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ACS Presentation

Digital Television for Australia

Presentation by: Neil Pickford

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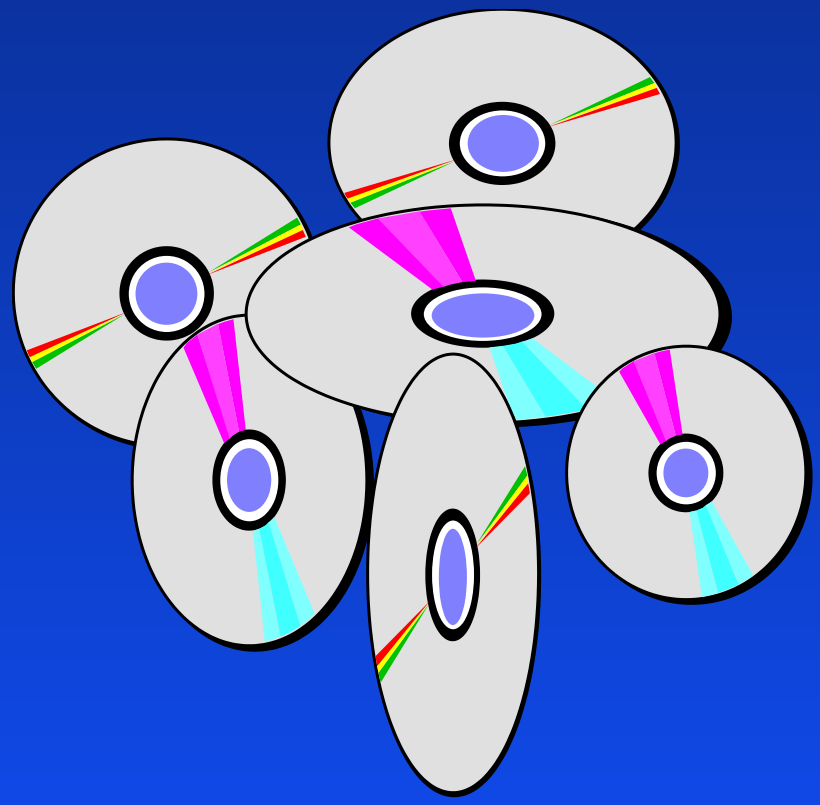
Digital Media

- First media systems were analog
- Most media are converting to digital
  - Computer storage
  - Music (LP-CD)
  - Telecommunications
  - Multimedia
  - Radio (DAB)
  - Television



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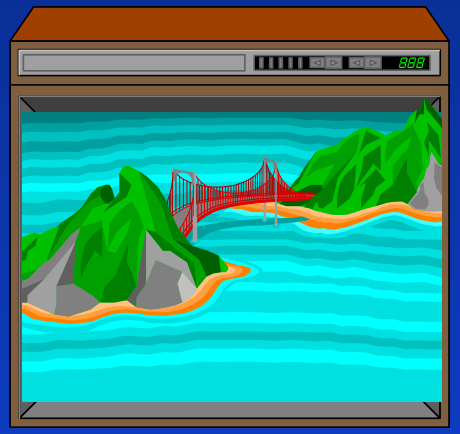
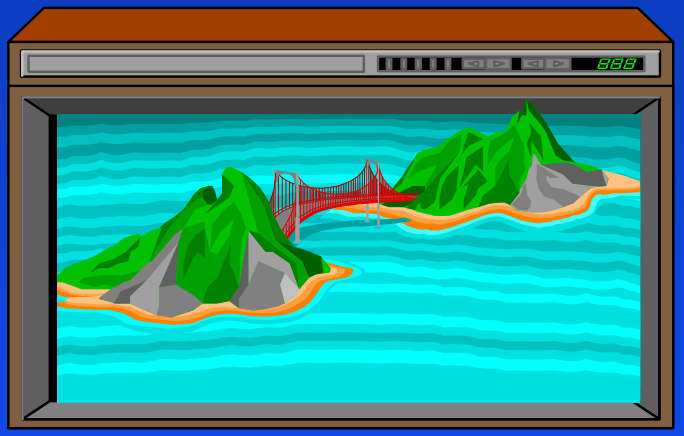
Digital Television

Why digital?

- Noise free pictures
- Higher resolution images
  Widescreen / HDTV
- No ghosting
- Multi-channel sound
- Other services.





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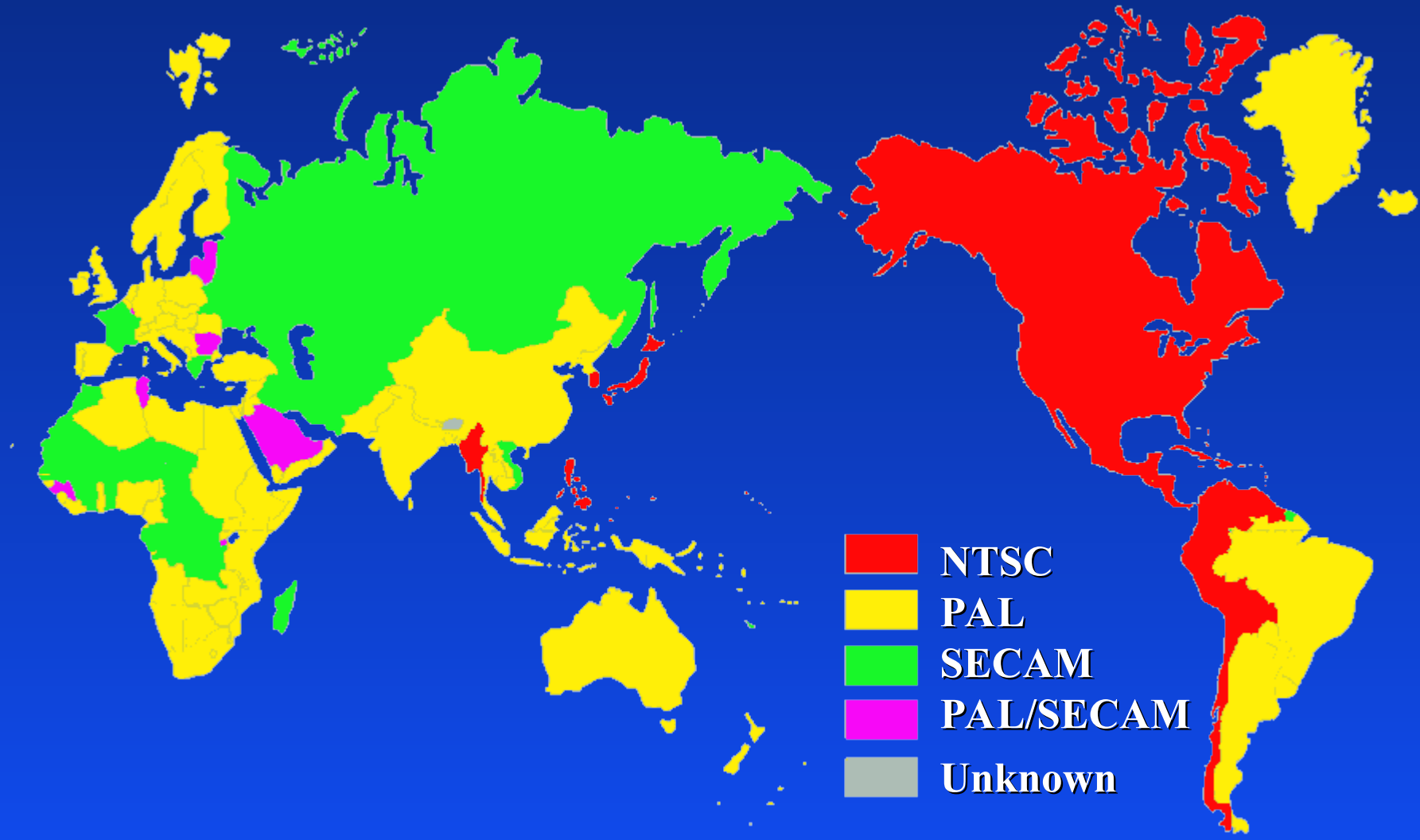
Broad Objectives of DTB

- Overcome limitations of the existing analog television system
- Improved picture
  - High quality (no interference)
  - Resolution (HDTV)
  - Format (16:9)
- Enhanced Audio services
- Data capacity available for other value added services

World TV Standards



Australia is PAL

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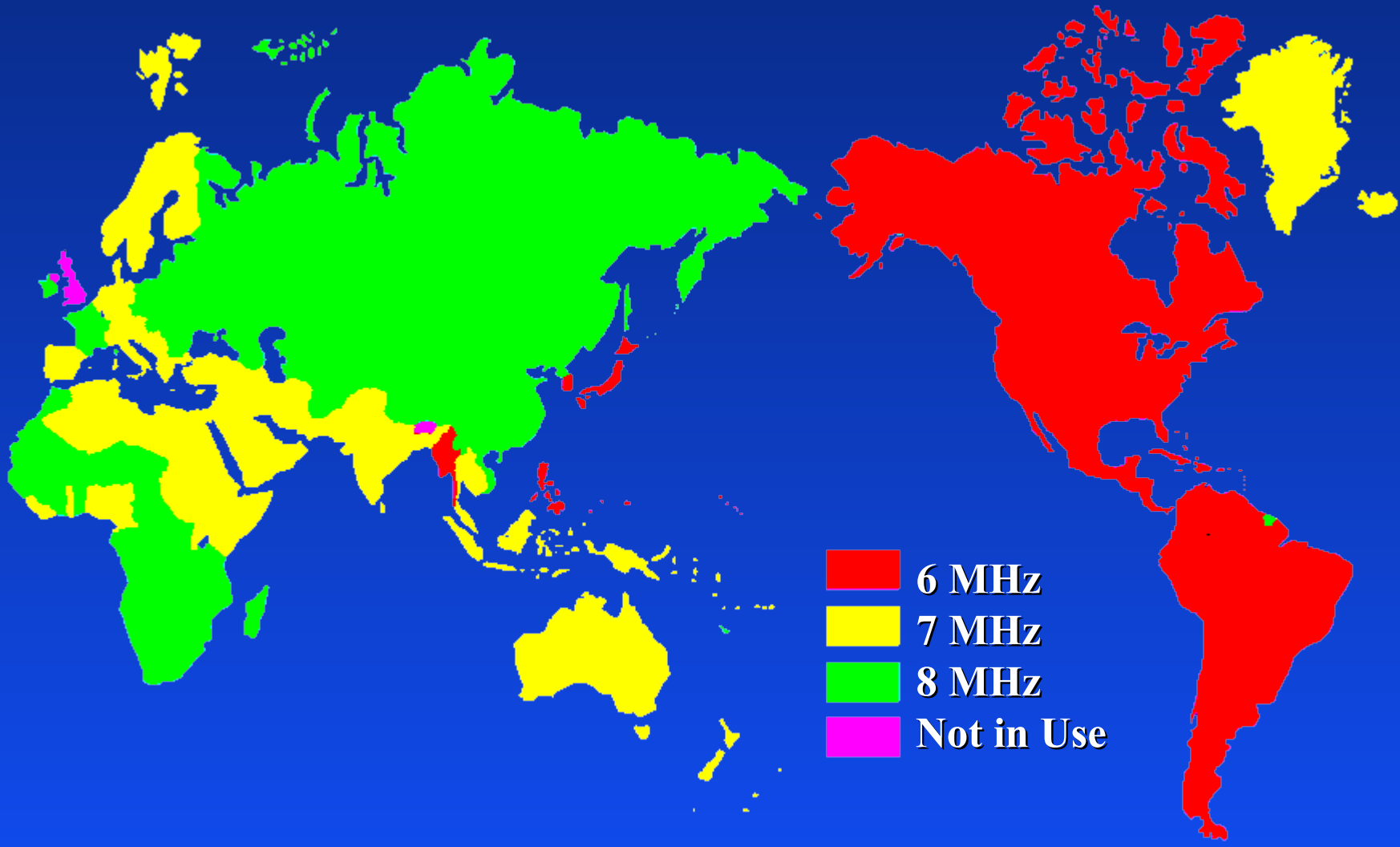
Transmission Bandwidth - VHF



Australia is 7 MHz

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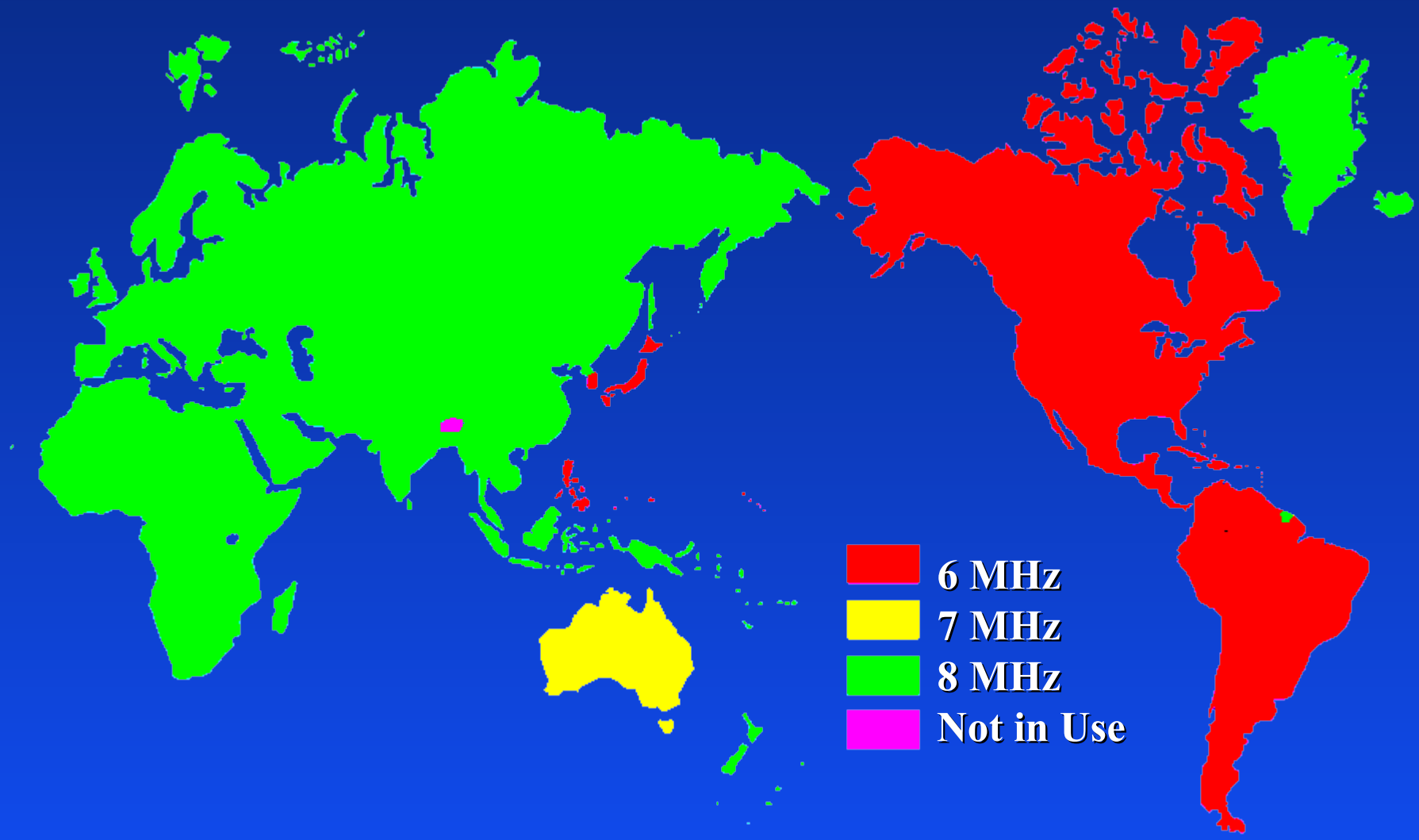
Transmission Bandwidth - UHF



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The Australian Broadcasting Environment

- The unique broadcasting environment of Australia has had a major influence on the way we have looked at digital television.

