Concordia University
Department of Electrical & Computer Engineering

ELEC 691X/498X – Broadcast Signal Transmission
Fall 2015

Instructor: DR. Reza Soleymani, Office: EV-5.125, Telephone: 848-2424 ext.: 4103.

Office Hours: Wednesday, Thursday, 14:00 – 15:00

Time: Tuesday, 2:45 to 5:30

Room: H 411

Lecture 1: Objective of the Course

- While you learn about techniques for compression, coding, modulation in different courses, you do not receive a comprehensive view of the broadcasting. The goal of this course is to provide a comprehensive view of a broadcasting system by integrating techniques from different areas: video and audio compression, communications, antenna, and RF.
- A more important outcome I wish to see is: Enabling students to approach a problem at the system level and to be capable of putting different pieces they have learnt in various courses together to solve a problem.

Lecture 1: Contents of the Course

- Digital Transmission Standards (ATSC, DVB-T/T2, DVB-S/S2).
- Video Compression Techniques: MPEG-2, H.264, HEVC, J2K.
- Performance measures for Digital TV: Noise, Error, Impairments.
- Packet Structure: Tables (PAT, PMT).
- Multiplexing and De-multiplexing.
- Channel Coding and Modulation for Digital Television.
- Cyclic codes
- Digital TV Transmitters: Up/converters, Power Amplifiers, Combiners, Equalizers and pre-correctors.
- Transmission Lines: Cables, Wave Guides, link budget calculation.
- Transmitting Antennas for Digital Broadcasting.
- Advanced Topics: COFDM, LDPC Codes.
- Satellite Broadcasting.
- IPTV and Multi-platform formats.

Lecture 1:
Grading Scheme

Graduate:

- Assignment: 5%
- Project: 20%
- Midterm : 25%
- Final Examination: 50%

- **Undergraduate:**
- Assignment: 10%
- Midterm : 30%
- Final Examination: 60%

Note 1: Undergraduate students may opt to follow the graduate scheme.
Note 2: Failing to write a Midterm results in losing the 30% assigned to the test.
Note 3: In order to pass the course, you should get at least 60% in the final.

Lecture 1:
Course Material

Textbook:

- Ioannis Pitas, Digital video and television – April 16, 2013

References:

- A/53: ATSC Digital Television Standard: Parts 1-6, 2007. Available at: http://atsc.org/wp-content/uploads/2015/03/a_53-Part-1-6-2007.pdf
- ETSI EN 300 744 V1.6.1 (2009-01) Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television. Available at: http://www.etsi.org/deliver/etsi_en/300700_300799/300744/01.06.01_60/en_300744v010601p.pdf
- ETSI EN 302 307 V1.2.1 (2009-08) Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting. Available at:

Lecture 1:
Course Material

References (Continued):

- http://www.etsi.org/deliver/etsi_en/302300_302399/302307/01.02.01_60/en_302307v010201p.pdf
- Interactive Services, News Gathering and other broadband satellite applications (DVB-S2). Available at: www.etsi.org/deliver/etsi_en/302300.../en_302307v010102p.pdf
- H264 (05/2003) Advanced video coding for generic audiovisual services, Telecommunication Standardization Section of ITU. Available at: https://www.itu.int/rec/T-REC-H.264
- Gerald W. Collins, Fundamentals of Digital Television Transmission, John Wiley and Sons, 2001.
- IEEE Transactions on Broadcasting: free for Concordia students at: http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=11.
- Course Notes.

Lecture 1:
About the Course Material

Concordia University
Department of Electrical & Computer Engineering

Why so many references?

- Most of the books written on the subject target practicing engineers and not the students. They cover either only a few topics or many topics with not enough depth.
- The area while mature is still evolving. So, it is good to learn to get to the source of things (Standards).

Why this text?

- It is well written and covers most of the topics in reasonable detail.
- It is very inexpensive: You may buy it online, e.g., from abebooks.com for $20 US. (around $30.00 Canadian with shipping).

Lecture 1:
What will be covered in this lecture

Department of Electrical & Computer Engineering

In addition to the **introduction** given so far, in this lecture, we will cover:

- The basic components of a broadcast system.
- Overview of Analog TV.
- Overview of Digital TV.
- Advantages of the Digital TV over Analog TV.

Lecture 1:
Components of a TV system

Concordia University
Department of Electrical & Computer Engineering

At the highest level, television system consists of two entities:

- **Service provider:** A TV station, a cable company, a satellite service provider, etc. You may include Internet based media streaming) services such as Youtube and NETFLIX.
- **A client (end user):** You and I sitting at home watching TV or some video on the Internet.

