refers to channel coding and modulation. The channel coder takes the data bit stream and adds additional information that can be used by the receiver to reconstruct the data from the received signal which, due to transmission impairments, may not accurately represent the transmitted signal. The modulation (or physical layer) uses the digital data stream information to modulate the transmitted signal. The modulation subsystem offers two modes: a terrestrial broadcast mode (8 VSB), and a high data rate mode (16 VSB).

Figure 5.2 illustrates a high level view of encoding equipment. This view is not intended to be complete, but is used to illustrate the relationship of various clock frequencies within the encoder. There are two domains within the encoder where a set of frequencies are related, the source coding domain and the channel coding domain.

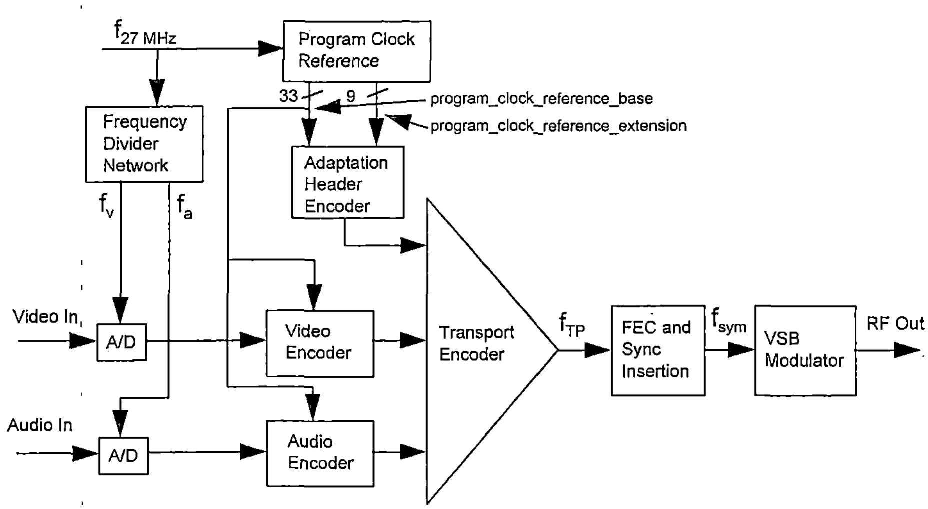

Figure 5.2 High level view of encoding equipment.

The source coding domain, represented schematically by the video, audio, and transport encoders, uses a family of frequencies which are based on a 27 MHz clock (f_{27MHz}). This clock is used to generate a 42-bit sample of the frequency which is partitioned into two parts defined by the MPEG-2 specification. These are the 33-bit program_clock_reference_base and the 9-bit program_clock_reference_extension. The former is equivalent to a sample of a 90 kHz clock which is locked in frequency to the 27 MHz clock, and is used by the audio and video source encoders when encoding the presentation time stamp (PTS) and the decode time stamp (DTS). The audio and video sampling clocks, f_a and f_v respectively, must be frequency-locked to the 27 MHz clock. This can be expressed as the requirement that there exist two pairs of integers, (n_a, m_a) and (n_v, m_v), such that:

$$f_a = \left(\frac{n_a}{m_a}\right) \times 27\ \text{MHz}$$

and

$$f_v = \left(\frac{n_v}{m_v}\right) \times 27\ \text{MHz}$$

The channel coding domain is represented by the FEC/Sync Insertion subsystem and the VSB modulator. The relevant frequencies in this domain are the VSB symbol frequency (f_{sym}) and the frequency of the transport stream (f_{TP}) which is the frequency of transmission of the encoded transport stream. These two frequencies must be locked, having the relation:

$$f_{tp} = 2 \times \left(\frac{188}{208}\right)\left(\frac{312}{313}\right) f_{sym}$$

The signals in the two domains are not required to be frequency-locked to each other, and in many implementations will operate asynchronously. In such systems, the frequency drift can necessitate the occasional insertion or deletion of a null packet from within the transport stream, thereby accommodating the frequency disparity.

The annexes that follow consider the characteristics of the subsystems necessary to accommodate the services envisioned.

NTSC STANDARDS

National Television System Committee

The name for the method used to transmit television signals in North America.

Actually, the name of the group that sets the broadcast television standards in North America. Originally formed to standardize the method for color television broadcasting. The method chosen (augmenting the existing monochrome *composite video signal*) was standardized in 1953 and is still the standard for North America and Japan.