Australia's Involvement in DTV

- Testing MPEG 1 & 2 SW profiles in early 90s
- ITU-R study groups 10 & 11
- Initiated formation of ITU-R task group 11/3
- TG 11/3 fostered convergence of systems
  - Source coding the same
  - Modulation different
- 1993 ABA inquiry into planning & system implications of DTTB
- 1997 recommended HDTV

HDTV - Why Do We Want It?

- HDTV has been coming for a long time & Australia has been following it for a long time
- Australia believes HDTV will be the FUTURE television viewing format.
- Any system we implement NOW must cater for HDTV in the FUTURE
- If HDTV is not designed in at the outset then you will be constrained by the lowest common denominator in the TV market.

MP@ML

MP@HL

All decoders sold in Australia will be MP@HL capable allowing all viewers access to HD resolution when it becomes available

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FACTS - Specialists Group

- Federation of Australian commercial television stations (FACTS) have formed the advanced television specialists group
  - Investigate all aspects of future television technology
  - Digital TV - transmission & distribution
  - HDTV technology
  - Digital encoding, interchange & distribution for current SDTV

The Benefits of Digital TV

The user will see the following benefits.

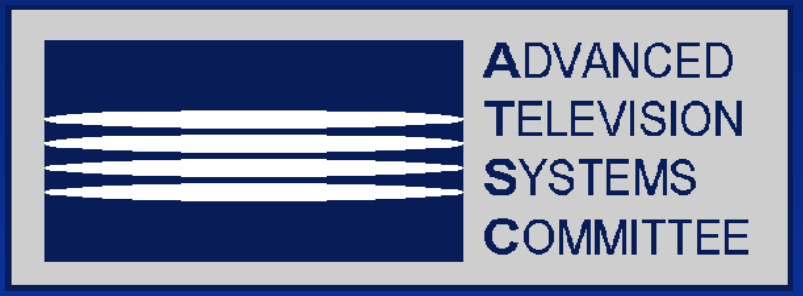
1. More predictable/reliable reception
2. A change in aspect ratio of pictures 4:3 ⇒ 16:9
3. Higher resolution pictures –
   high definition for those with HD displays
4. Multichannel digital surround sound technology.
5. More capacity for additional services

DTTB Transmission Systems

- 3 systems are being developed at present.
  - USA ATSC 8-VSB HDTV
  - Europe DVB-T COFDM SDTV
  - Japan ISDB Band Segmented OFDM

Only European and American systems are sufficiently developed to allow implementation by 2001

8-VSB - USA



- Developed by the advance television systems committee - ATSC
- Developed for use in a 6 MHz channel
  - A 7 MHz variant is possible.
- Uses a single carrier with pilot tone
- 8 level amplitude modulation system
- Payload data rate of 19.3 Mb/s
- Relies on adaptive equalisation
- Existing AM technology highly developed

COFDM - Europe

- Developed by the digital video broadcasting project group - DVB
- Uses similar technology to DRB
- Uses 1705 or 6817 carriers
- Variable carrier modulation types are defined allowing data rates of 5-27 Mb/s in 7 MHz
- Developed for 8 MHz channels
  - A 7 MHz variant has been produced and tested
- Can use single frequency networks - SFNs
- New technology with scope for continued improvement & development

ISDB - Japan

- Japanese are developing integrated services digital broadcasting (ISDB)
- System integrates all forms of broadcasting services into one common data channel which can be passed by satellite, cable or terrestrial delivery systems
- Video services
  - Sound services
  - Bulk data services
  - Interactive data services

ISDB - Concept

- Proposed to use band segmented transmission - orthogonal frequency division multiplex (BST-OFDM)

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The Testing

- Communications laboratory function is to advise the Australian government on new communications technology
- 1990 - L-band Eureka 147 DAB experiments including coverage, gap fillers & SFNs
- 1994 - CCI & ACI testing of PAL receivers using noise to simulate digital transmissions.
- 1996 HD-divine COFDM modem
  - BER & interference testing

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1996 DVB-T Demonstration

- NDS built a VHF 7 MHz receiver in 4 weeks
- Complete 2K DVB-T transmission system loaned to FACTS
- November 1996 - DVB-T demonstrated at ITU-R TG 11/3 final meeting in Sydney
- Minister switched on first Australian SDTV 16:9 digital program at FACTS dinner
- Transmission system remained in Australia for further testing.

Laboratory Testing of DVB-T

- Testing commenced March 1997
- Automated test system used to minimise error

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Laboratory Testing of DVB-T

- Digital failure primarily determined by bit error rate measurement
- Analog system interference assessed by subjective evaluation using Limit of Perceptibility (LOP) and Subjective Comparison Method (SCM) techniques.
- Tests designed to evaluate Australian conditions

ATSC Testing

- During DVB-T tests efforts were made to obtain & evaluate the ATSC system
- ATSC system was made available over 4 week period in July 1997
- The same measurements preformed on DVB-T were repeated for ATSC.
- Australian operational conditions were used throughout treating the 6 MHz ATSC system the same as a 7 MHz system.

Main Results - Lab Tests

- C/N ATSC 4 dB better than DVB-T.
  This Advantage offset by Poor Noise Figure
- DVB-T is better than ATSC for Multipath
- ATSC is better than DVB-T for Impulse Noise
- ATSC cannot handle Flutter or Doppler Echoes
- ATSC is very sensitive to Transmission system impairments and IF translation
- DVB-T is better at handling Co-channel PAL
- DVB-T is better rejecting on channel interference (CW)

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Field Testing - Van

- A field test vehicle was built in a small van.

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Field Testing

- Field tests were conducted in Sydney over a 1 month period on VHF channel 8.

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Field Testing

- Over 115 sites were measured
- Power level for the field test was 14 dB below adjacent analog television channels 7 & 9
- Analog and digital television performance for both systems were evaluated at each site.

The Tests - Some World Firsts

- First independent direct comparative tests between the two digital modulation systems
- First extensive tests of both systems in a 7 MHz PAL-B channel environment
- First tests of VHF adjacent channel operation
- First test of ATSC in a PAL environment
- First test of DVB-T in the VHF band

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HDTV - Demonstrations

- In October and November 1997 the ATSC and DVB-T system proponents both demonstrated their systems by transmitting HDTV programs to audiences in Sydney.
- These demonstrations showed that both systems were HDTV capable.

Test Reports

- Lab and field data was compiled and factually presented in detailed reports.
- Aim to present data in an unbiased way without drawing conclusions based on single parameters
- Summary reports for both the laboratory and field trials were also produced, concentrating on the interesting data.
- These reports provided a solid technical basis to assess the two DTTB modulation systems.

The Selection Committee

- A selection committee was formed from FACTS ATV specialists group Representing:
  - National broadcasters (ABC and SBS)
  - The commercial networks (7,9 & 10)
  - The regional commercial broadcasters
  - The Department of Communications and the Arts
  - The Australian Broadcasting Authority

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Selection Panel - Responsibility

- Analysing the comparative tests and other available factual information
- Establishing the relevance of the performance differences to Australian broadcasting
- Recommending the system to be used

Selection Result - June 1998

- The selection committee unanimously selected the 7 MHz DVB-T modulation system for use in Australia

- The criteria that were set aside would, however, not have changed the selection decision

More Selections

- Sub-committees formed to investigate:
  - Service information data standard
  - Multichannel audio system
  - HDTV video production format
- July 1998 3 further recommendations
  - SI data standard be based on DVB-SI
  - AC3 multichannel audio is the preferred audio encoding format
  - 1920/1080/50 Hz interlaced 1125 lines is the preferred video production format

Enabling Technologies

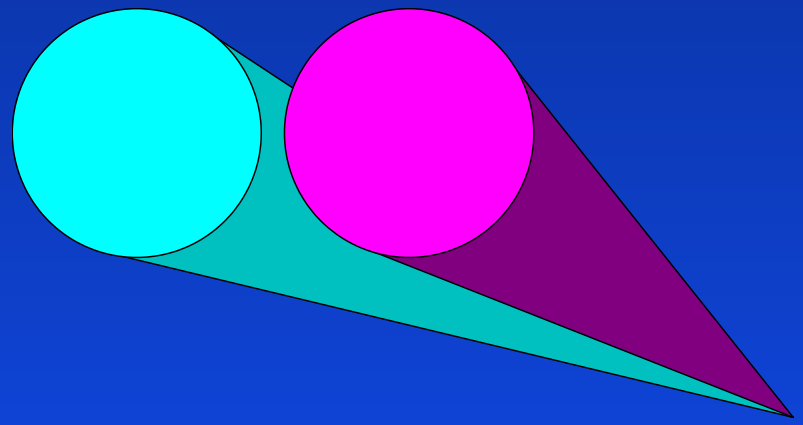
- Transmission technology (modulation)
- Source digitisation (Rec 601 digital studio)
- Compression technology (MPEG, AC-3)
- Data multiplexing (MPEG)
- Display technology (large wide screens)
- Production

Transmission Technology

- The transmission system is used to transport the information to the consumer.
- The system protects the information being carried from the transmission environment
- Current Australian analog television uses the PAL-B AM modulation system

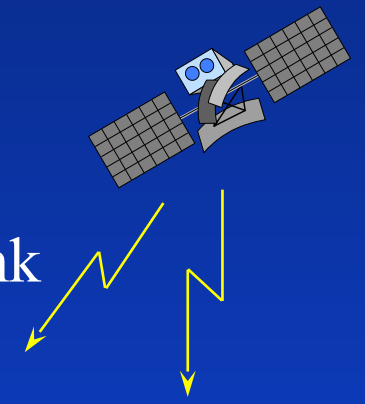
Digital TV Transmission Technology

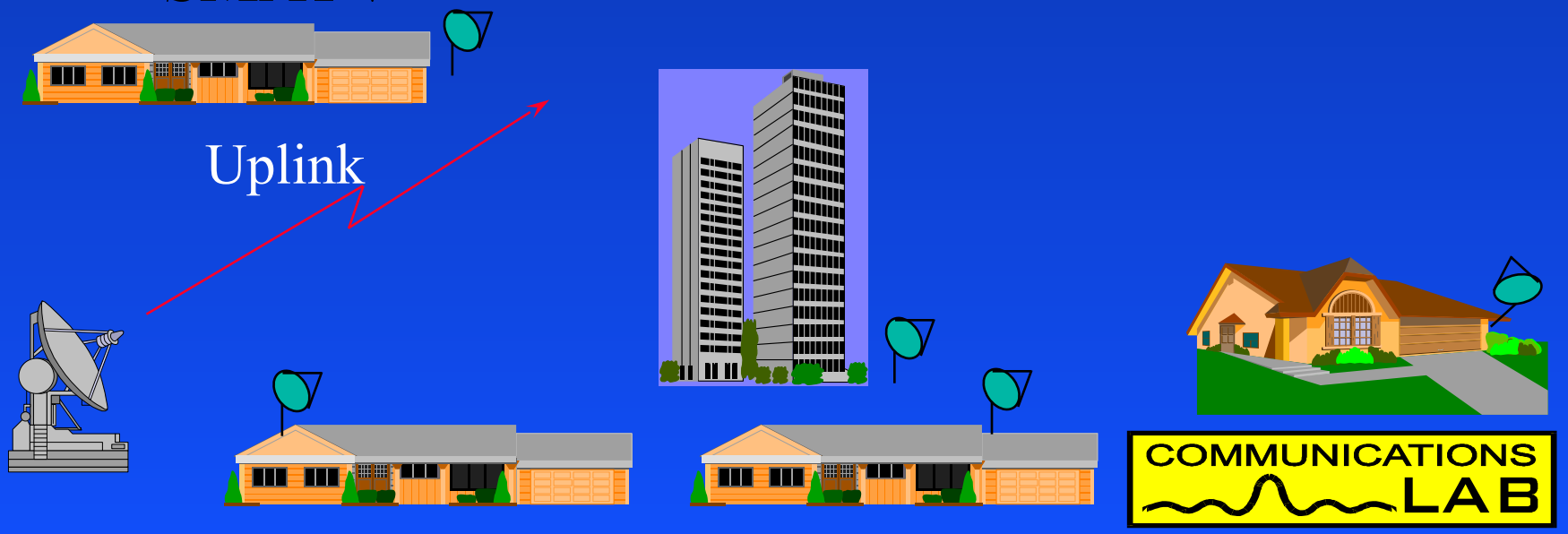
- The transmission system is a "data pipe"
- Transports data rates of around 20 Mb/s
- Transports data in individual containers called packets