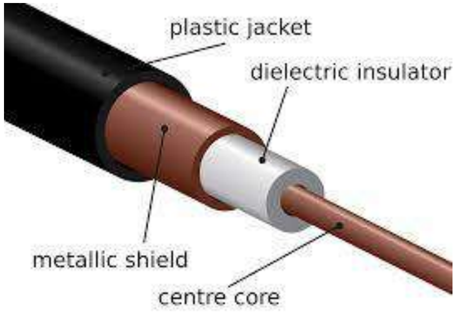
Let's start with the receiver side (end user), not because it is more important but because it is simpler.

- The first thing you need is a device to see video and listen to the sound, that is, a TV, a computer monitor a tablet, a smart phone.
- Next you need some connection to the outside world, i.e., some way to get the Video signal into your house. This can be a Yagi antenna in case of terrestrial TV, a Dish antenna in case of satellite TV, a coaxial cable in case of Cable TV, some sort of Internet connection in case of IPTV.

Lecture 1:
Components of a TV system

Yagi Antenna

A satellite TV dish



Coaxial Cable

Lecture 1:
Components of a TV system

- An antenna, a cable or a wire bring Radio Frequency (RF) signal to your house and your TV or monitor only understand levels specifying the colour and luminance of the image pixels. Hence, you need something to transform the RF content of the cable, wire or antenna to video (and audio) signal. First you need to waveform from RF to IF (Intermediate Frequency) easy for your electronic components to handle. This is called a **down converter** (D/C). For example, a satellite TV signal working at Ku-band has a center frequency in the 12 GHz*. Range. A down converter can bring it to the IF range of 0.95 to 2.15 GHz. You need then to amplify this before putting it again into a cable. This is done using an LNA (Low Noise Amplifier). In the case of satellite TV, the down converter and LNA are integrated into a device called Low Noise Block (LNB).

* GHz stands for a billion Hz.

Lecture 1:
Components of a TV system

Department of Electrical & Computer Engineering

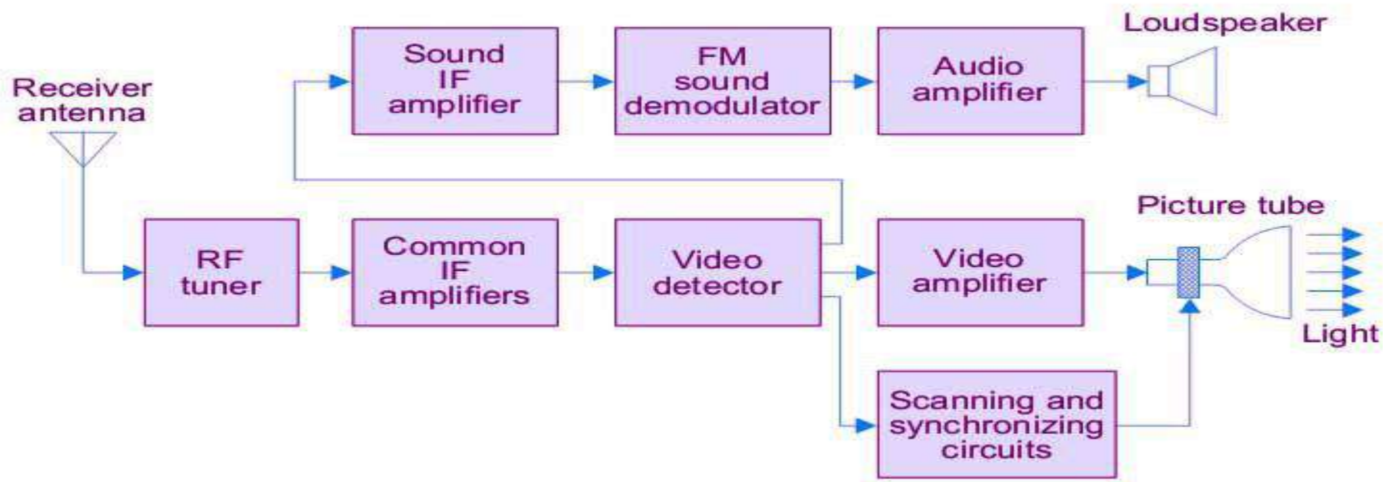
An LNB

LNB installed on a dish

Lecture 1:
Components of a TV system

Université Concordia University
Department of Electrical & Computer Engineering

- Finally, you need a **set top box** to demodulate the waveform and separate video and audio signals and give the video to the screen and the audio to the speakers. We start with an old black and white analog receiver. Later, we talk mostly about digital receivers.