The *frame rate* is 29.97 frames per second (0.1% slower than the original 30 frames per second, to avoid interference with the color subcarrier part of the NTSC television signal). In contrast, computer video usually runs at 30 frames per second, since it does not use NTSC.

Each frame is made up of *two fields*, with the second field writing between the lines of the first, to provide more displayed lines per frame (the *persistence* of the CRT phosphor is long enough that the first field remains displayed while the second is being written).

Each frame is made up of 481 horizontal lines (240.5 lines per field) that are visible (sometimes called "*active*") plus another 44 lines (22 per field) that arc *blanked* (the electron beam is turned off), since they occur while the scanning beam returns to the upper-left comer of the screen. This makes a total of 525 lines per frame.

Such *interlaced* scanning was necessary to fit the screen resolution desired into the video bandwidth available. Newer technologies (such as computer monitors and HDTV) usually use noninterlaced (also called *progressive*) scanning.

The term "NTSC" is also used to refer to the standard video signal that is used (for example) between *a videocassette* recorder (a standard home VCR) and television (it uses what is often called an RCA connector).

When broadcasted, an NTSC signal requires a *6-MHz bandwidth*. That is, channel 2 is 54 to 60 MHz; channel 3 is 60 MHz to 66 MHz, and so on. To reduce interference, adjacent television channels (for example, channels 3 and 4) are not assigned in the same coverage area, and the transmitting antennas of transmitters that are assigned to the same frequency must be at least 155 miles apart.

For each 6-MHz channel:

- The main (sometimes called video) carrier frequency is 1.25 MHz above the base frequency (of 54 MHz for channel 2, for example-so the video carrier is at 55.25 MHz).
- This carrier is *amplitude modulated* (AM) by the *composite video signal* (which has all of the picture and synchronization information).
- The (left + right) sound information is sent by *frequency modulating* (FM) a sound subcarrier that is 4.5 MHz above the video carrier frequency (so the sound for channel 6 is at 87.75 MHz--which explains why you can usually hear broadcast TV audio on a standard FM radio, since FM starts just above this. at 88 MHz).
- For stereo signals, an FM left-right audio signal is also sent, at a pilot frequency above the sound subcarrier.

Standard television has a 4:3 (horizontal; vertical) aspect ratio. Regular *monochrome* (black-and-white) television broadcasts began in 1936 in Britain and in 1939 in the U.S.

NTSC video can produce the changes per horizontal line listed in the following table. (These limitations are due to the modulation methods and frequencies chosen.)

Value	Changes per Line	Used for
Luminance (intensity)	267	Fine monochrome detail
Orange-blue color	96	Flesh tones and other colors
Purple-green color	35	Other colors

PAL and SECAM are similar-technology systems that are used outside of North America.

A higher-quality (than NTSC) standard is called *S- Video* and is supported by some VCRs and televisions.

See *CATV*, *Color*, *Composite Video Signal*, *HDTV*, *Interlaced*, *PAL*, *SECAM*, *VHS*, and *Video*.

Video Standards

NTSC

NTSC stands for National Television System Committee, which devised the NTSC television broadcast system in 1953. NTSC is also commonly used to refer to one type of television signal that can be recorded on various tape formats such as VHS, 3/4" U-matic and Betacam.

The NTSC standard has a fixed vertical resolution of 525 horizontal lines stacked on top of each other, with varying amounts of "lines" making up the horizontal resolution, depending on the electronics and formats involved. There are 59.94 fields displayed per second. A field is a set of even lines, or odd lines. The odd and even fields are displayed sequentially, thus interlacing the full frame. One full frame, therefore, is made of two interlaced fields, and is displayed about every 1/30 of a second.

NTSC countries are: USA, Antigua, Bahamas, Barbados, Belize, Bermuda, Bolivia, Burma, Canada, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Greenland, Guam, Guatemala, Guyana, Honduras, Jamaica, Japan, South Korea, Mexico, Netherlands Antilles, Nicaragua, Panama, Peru, Philippines, Puerto Rico, St. Vincent & the Grenadines, St. Kitts, Saipan, Samoa, Surinam, Taiwan, Tobago, Trinidad. Venezuela, Virgin Islands.

The following countries were listed as Monochrome 625/50 in one resource: Angola, Burkina Faso, Burundi, Central African Replublic, Equatorial Guinea, Ethiopia (or PAL or SECAM in other

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