Digital Television - Types

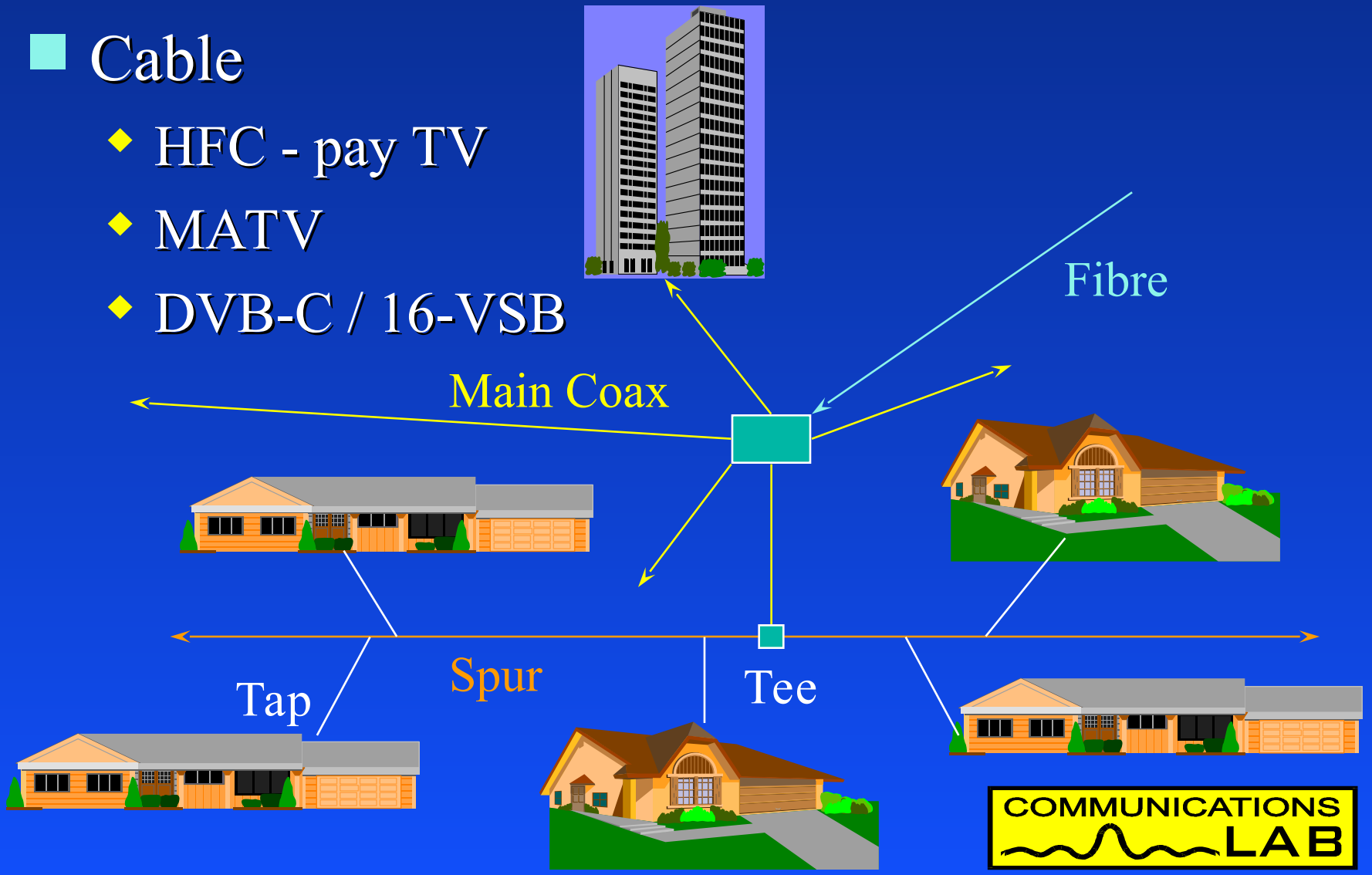
- Satellite (DBS)
  - DVB-S
  - Program interchange
  - Direct view / pay TV
  - SMATV





Digital Television - Types

- Cable
  - HFC - pay TV
  - MATV
  - DVB-C / 16-VSB



Digital Television - Types

- Terrestrial (DTTB)
  - DVB-T / 8-VSB
  - Free to air TV (broadcasting)
  - Narrowcasting/value added services
  - Untethered - portable reception

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Digital Terrestrial Television Broadcasting - DTTB

- Regional free to air television
- Replacement of current analog PAL broadcast television services
- Operating in adjacent unused “taboo” channels to analog PAL service
- Carries a range of services
  HDTV, SDTV, audio, teletext, data
- Providing an un-tethered portable service

Mobile Digital TV Onboard a Tram in Cologne - Germany

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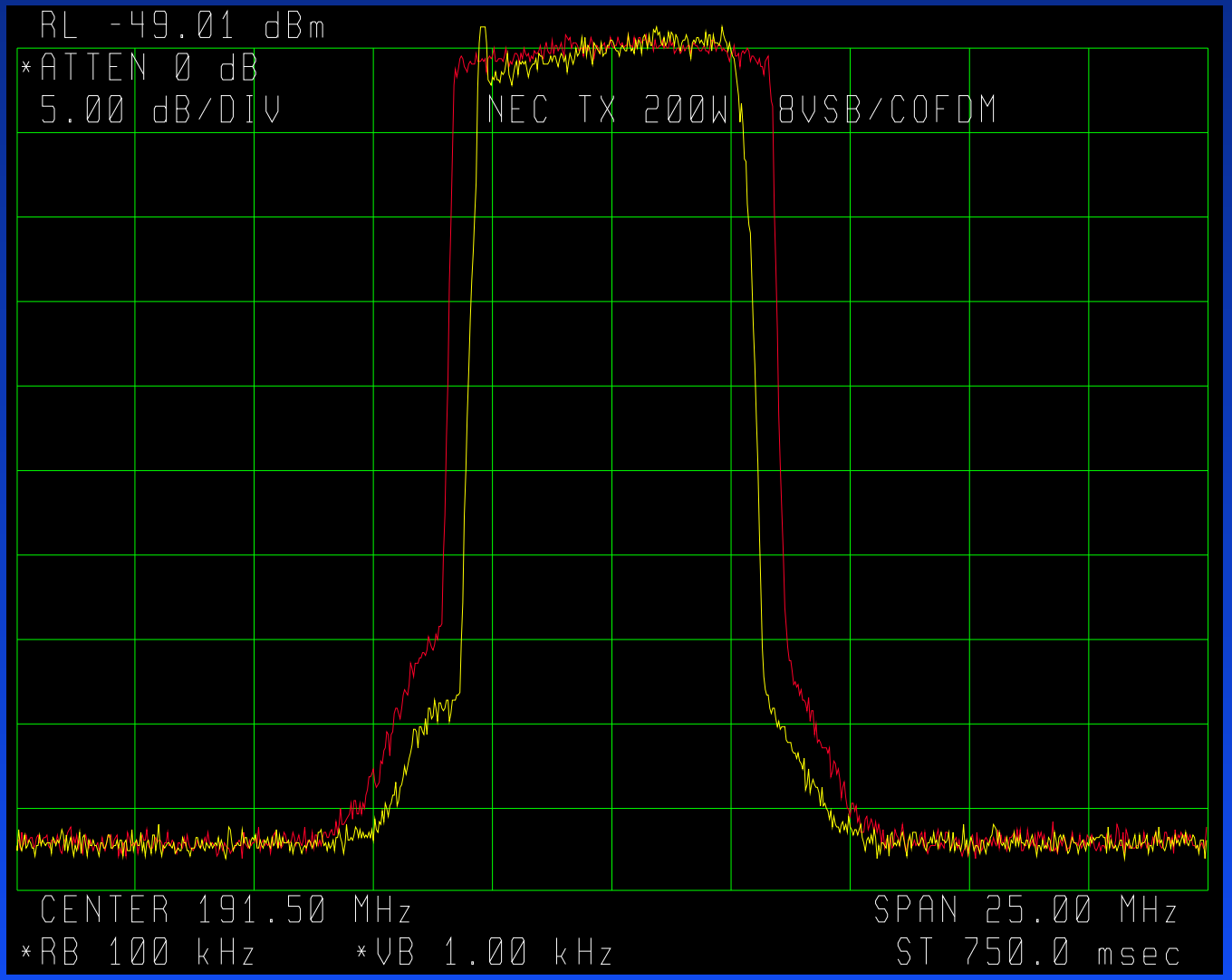
Terrestrial Transmission Problems

- Multipath interference - ghosts
- Noise interference - snow
- Variable path attenuation - fading
- Interference to existing services
- Interference from other services
- Channel frequency assignment - where to place the signal

Digital Modulation - Functions

- Spreads the data evenly across the channel
- Distributes the data in time
- Maintains synchronisation well below data threshold
- Employs sophisticated error correction.
- Equalises the channel for best performance

8-VSB & COFDM - Spectrum



8-VSB

COFDM

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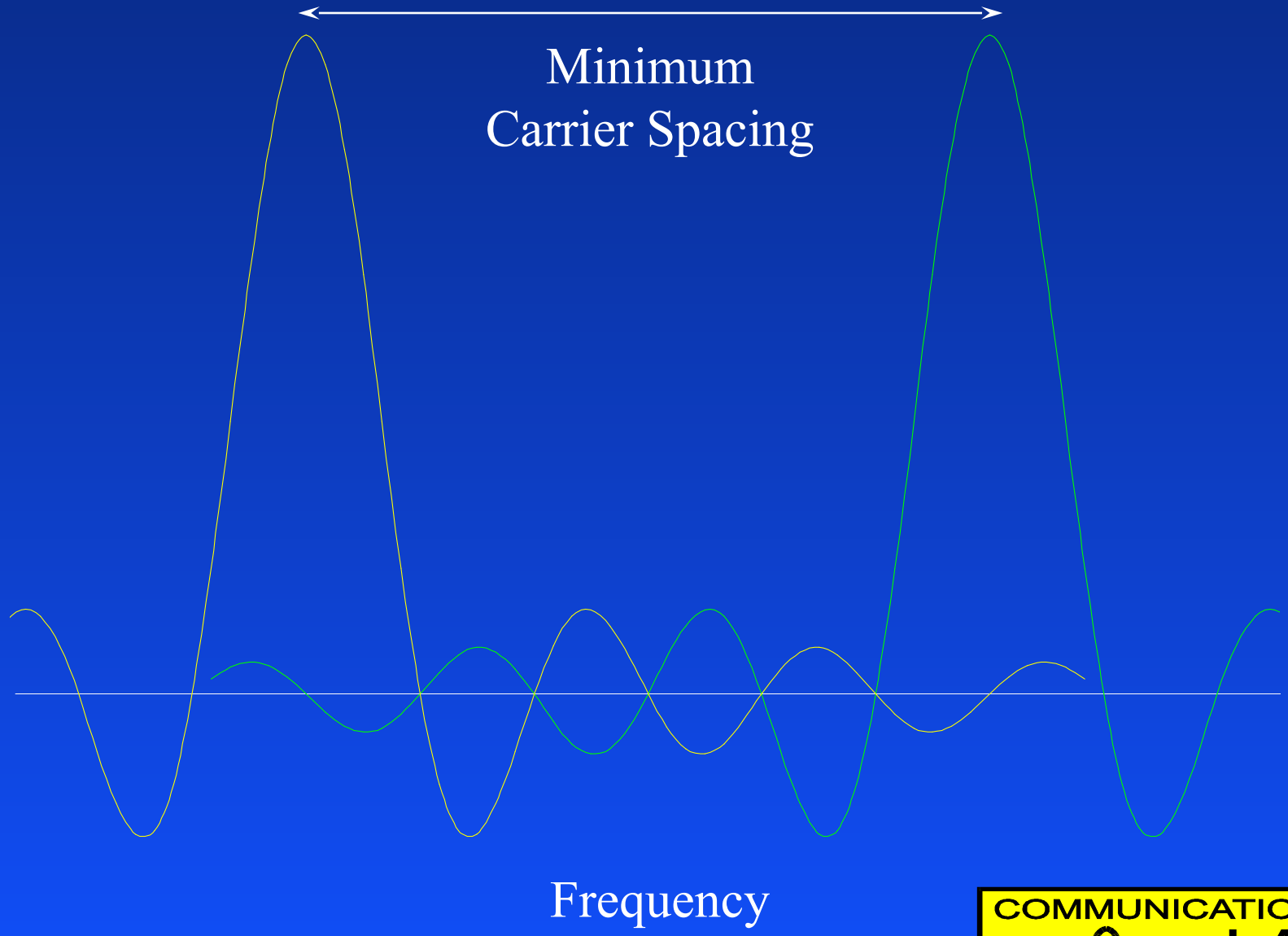
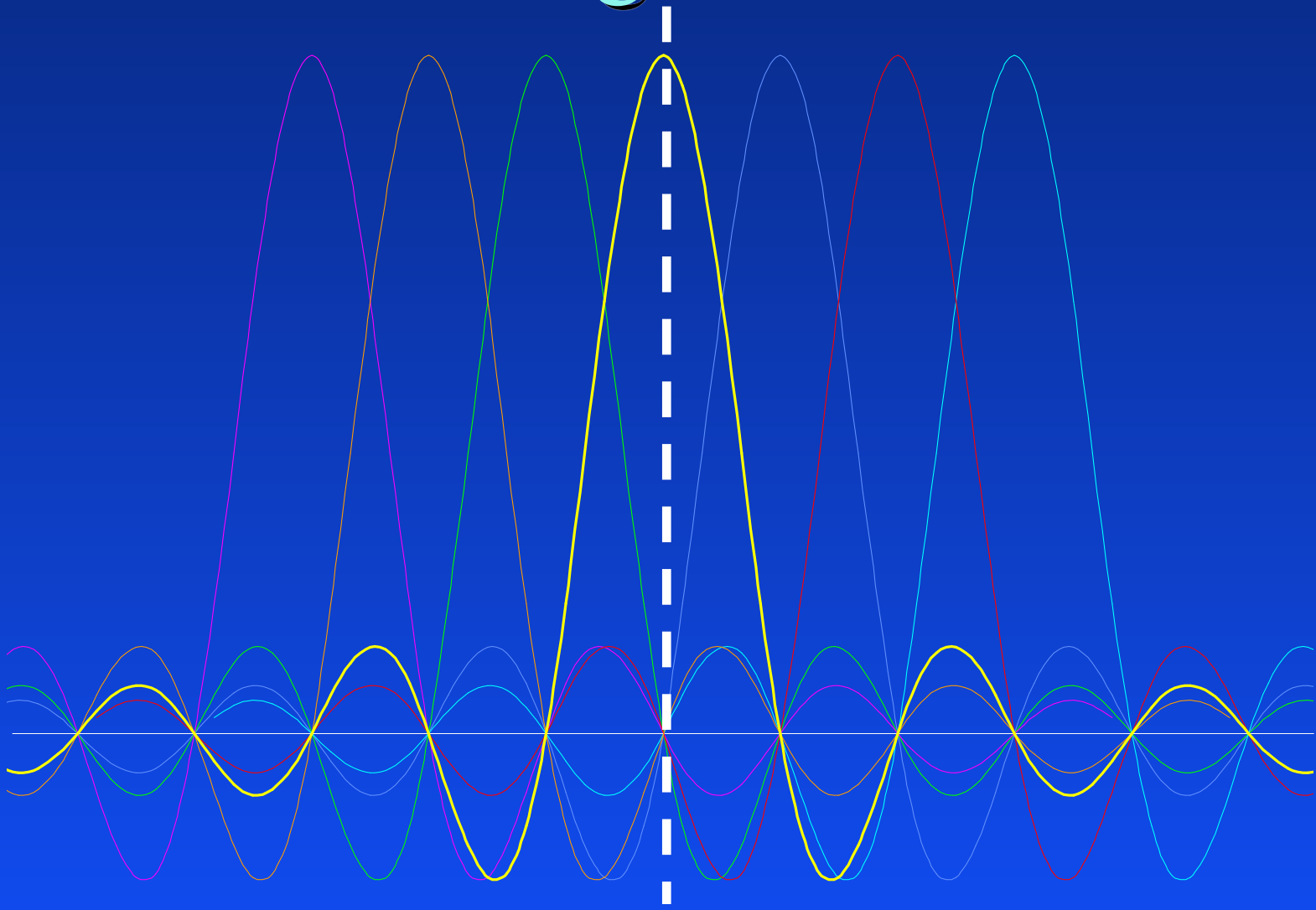
Traditional SCPC Modulation