Simplified block diagram of a black and white TV receiver.

Lecture 1: Components of a TV system

Department of Electrical & Computer Engineering

- In the case of digital set top boxes, we have all the components you learn in ELEC6831: Digital Transmission I. These include:
  - Analog to Digital Converter,
  - Matched filter,
  - Decoder (if applicable),
  - Demodulator.
- New TV sets have the receiver for terrestrial TV, so you do not need an external set top box. Some models of TV (so called, Smart TV) also have Ethernet input as well as WiFi.
- For satellite TV still you need a set top box. However, it is due to economic (small market size) of satellite TV rather than technical reasons.
- For cable TV you need set top box (DVR)mainly for recoding and auxiliary functions such as forward/backward, picture in picture, etc. Otherwise given the volume, the receiver can be economically integrated in the TV

Université Concordia University
Department of Electrical & Computer Engineering

Components of the transmitting side:

We started by discussing the equipment at the receiver (viewer) side not because it is more important, but because it is simpler and we deal with more familiar devices: things that we deal with in our daily lives such as a TV, and antenna, cable or telephone wire, DVR, etc. Now, we use our knowledge of what we use at home to list the entities (hardware and software) that a service provider such as television station, a cable company or a satellite TV company needs to have in order to be able to send the signal to our homes.

Most of you have some communications background. In particular, many of you have taken digital communications course or possibly are taking it concurrently with this course. So, you are familiar with the fact that any device you have at the transmitter side has a counterpart at the receiver side, i.e., an entity that undoes what the transmitter side entity has done. For example, you have a **modulator** at the transmitting station and need a **demodulator** at the receiver side to translate back the modulated information to the its original form, maybe with some error. Similarly, an **encoder** at the transmitter requires a **decoder** at the receiver.

Lecture 1: Components of a TV system

The terms like MODEM (modulator plus demodulator) or CODEC (a coder and a decoder) have been tossed to emphasize this fact. It is important to note that, in a communication system we have **modem** or **codec** because the communications process in bi-directional (or in technical terms, full-duplex), i.e., each node is both transmitter and the receiver. However, a TV system is almost always one way, i.e., there is no signal going from our TV to the TV station or cable company. There might be a minor level of interactivity in new systems, but they are usually at much lower data rate and are for request and signalling. So, the good news is that most of the things you have learnt in your digital communications course can help you in grasping the subjects discussed in this course. On the other hand if you have not taken any communications course, what you learn in this course will prepare you for such course.

Now, let’s see what we need to have in order to broadcast a TV program. In order not to be very abstract, let’s focus on regular (terrestrial) TV station.

The first thing a TV station needs is a way to generate the content (of course some of the content such as movies are generated by third party). In order to create content, a TV station needs rooms furnished according to their functionality.

Lecture 1: Video Signal

Department of Electrical & Computer Engineering

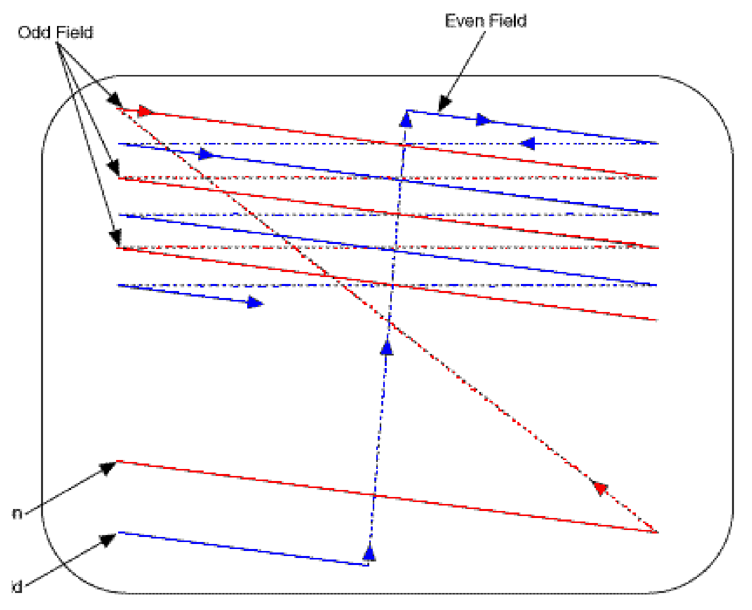
For example, a News room for broadcasting news another for interviews. Each of these will be called a **studio.** In addition to the furniture, a studio needs lighting, cameras, mixers, etc. In this course, we will not be concerned with the studio and studio equipment. Our job starts at the output of the studio, that is, with a cable providing us with video and accompanying audio and possibly data signals. The most important part of the signal coming out of the studio, and the one taking most our transmission bandwidth is **video** signal. Let's digress from the station equipment and see what the video signal is.