COFDM - Orthogonal Carriers



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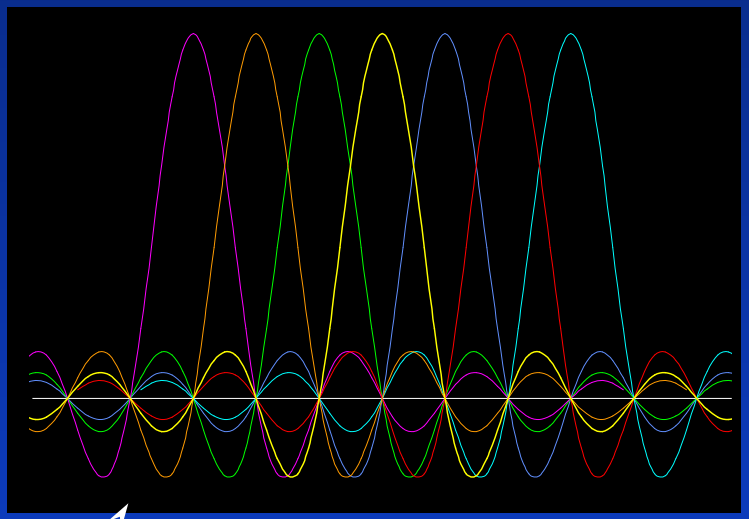
Spectrum of COFDM DTTB

Carrier Spacing
2k Mode 3.91 kHz
8k Mode 0.98 kHz



Almost
Rectangular
Shape

1705 or 6817 Carriers

6.67 MHz in 7 MHz Channel

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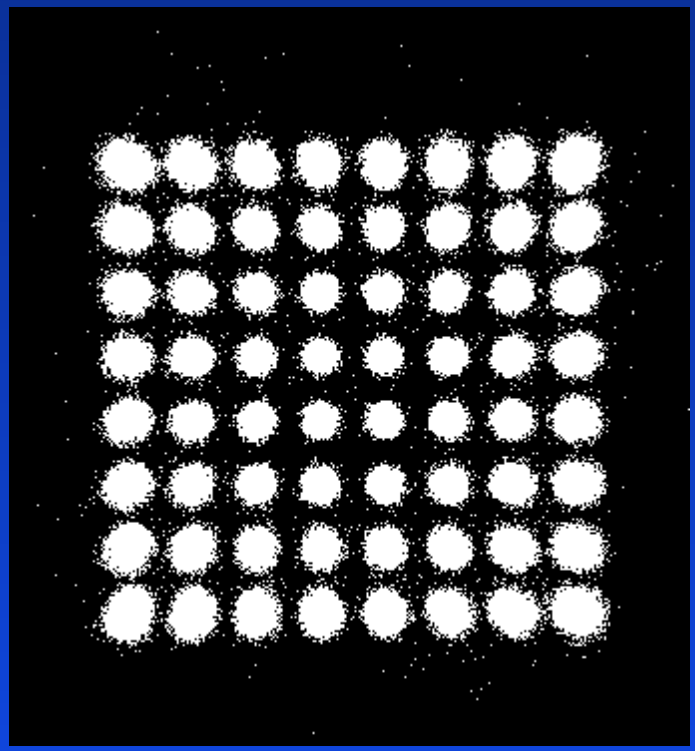
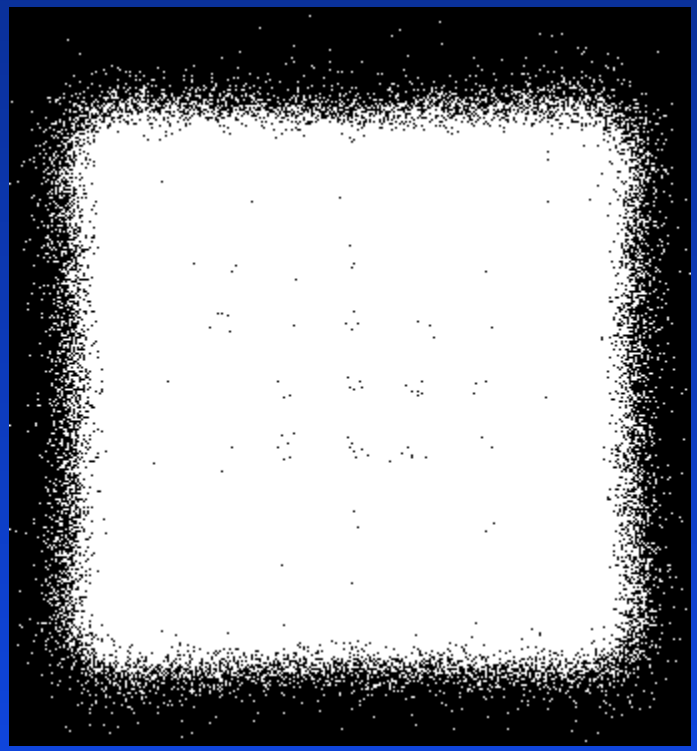
64-QAM - Perfect & Failure





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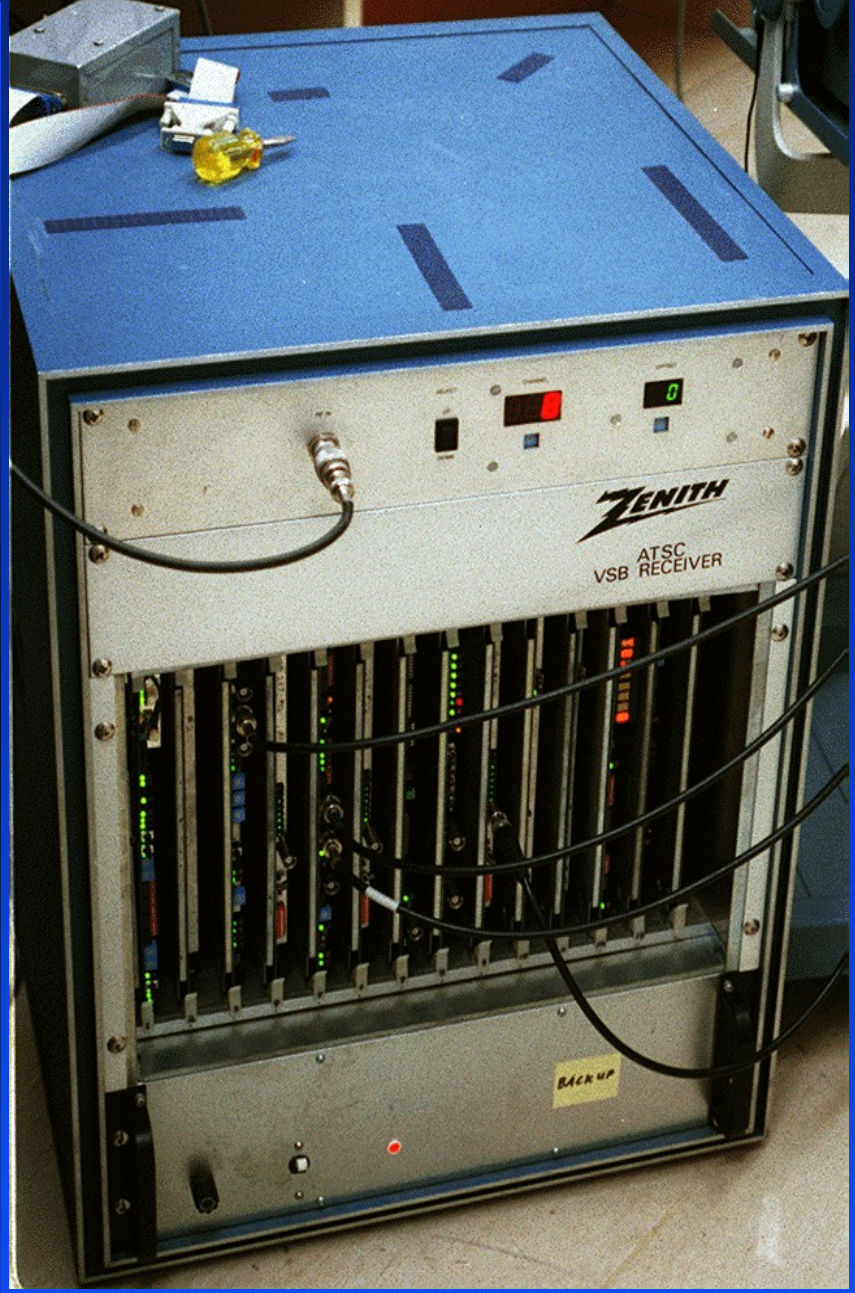