A **video** signal is a sequence of still pictures. In order for us to feel the movement there should be a certain number of still pictures per unit of time. Human visual system can process 10 to 12 images per second. So in order to perceive any motion at all, we need the number of still images (called **frames**) to exceed ten. Of course such low numbers does not result in natural looking video. The number of frames per second (frame rate) for the movies was established as 24 frames per second. For the TV the frame rates are 30 in North America and Japan, and 25 in most other places.

Lecture 1: Video Signal

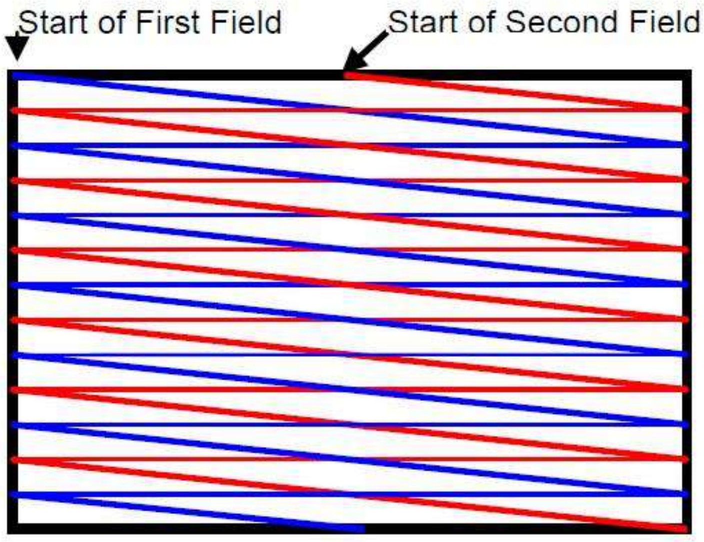
Department of Electrical & Computer Engineering

Although rates such as these (25 or 30) give the feeling of motion to the viewer, and are good for projecting movies on the TV, due to low refresh rate of the screen (CRT in particular), they cause an effect called flickering. Flickering is a result of drop in the screen brightness for sufficiently long periods of time so that it is perceivable by the human eye. To avoid flickering a technique called interlacing is used. In an interlaced system, each frame is divided into two fields. These are called odd and even fields.



Lecture 1: Video Signal

The original full frame scanning is called progressive. A scanning scheme with 30 frames per second and 30 refreshes is denoted as 30p while, a 30 frame per second scheme where each frame is divided into two field is denoted as 60i. The interlacing results in removing the flickers without increasing the b



These days the TV industry is moving towards 60p and even 120p and frame rates up to 350p are being considered by researchers BBC.

Lecture 1: Video Signal

The lines seen in the above figures are a trace of the intensity of light coming out of the camera. Let's first consider a black and white TV. If the video signal were kept constant, i.e., a voltage in the dynamic range of the CRT input, then we would see a shade of gray caused by lines of the same color. However, if the signal changed in proportion to the brightness (luminosity) of the object in front of the camera.

The number of lines per frame, which is twice the number of lines per field in an interlaced video signal, is a measure of the resolution.

Lecture 1: Video Signal

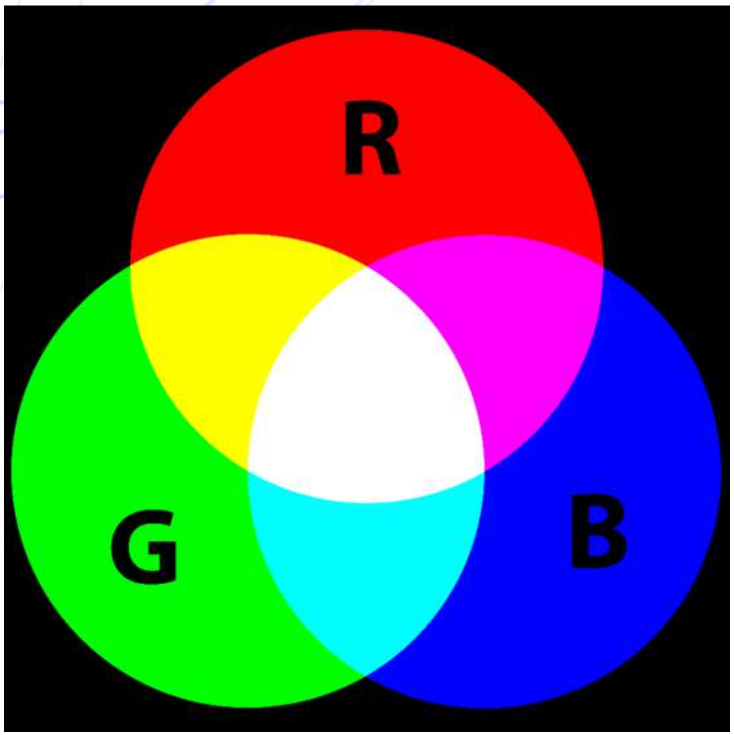
The number of lines per frame for analog TV were 525 in North America (NTSC standard) and 625 in the European standards (PAL and SECAM).

In addition to luminosity, a video signal contains audio and signaling information. The latter refers to control information specifying the beginning of a field and end of a trace.

Now let's move to **colour TV** (We are still talking about analog TV). In addition to luminosity, we need the video signal to convey the colour. From high school physics you know that all colours can be generated by proper mix of three distinct colours. In TV and computer industry, the three basic colours used are Red (R), Green (G) and Blue (B) thus the notation RGB. The RGB (**component**) interface has five cables: 3 four colours Red, Green and Blue and 2 for audio (stereo). The picture in next page shows and RGB to HDMI converter.

Lecture 1: Video Signal: Component

Department of Electrical & Computer Engineering



UNIVERSITÉ Concordia UNIVERSITY
Department of Electrical & Computer Engineering

Lecture 1:
Video Signal: Composite

While it is not a big deal running five wires between two devices close to one another such as a camera and a monitor, recorder or encoder (except for some inconvenience), it is not a good idea to have five separate lines when it comes to transmission. It is best if we could combine all these five signals into one and convey it with one cable to the RF section for modulation and transmission. This was the reason for introducing **composite** video.

Before talking about composite video, let's mention that, we do not need necessarily to send the three colours Red, Green and Blue. Any linear combination of these three colours can be transmitted and the receiver can recover the three colours. It is just solving a system of three linear equations with three unknowns. The tree signals sent are $k_r R + K_g G + K_b B$ $C_b = Y - B$ and $C_r = Y - R$. The signal Y is the luminosity (called luma) and makes the colour TV backward compatible with black and white TV.

Lecture 1:
Video Signal: Composite

Department of Electrical & Computer Engineering

C_b and C_r convey the colour information thus called chroma. The above scheme denoted by YC_bC_r was suggested by CCITT* predecessor to ITU-T** and ITU-R***). The TV standards in North America and Europe used YIQ (NTSC in North America and Japan) and YUV (PAL and SECAM in Europe and most other parts of the world). In order to recover R, G and B from YCbCr one has to know k_r, k_g and k_b. There are several values used based on the standard as well as the application. The one suggested by ITU-R called BT.601 is $Y = k_rR + (1 - k_r - k_b)G + k_bB$, $C_b = \frac{1}{2}.\frac{B-Y}{1-k_b}$ and $C_r = \frac{1}{2}.\frac{R-Y}{1-k_r}$ with $k_b = 0.114$ and $k_r = 0.299$.

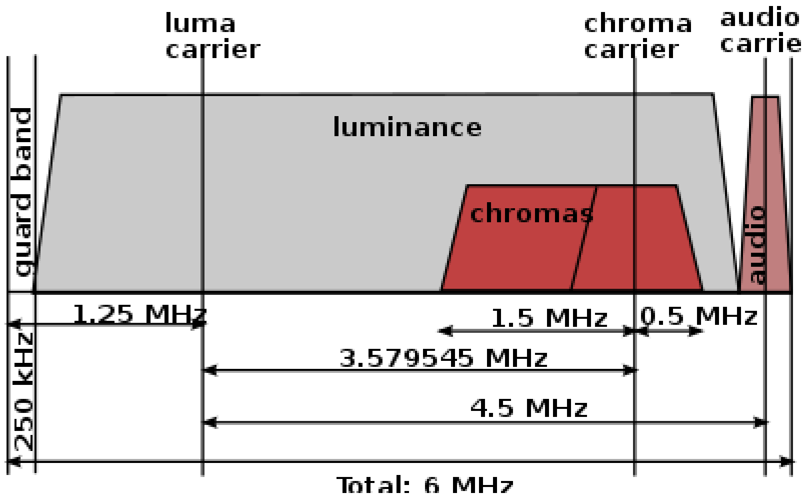
The three video signals generated according to the above scheme are frequency multiplexed forming a single signal called the **composite** signal.