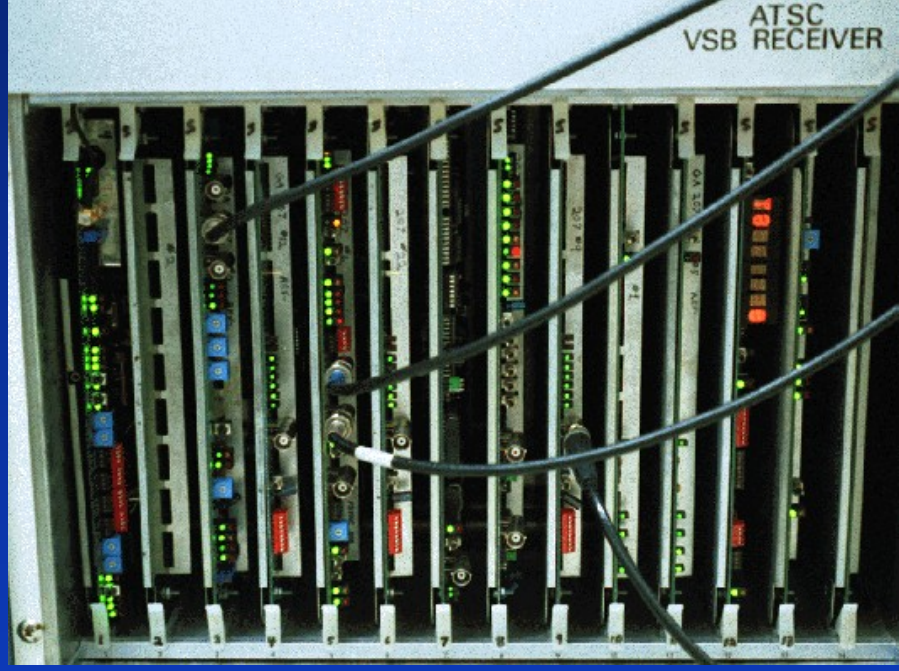

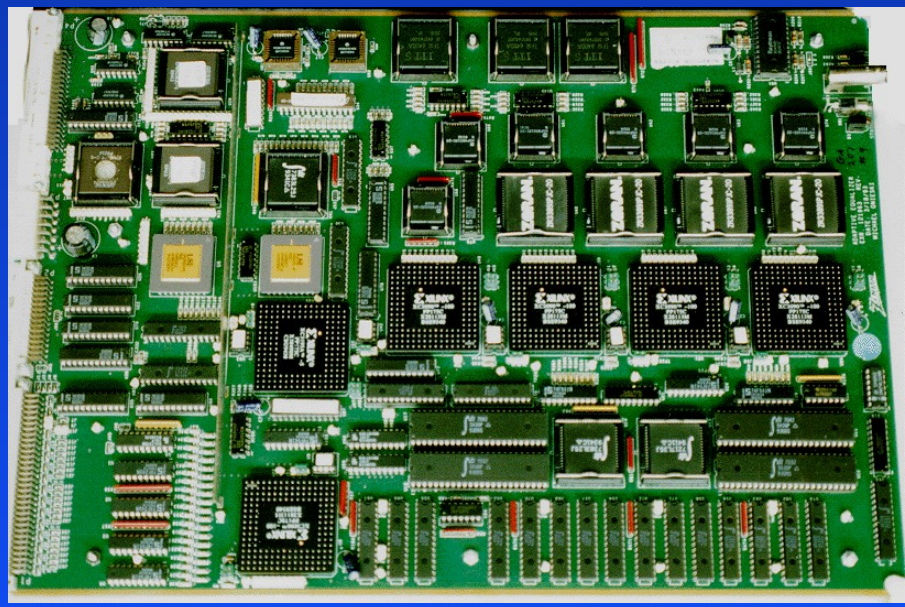

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COFDM - Commercial Receiver

- News Data Systems - System 3000

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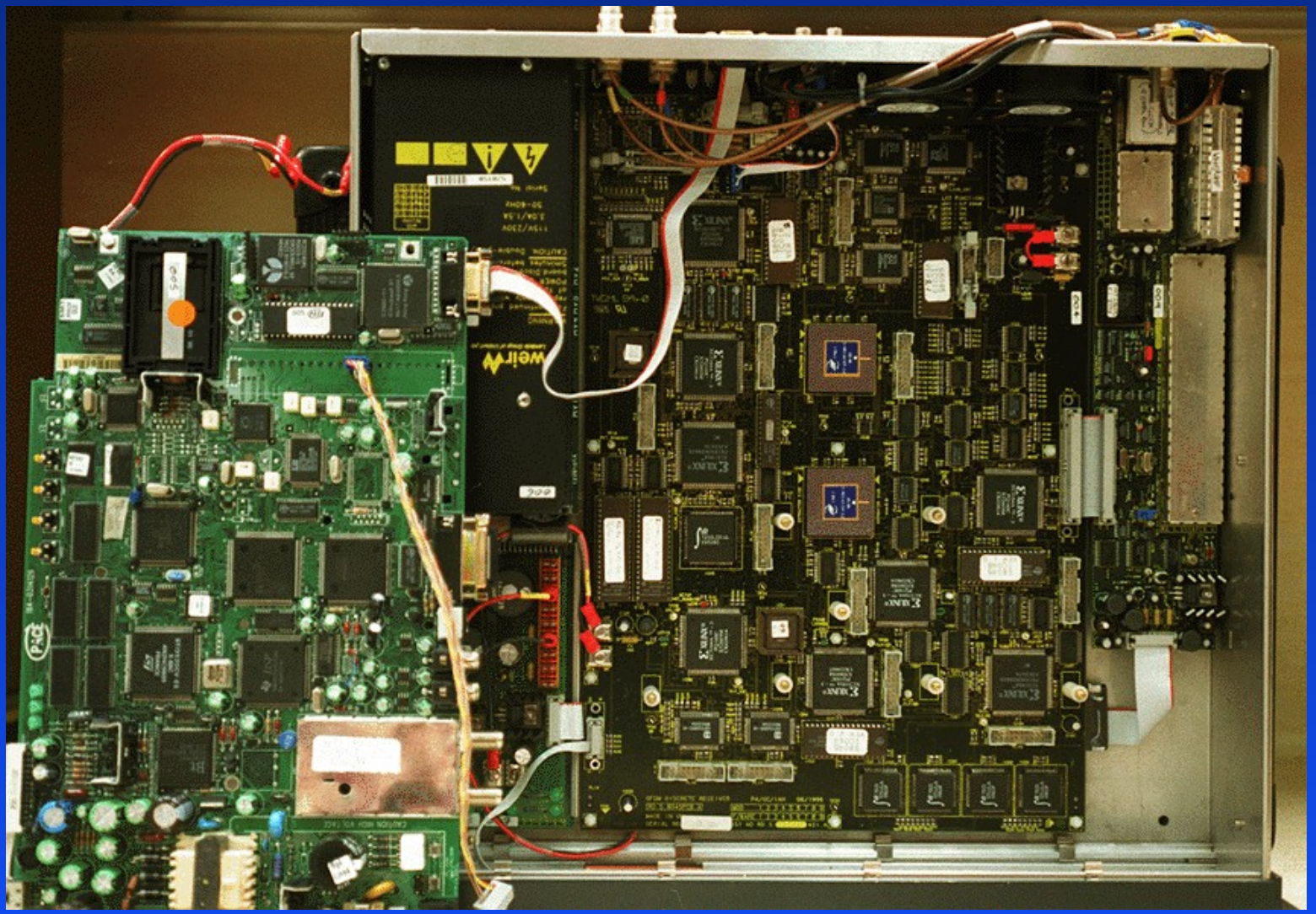
COFDM - Current Hardware



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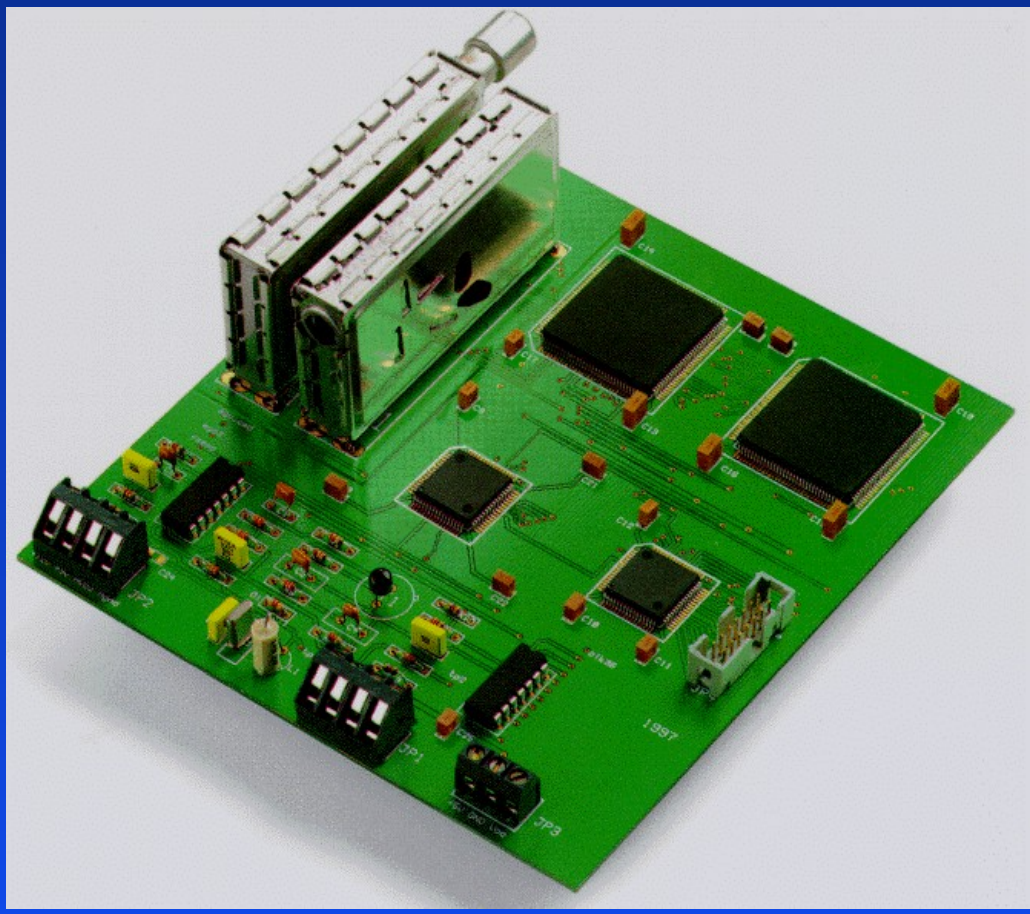
DVBird - Receiver



- 4 VLSI COFDM receiver
- Implements an 8K FFT (2K/8K mode)
- QPSK, 16QAM & 64QAM
- 1/4,1/8 & 1/32 guard intervals
- Onboard tuner

Australian DTTB System Evaluation

- Australia has a Unique Broadcasting Environment.
- Australian TV channels are 7 MHz wide on both VHF & UHF
- We use PAL-B with sound system G
- Any DTTB system will need to be configured to suit the existing television broadcasting environment during the transition period
- Digital has to Fit in with PAL-B

Digital Has to Fit In With PAL

- World TV channel bandwidths vary
  - USA / Japan 6 MHz
  - Australian 7 MHz
  - Europeans 8 MHz
- Affects:- tuning, filtering, interference & system performance

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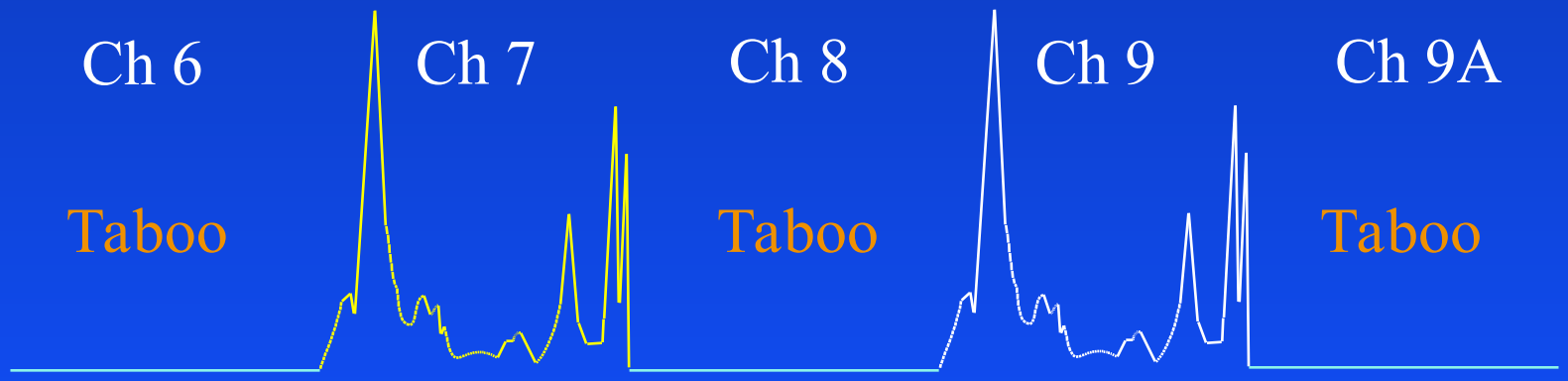
Digital Has to Fit In With PAL

- Digital television system development is focused in Europe & USA
  - The systems standards are designed to meet the needs of the developers
  - They focus on their countries needs first
  - Australian input is through standards organisations such as the ITU-R, DVB & ATSC
  - Australia is looking for a system to satisfy its OWN Future Broadcasting Needs

Channel Spacing

- Existing analog TV channels are spaced so they do not interfere with each other.
- Gap between PAL TV services
  - VHF 1 channel
  - UHF 2 channels
- Digital TV can make use of these gaps



VHF Television Spectrum

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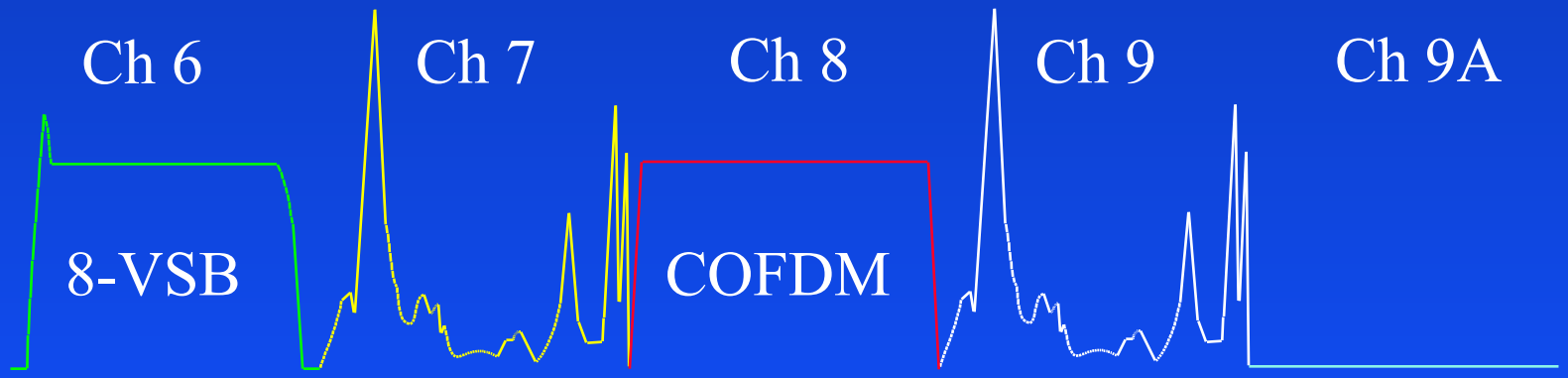
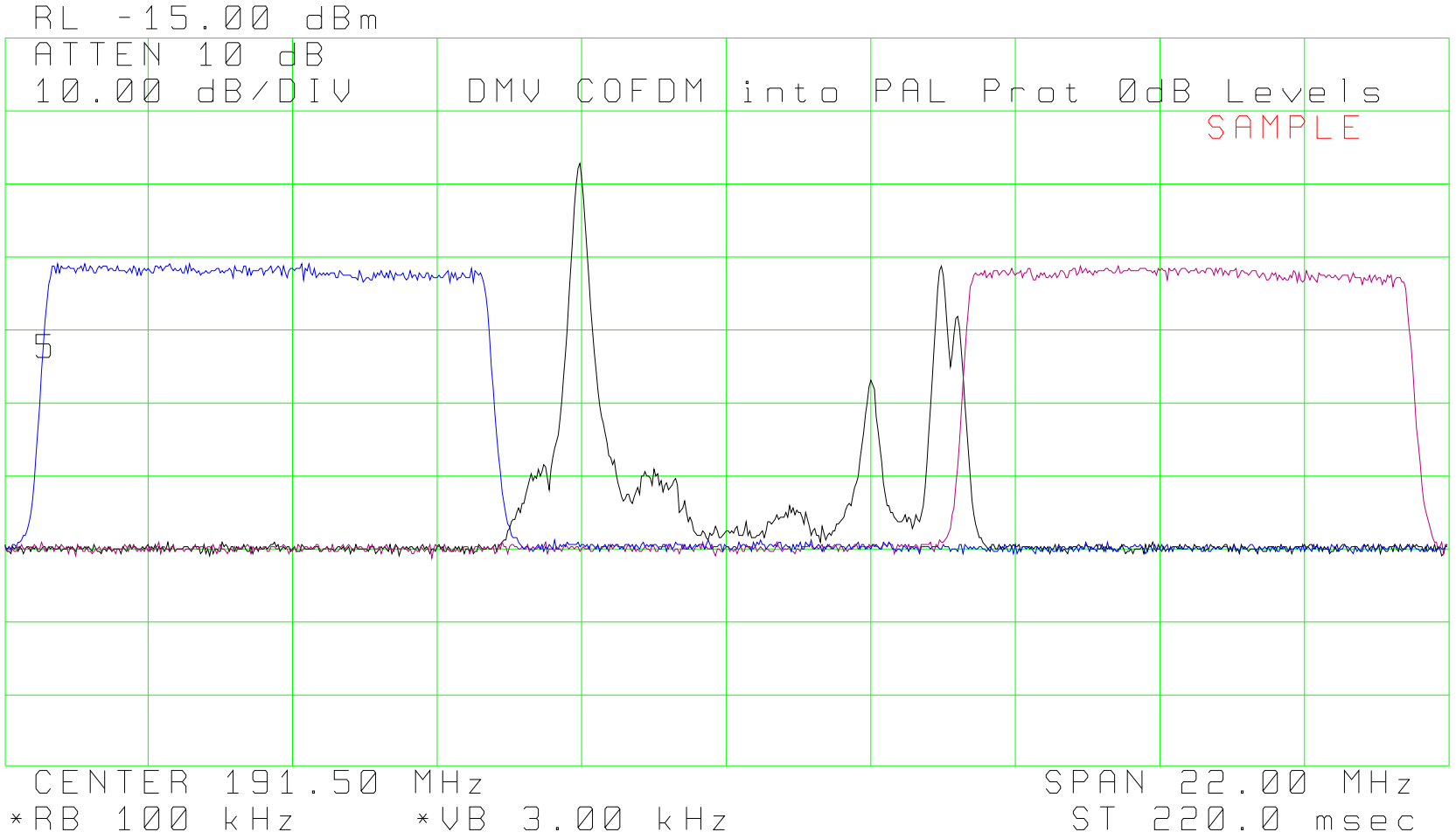
Digital Challenges