- * Comité Consultatif International Téléphonique et Télégraphique.
- ** International Telecommunications Union – Telecommunications Sector.
- *** International Telecommunications Union – Radiocommunications Sector.

Lecture 1:
Video Signal: Composite

Université Concordia University
Department of Electrical & Computer Engineering

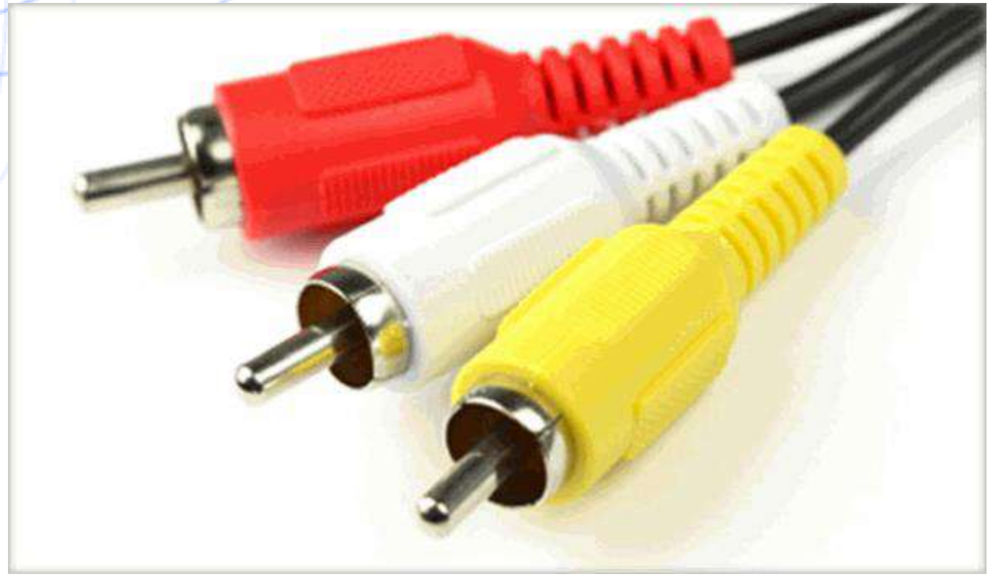
Figure below shows the composite signals in NTSC (National Television System Committee).



A composite interface has all the video on one RCA cable (the yellow one) and two cables for Left and Right Audio see next slide).

Lecture 1: Video Signal: Composite

Université Concordia University
Department of Electrical & Computer Engineering



Lecture 1:
Video Signal: S-Video

Concordia University
Department of Electrical & Computer Engineering

A compromise between component video and composite video is **Separate Video** named **S-Video**, **Super-Video** or **Y/C**.

In S-video, carries video using two synchronized signal and ground pairs, termed Y and C.

Y is the luma signal, which carries the luminance - or black-and-white - of the picture, including synchronization pulses.

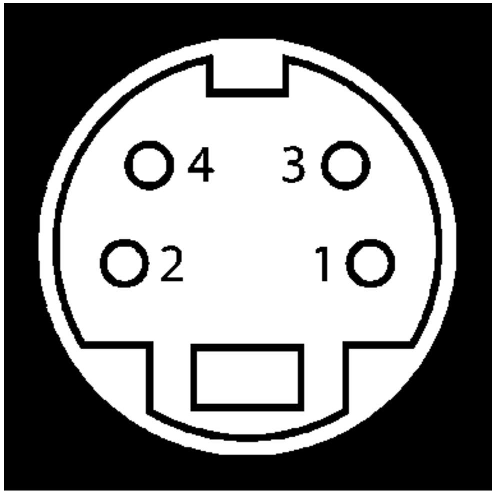
C is the chroma signal, which carries the chrominance of the picture.