- Digital TV must co-exist with existing PAL services
  - DTV operates at lower power
  - DTV copes higher interference levels
  - Share transmission infra-structure
  - DTV needs different planning methods



VHF Television Spectrum

DTTB & PAL



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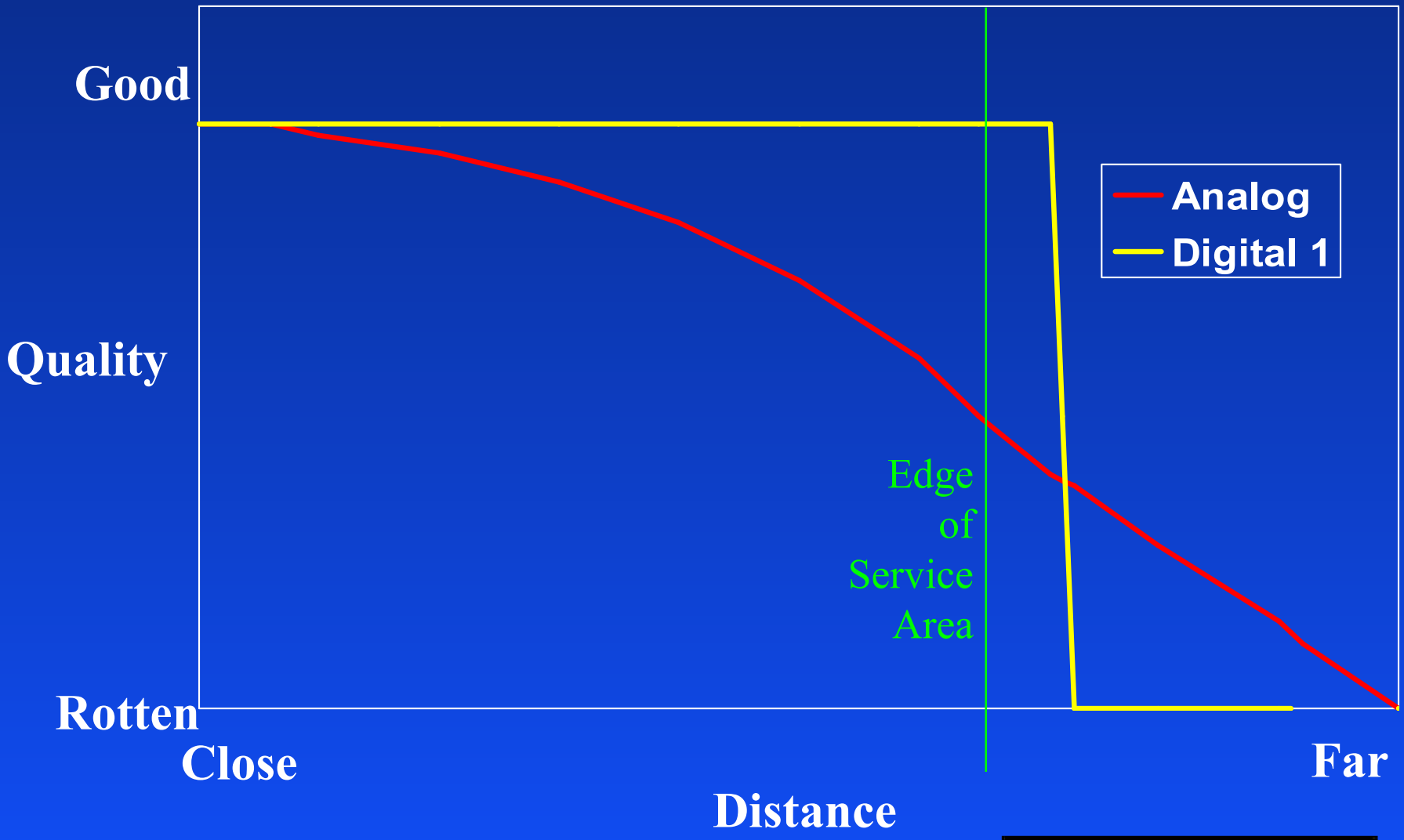
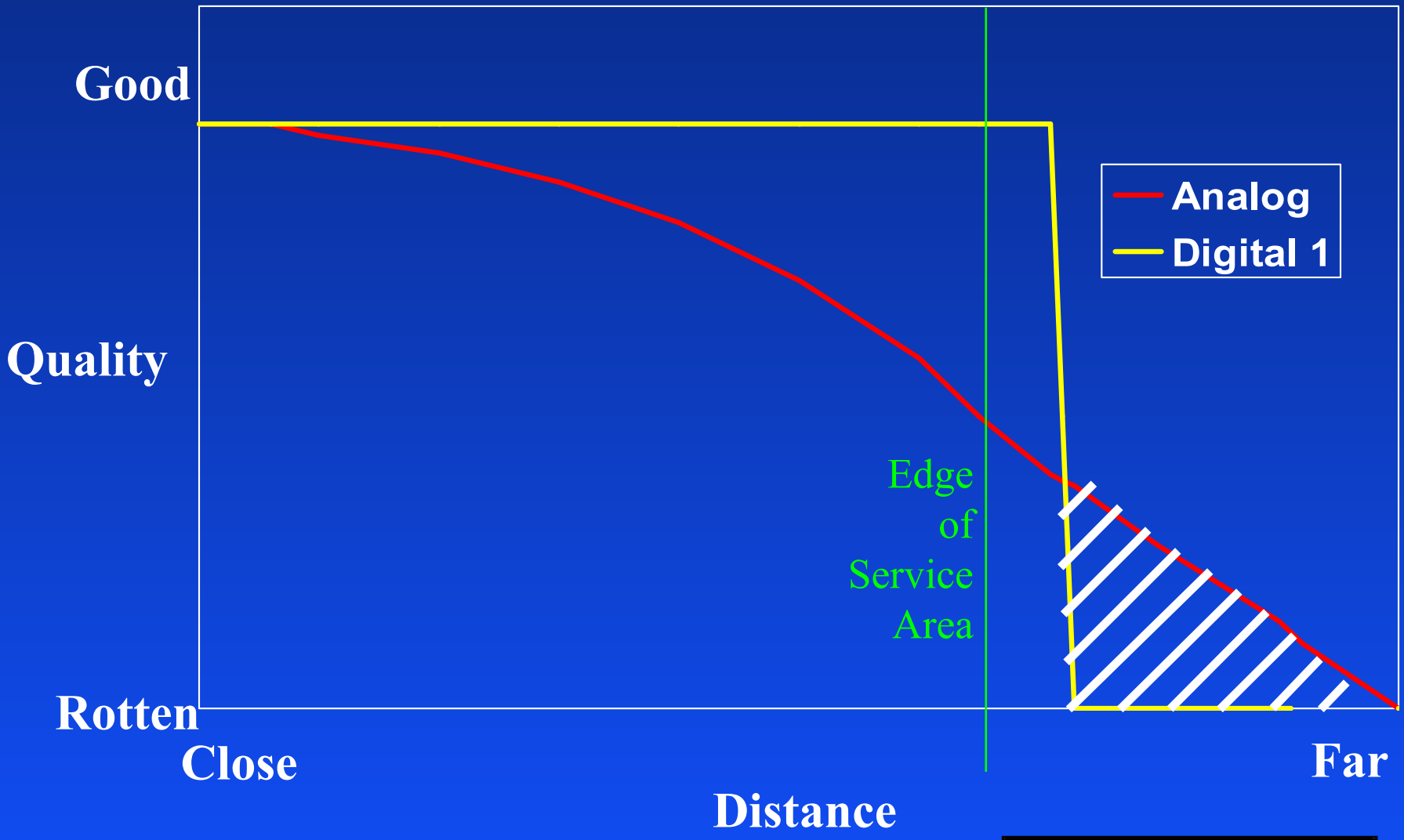
Digital Service Area Planning

- Analog TV has a slow gradual failure
  - Existing PAL service was planned for:
    50 % availability at
    50 % of locations
- Digital TV has a “cliff edge” failure
  - Digital TV needs planning for:
    90-99 % availability at
    90-99 % of locations

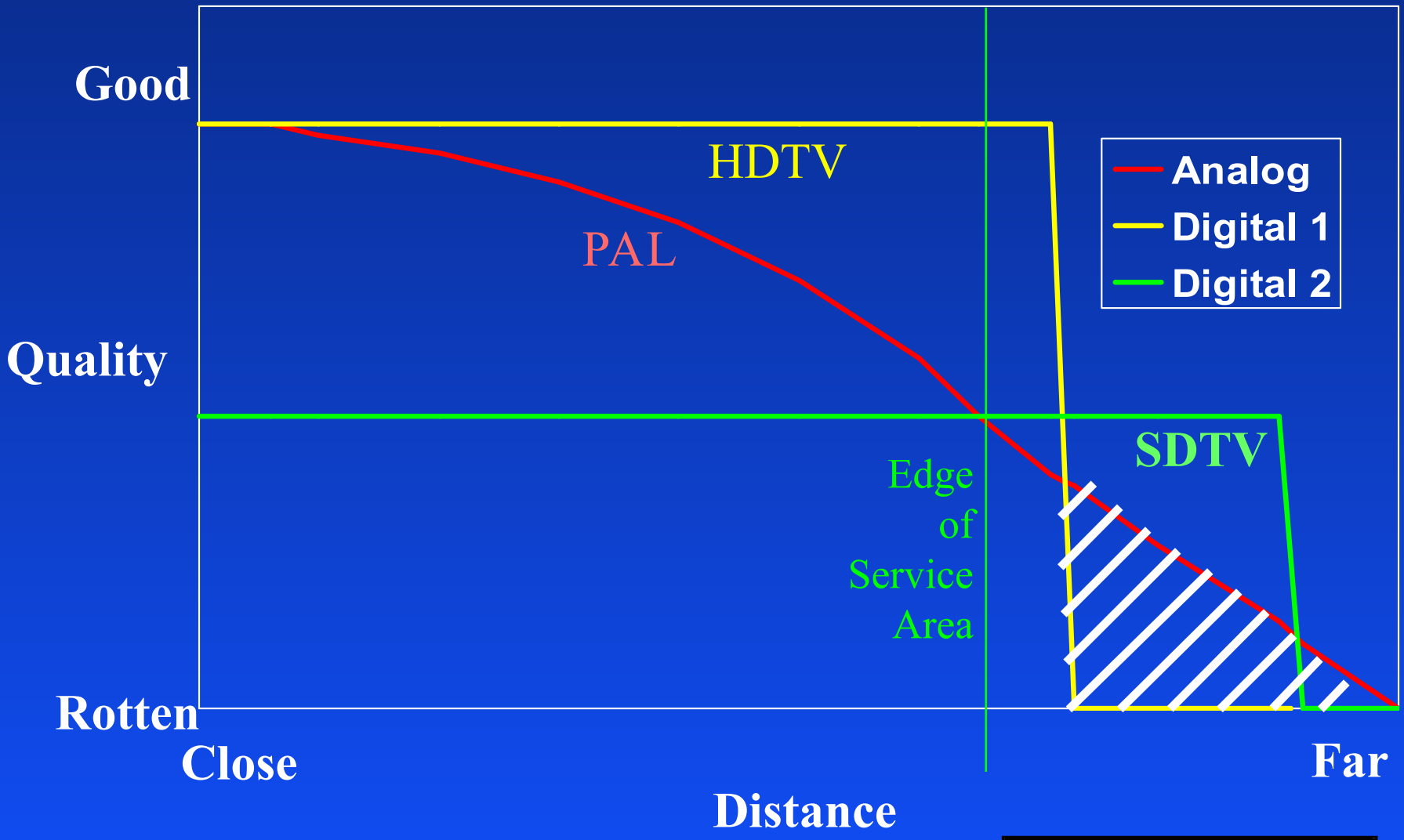
TV System Failure Characteristic



TV System Failure Characteristic



TV System Failure Characteristic



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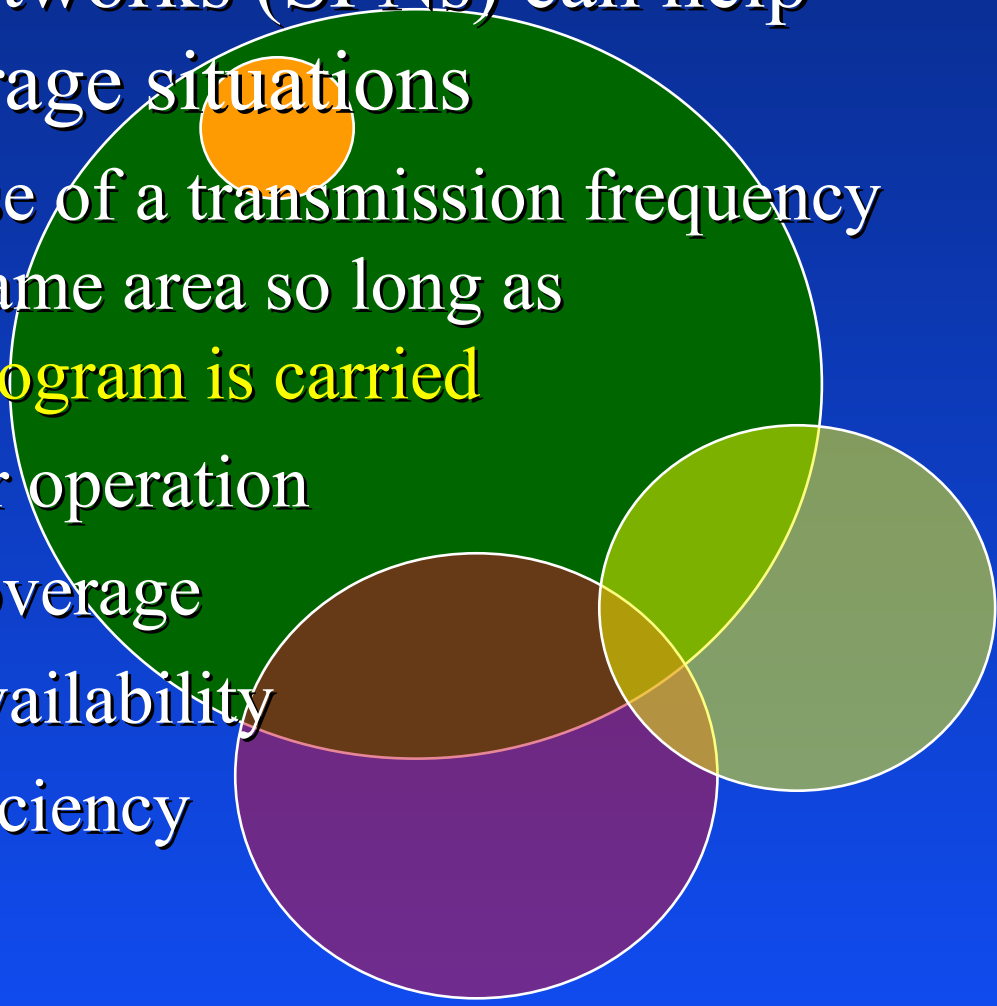
Digital Provides New Concepts