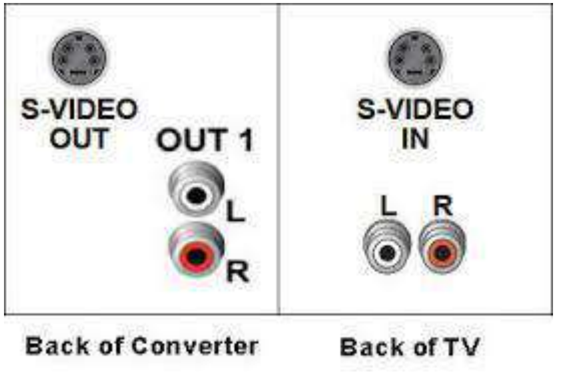
Pin 1: GND Y

Pin 2: GND C

Pin 3: Y

Pin 4: C





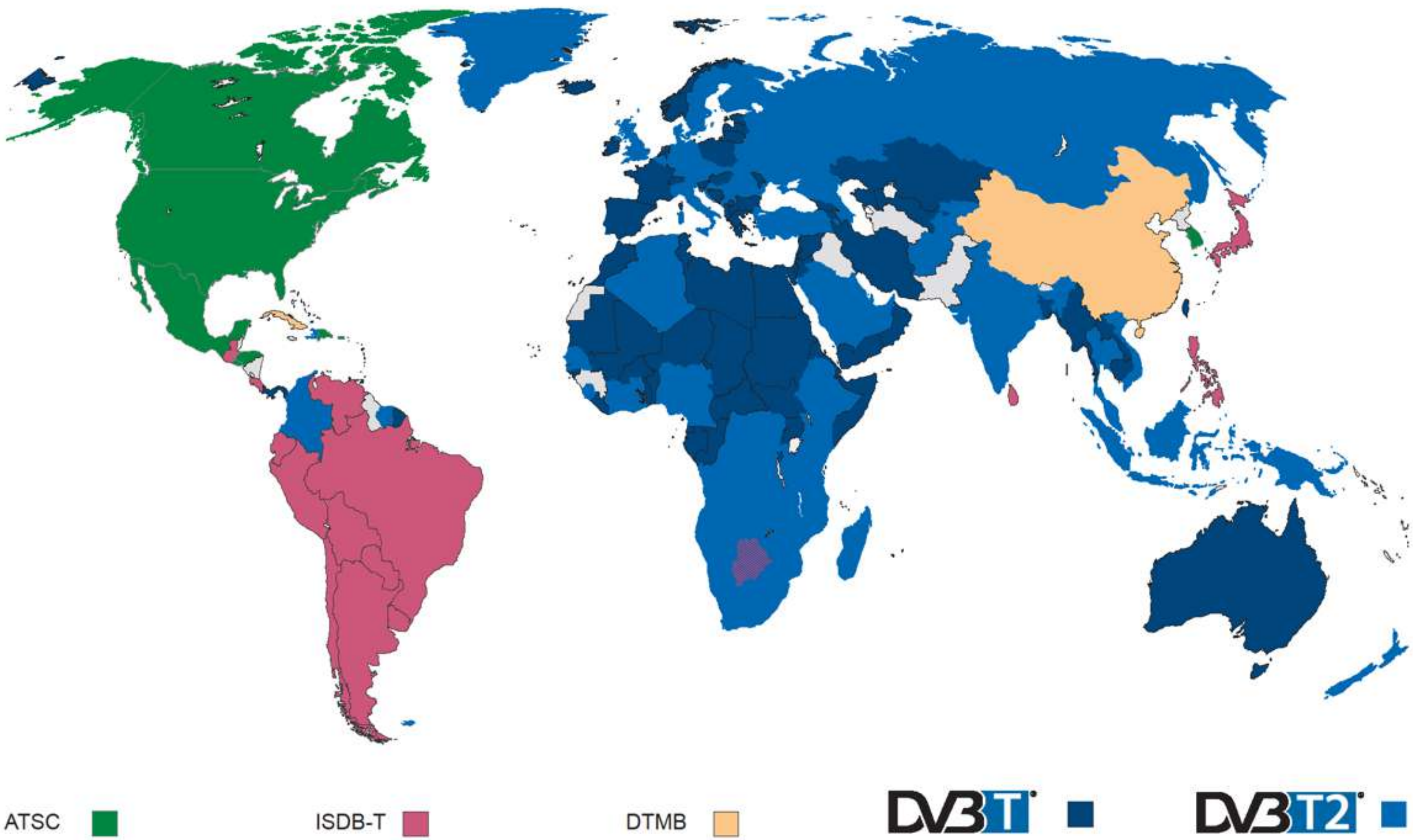
Lecture 1: Digital Television standards

There are mainly four Digital TV (DTV)standards:

- DVB: Digital Video Broadcasting.
- ATSC: Advanced Television Systems Committee.
- DTMB: Digital Terrestrial Multimedia Broadcast used in People's Republic of China, Hong Kong, and Macau.
- ISDV: Integrated Services Digital Broadcasting used in Japan and most of South America.