- Single frequency networks (SFNs) can help solve difficult coverage situations
  - SFNs allow the reuse of a transmission frequency many times in the same area so long as exactly the same program is carried
  - Allows lower power operation
  - Better shaping of coverage
  - Improved service availability
  - Better spectrum efficiency



DTTB - Content & Services

- DTTB was designed to carry video, audio and program data for television
- DTTB can carry much more than just TV
  - Electronic program guide, teletext
  - Broadband multimedia data, news, weather
  - Best of internet service
  - Interactive services
  - Software updates, games
- Services can be dynamically reconfigured

Video Program Capacity

For a payload of around 19 Mb/s

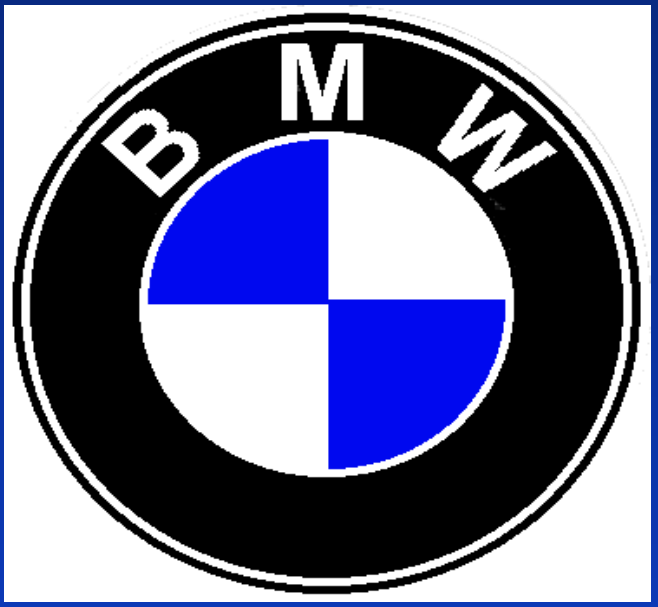
- 1 HDTV service - sport & high action
- 2 HDTV services - both film material
- 1 HDTV + 1 or 2 SDTV non action/sport
- 3 SDTV for high action & sport video
- 6 SDTV for film, news & soap operas

However you do not get more for nothing.

- More services means less quality

Spare Data Capacity

- Spare data capacity is available even on a fully loaded channel.
- Opportunistic use of spare data capacity when available can provide other non real time data services.
- Example: 51 second BMW commercial



The Commercial was shown using 1080 Lines Interlaced. 60 Mb of data was transferred during it. In the Final 3 seconds the BMW Logo was displayed allowing 3 Phone Books of data to be transmitted.

Standard Definition Television SDTV

- The current television display system
- 4:3 aspect ratio picture, interlace scan
- Australia/Europe
  - 625 lines - 720 pixels x 576 lines displayed
  - 50 frames/sec 25 pictures/sec
  - 414720 pixels total
- USA/Japan
  - 525 lines - 704 pixels x 480 lines displayed
  - 60 frames/sec 30 pictures/sec
  - 337920 pixels total

Enhanced Definition Television EDTV

- Intermediate step to HDTV
- Doubled scan rate - reduce flicker
- Double lines on picture - calculated
- Image processing - ghost cancelling
- Wider aspect ratio - 16:9
- Multi-channel sound

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High Definition Television HDTV

- Not exactly defined - number of systems
- System with a higher picture resolution
- Greater than 1000 lines resolution
- Picture with less artefacts or distortions
- Bigger picture to give a viewing experience
- Wider aspect ratio to use peripheral vision
- Progressive instead of interlaced pictures

Interlaced Vs Progressive Scan

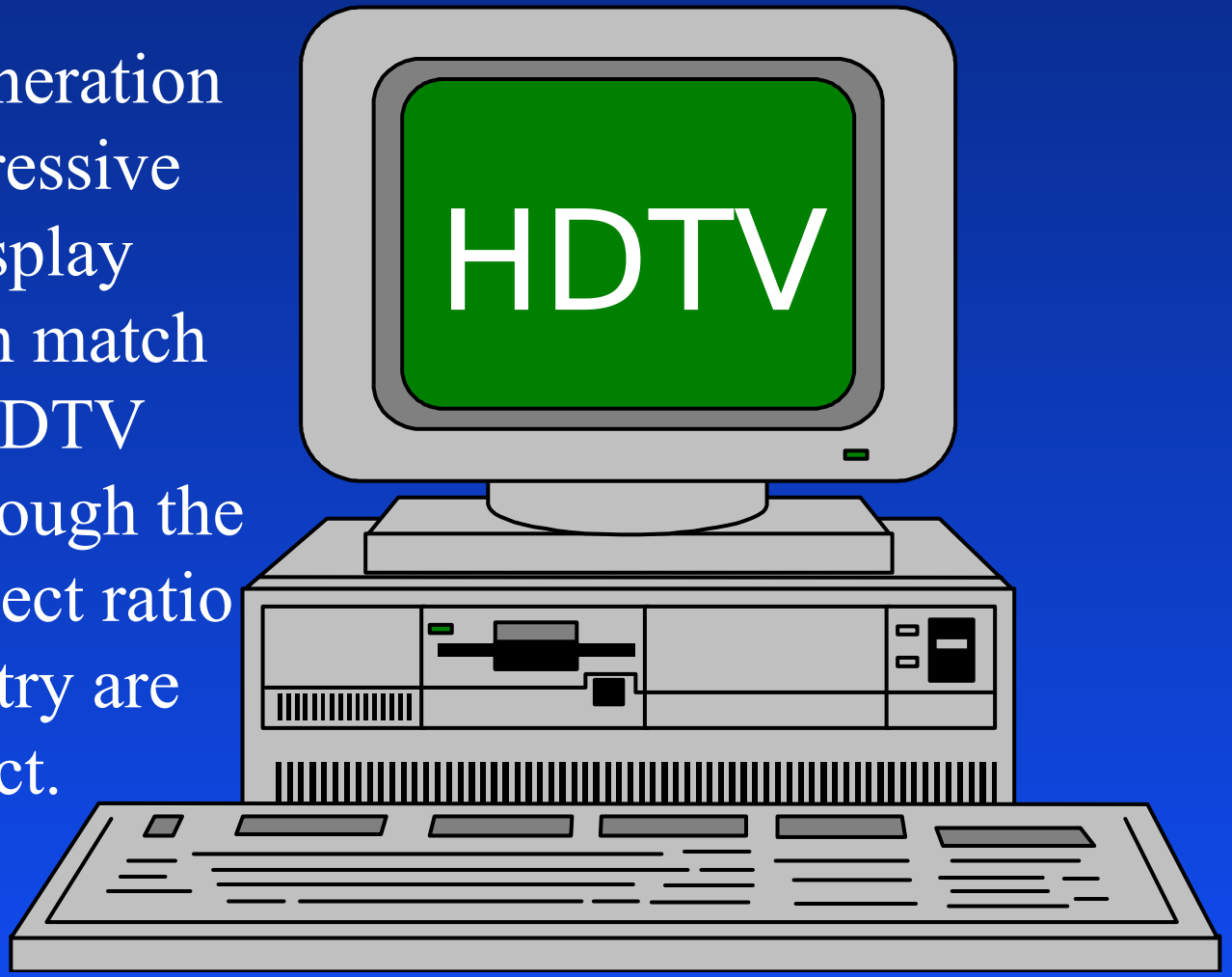
- Interlaced pictures. - 1/2 the lines presented each scan
  1,3,5,7,9,11,13.....623,625 field 1
  2,4,6,8,10,12,14.....622,624 field 2
- Because the fields are recorded at separate times this leads to picture twitter & judder
- Progressive pictures - all the lines sent in the one scan.
  1,2,3,4,5,6,7,8.....623,624,625 picture
- No twitter or judder.
- But twice the information rate.

HDTV
Have We Heard This Before?

- The first TV system had just 32 lines
- When the 405 line system was introduced it was called HDTV!
- When 625 line black & white came along it was called HDTV!
- When the PAL colour system was introduced it was called HDTV by some people.
- Now we have 1000+ line systems and digital television - guess what? Its called HDTV!

Do You Use A PC?

All Current Generation PCs use Progressive Scan and display Pictures which match or exceed HDTV resolutions although the pixel pitch, aspect ratio and colorimetry are not correct.



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Video Formats - SDTV - 50 Hz

Pixel x Line	Pixels/Picture	Bitrate Mb/s
704 x 576	405,504	5.0 - 15.0
544 x 576	313,344	3.5 - 8.0
352 x 576	202,752	2.5 - 4.0
544 x 288	156,672	1.5 - 3.0
352 x 288	101,376	1.0 - 2.5

All these formats are Interlaced

Video Formats - HDTV - 50 Hz

Pixel x Line	Pixels/Picture	Bitrate Mb/s
1920 x 1080 P	2,073,600	19 - 25
1920 x 1035 P	1,987,200	18 - 25
1440 x 1152 P	1,658,880	15 - 20
1280 x 720 I/P	921,600	8 - 11
720 x 576 I	414,720	6 - 15
720 x 480 I	345,600	5 - 12

Common Image Format CIF

- 1920 pixels x 1080 lines is now being promoted as the world CIF.
- All HDTV systems will need to support this image format and then allow conversion to any other display formats that are supported by the equipment.
- In Australia we have adopted the CIF for our HDTV production format. The Recommended Video format is 1920 x 1080 Interlaced at 50 Hz with a total line count of 1125 lines.

Video Bitrate - HDTV

- **2 M pixels * 25 pictures * 3 colours * 8 bits**

= 1.24416 G bits / sec for Interlace Scan

or

= 2.4833 G bits / sec for Progressive

We need to Compress this a bit!

Compression Technology

- When low bandwidth analog information is digitised the result is high amounts of digital information.

  5 MHz bandwidth analog TV picture

  ≡

  170 - 270 Mb/s digital data stream.

- 270 Mb/s would require a bandwidth of at least 140 MHz to transport
- Compression of the information is required

Compression - Types

- Two types of compression available
  - Loss-less compression
    2 to 5 times
  - Lossy compression
    5 to 250 times

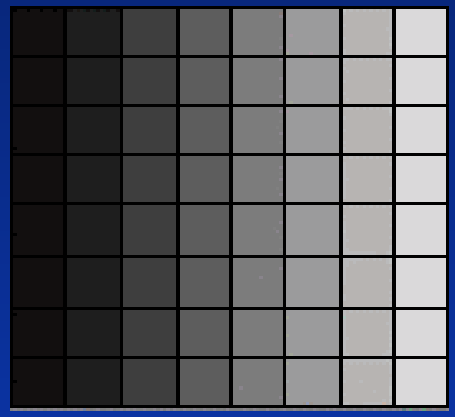
Compression - Loss-less Types

- Picture differences - temporal
- Run length data coding - GIF
  - 101000100010001001101 = 1 + 4x0100 + 1101
  - 21 bits source = 12 bits compressed
- Huffman coding - PKZIP
  - Short codes for common blocks
  - Longer codes for uncommon blocks
- Lookup tables

Compression - Lossy Types

- Quantisation - rounding
- Motion vectors
- Prediction & interpolation
- Fractal coding
- Discrete cosine transform (DCT)

Compression - DCT



0	12	25	37	50	62	75	87
0	12	25	37	50	62	75	87
0	12	25	37	50	62	75	87
0	12	25	37	50	62	75	87
0	12	25	37	50	62	75	87
0	12	25	37	50	62	75	87
0	12	25	37	50	62	75	87
0	12	25	37	50	62	75	87

50	-40	0	-4	0	-1	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

8x8 Pixels

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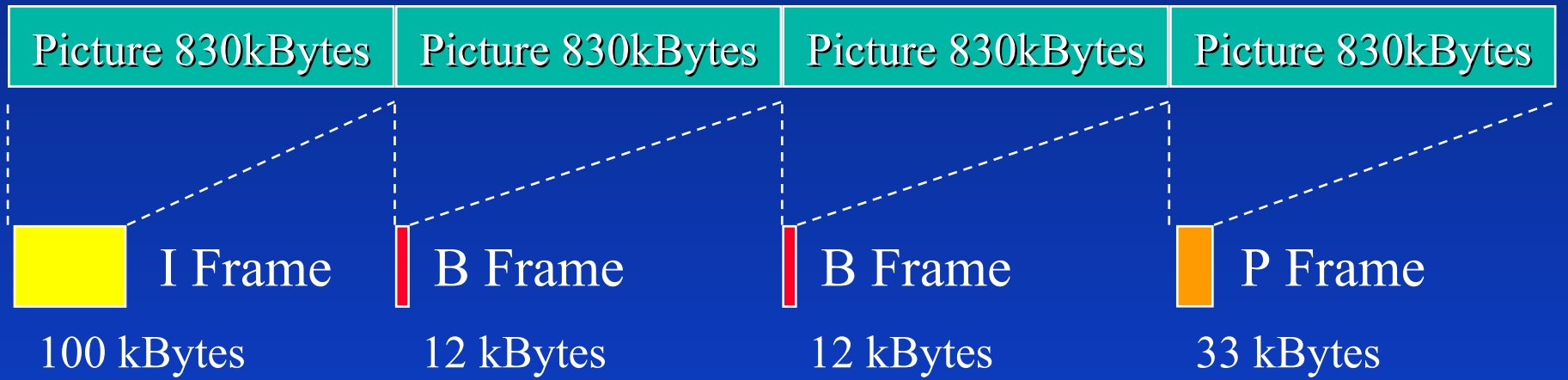
MPEG-2 - I, P & B Frames

Uncompressed SDTV Digital Video Stream - 170 Mb/s



MPEG-2 Compressed SDTV Digital Video Stream - 3.9 Mb/s

- **I** - intra picture coded without reference to other pictures. Compressed using spatial redundancy only
- **P** - predictive picture coded using motion compensated prediction from past I or P frames
- **B** - bidirectionally-predictive picture using both past and future I or P frames

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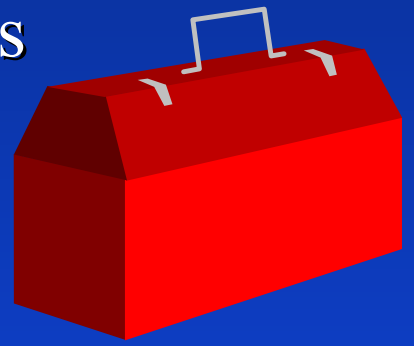
MPEG-2

- Compresses source video, audio & data
- Segments video into I, P & B frames
- Generates system control data
- Packetises elements into data stream
- Multiplexes program elements - services
- Multiplexes services - transport stream
- Organises transport stream data into 188 byte packets

MPEG-2 - Formats ML & HL

- MPEG-2 defines profiles & levels
  - They describe sets of compression tools
- DTTB uses main profile.
- Choice of levels
- Higher levels include lower levels



Level	resolution	
Low level (LL)	360 by 288	SIF
Main level (ML)	720 by 576	SDTV
High level (HL)	1920 by 1152	HDTV

Digital Terrestrial TV - Layers

. . . provide clean interface points. . . .