Lecture 1
Coverage of different standards

Université Concordia University
Department of Electrical & Computer Engineering



Digital Terrestrial Television Systems. Blue indicates countries that have adopted or deployed DVB-T and DVB-T2. August 2015

Lecture 1:
Digital Television: DVB

Université Concordia University
Department of Electrical & Computer Engineering

- DVB is a suite of internationally accepted standards developed under DVB project which is an industry alliance with over 200 members formed in 1993 (www.dvb.org). The first versions of DVB were released in 1997 and was published by a Joint Technical Committee (JTC) of the European Telecommunications Standards Institute (ETSI), European Committee for Electrotechnical Standardization (CENELEC) and European Broadcasting Union (EBU).
- DVB has standards for different media such as:
  - DVB-T/T2 for terrestrial.
  - DVB-S/S2/S2X for satellite.
  - DVB-C/C2 for cable.
  - DVB-H for Handheld devices (mobile).
  - DVB-IPTV for streaming content over IP.

Lecture 1
DVB-X2 Parameters

UNIVERSITÉ Concordia UNIVERSITY
Department of Electrical & Computer Engineering

	DVB-S2	DVB-T2	DVB-C2
Input Interface	Multiple Transport Stream and Generic Stream Encapsulation (GSE)	Multiple Transport Stream and Generic Stream Encapsulation (GSE)	Multiple Transport Stream and Generic Stream Encapsulation (GSE)
Modes	Variable Coding & Modulation and Adaptive Coding & Modulation	Variable Coding & Modulation[4]	Variable Coding & Modulation and Adaptive Coding & Modulation
FEC	LDPC + BCH 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10	LDPC + BCH 1/2, 3/5, 2/3, 3/4, 4/5, 5/6	LDPC + BCH 1/2, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10
Carrier Modulation	Single Carrier PSK with Multiple Streams	OFDM	absolute OFDM
Modulation Schemes	QPSK, 8-PSK, 16-APSK, 32-APSK	QPSK, 16-QAM, 64-QAM, 256-QAM	16- to 4096-QAM
Guard Interval	Not Applicable	1/4, 19/256, 1/8, 19/128, 1/16, 1/32, 1/128	1/64 or 1/128
Fourier transform size	Not Applicable	1k, 2k, 4k, 8k, 16k, 32k DFT	4k Inverse FFT
Interleaving	Bit-Interleaving	Bit- Time- and Frequency-Interleaving	Bit- Time- and Frequency-Interleaving
Pilots	Pilot symbols	Scattered and Continual Pilots	Scattered and Continual Pilots

Lecture 1: Digital Television: ATSC

ATSC standard has been developed by the **Advanced Television Systems Committee, Inc.**, which is an international, non-profit organization developing voluntary standards for digital television.

ATSC was formed in 1982 by the member organizations of the Joint Committee on InterSociety Coordination (JCIC): the Electronic Industries Association (EIA), the Institute of Electrical and Electronic Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Telecommunications Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE). ATSC members represent the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

ATSC standard is used in Canada, Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, and South Korea.

Lecture 1: Digital Television: ATSC

ATSC standard has been developed by the **Advanced Television Systems Committee, Inc.**, which is an international, non-profit organization developing voluntary standards for digital television.

ATSC was formed in 1982 by the member organizations of the Joint Committee on InterSociety Coordination (JCIC): the Electronic Industries Association (EIA), the Institute of Electrical and Electronic Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Telecommunications Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE). ATSC members represent the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

ATSC standard is used in Canada, Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, and South Korea.

Lecture 1:
Advantages of Digital TV over Analog TV

- Digital information is made up of symbols, e.g., bits taking a finite number of distinct hence easily identifiable values. This reduces the effect of noise.
- Having video in digital format allows us to use the digital electronics and digital signal processing techniques to modify the video information like any other computer data. For example, we can perform:
  - Data compression,
  - Error Control Coding,
  - Using new digital modulation techniques,
  - Translation between formats,
  - Changing the rate of transmission according to user's demand,
  - Performing advanced video editing such as collage, zooming, special effects,
  - Easy storage of information as well as easy retrieval, content search, etc.

Lecture 1:
Advantages of Digital TV over Analog TV

Department of Electrical & Computer Engineering

- Digital TV allows non-linear TV, i.e., stopping the program, forward, backward, schedule recording, etc. The viewers do not have to lose content because they cannot sit in front of the TV all the time.
- Digital TV moves the video from a stream based system into a file based system. The file can be retrieved, parts of it extracted or some other video be added to it. It is also possible to add metadata allow the viewers to effortlessly discover the content they want to watch across multiple platforms.
- Being able to change between formats and adding metadata, DTV brings forward TV Everywhere (TVE) allowing the people watch programs of their choice on TV, over the PC, Tablet, smartphone, even in metro stations.