Picture Layer

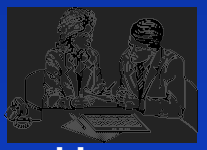
1920 x 1080
1280 x 720
60,30, 24 Hz

Multiple Picture Formats and Frame Rates

Video Compression Layer

Data Headers

Motion Vectors



Chroma and Luma DCT Coefficients

Variable Length Codes

MPEG-2 compression syntax ML@MP or HL@MP

Transport Layer

Packet Headers

Flexible delivery of data

Video packet | Audio packet | Video packet | Aux data

MPEG-2 packets

Transmission Layer

VHF/UHF TV Channel

7 MHz

COFDM / 8-VSB

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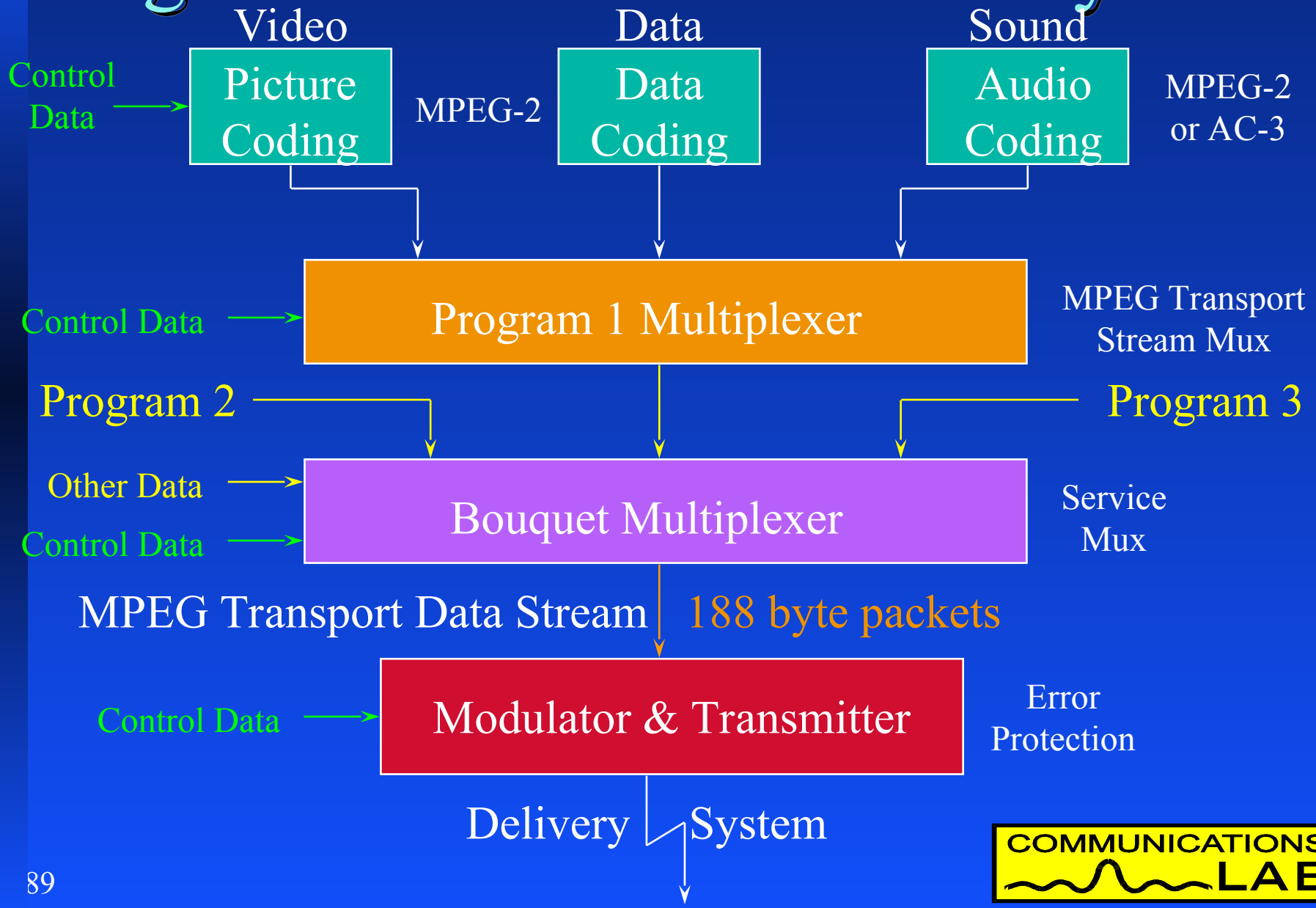
Digital Television Encode Layers



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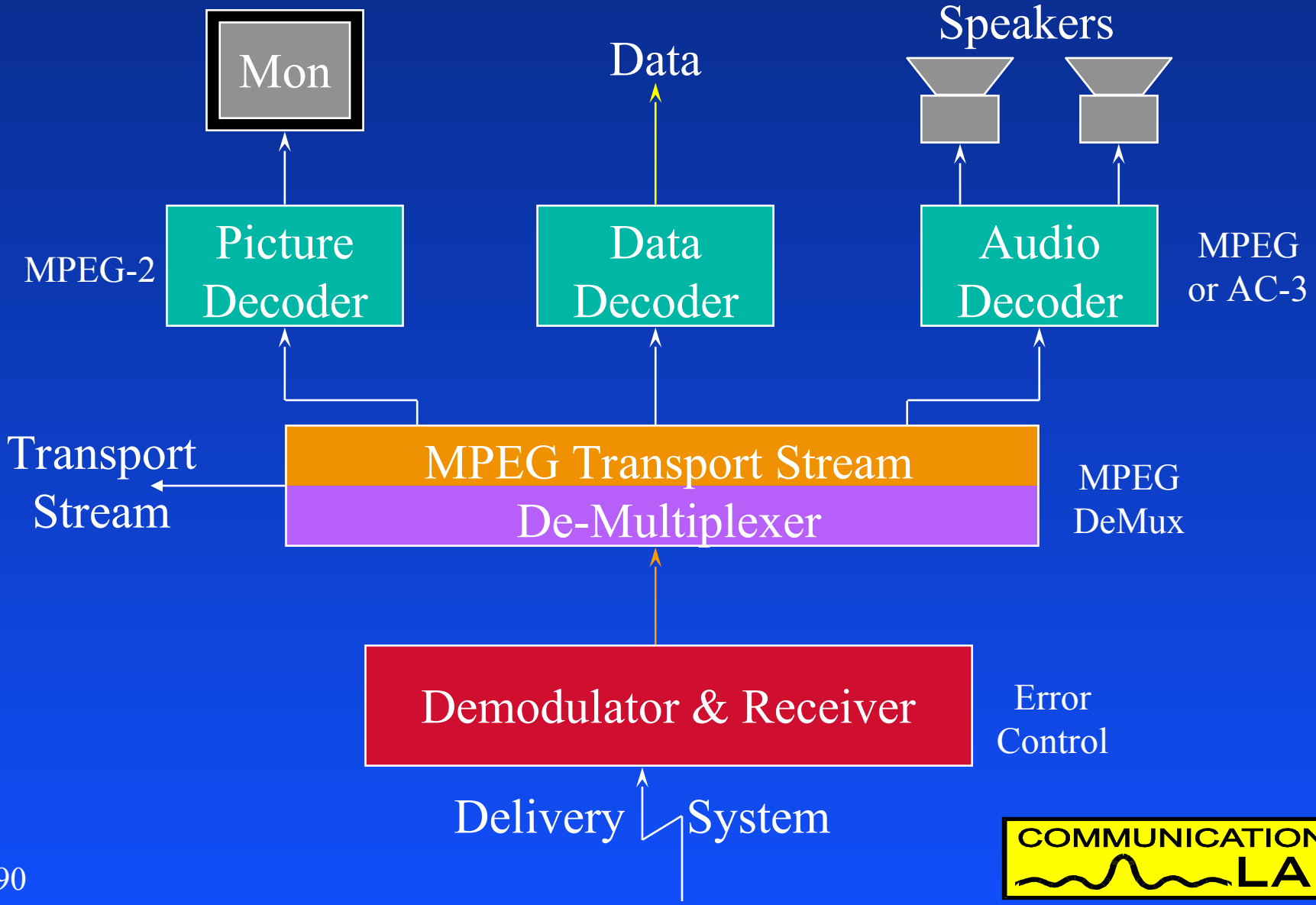
Digital Television Decode Layers



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Set top Box (STB) - Interfacing

- Domestic and Professional interfaces still to be defined
- Most probably Transport Stream via IEEE 1394 (Firewire)
- Baseband Audio & RGB/YUV Video signals.
- STB can convert between line standards so you do not have to have a HD display.
- Display and transmitted information must be at same Frame/Field rate. (25/50)

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Multichannel Sound - MPEG 1/2

- Two sound coding systems exist
- MPEG Audio Layer II was developed in conjunction with the European DVB technology
  - Uses Musicam Compression with 32 sub bands
  - MPEG 1 is basic Stereo 2 channel mode
  - MPEG 2 adds enhancement information to allow 5.1 or 7.1 channels with full backwards compatibility with the simple MPEG 1 decoders
  - MPEG 1 Is compatible with Pro-Logic processing.
  - Bitrate 224 kb/s MPEG 1
  - Bitrate 480 kb/s MPEG 2 5.1

Multichannel Sound - Dolby AC-3

- Dolby AC-3 was developed as a 5.1 channel surround sound system from the beginning.
  - Compression Filter bank is 8 x greater than MPEG 2 (256)
  - Must always send full 5.1 channel mix
    One bitstream serves everyone
  - Decoder provides downmix for
    Mono, Stereo or Pro-Logic
  - Listener controls the dynamic range,
    Audio is sent clean
  - Bitrate 384 kb/s or 448 kb/s

Studio Multichannel Sound

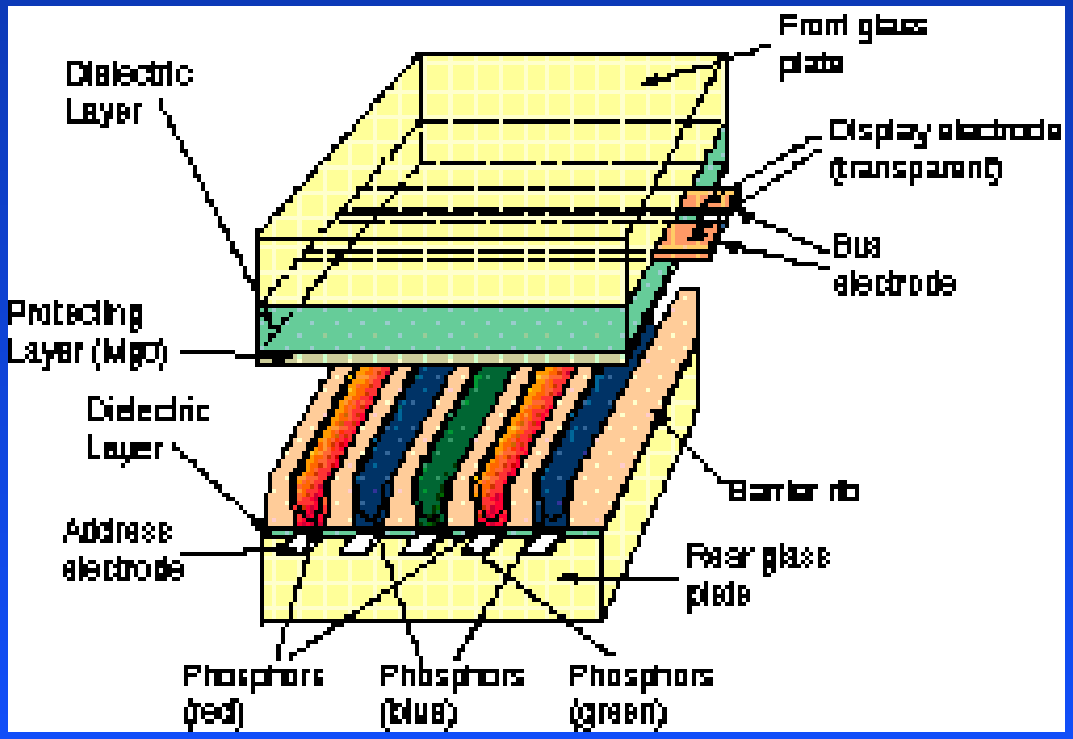
- Present AES3 PCM Audio
  does not cater for 5.1 channel surround.
- Dolby has produced a system called Dolby E
  - Handles 6-8 audio inputs
  - Uses low compression 3-4:1
  - Can be transported/stored on 2ch PCM audio equipment
  - Incorporates time stamps and is segmented at the video frame rate allowing editing on video frame boundaries

Display Technology

- For HDTV displays need to be large
- Captures viewers perceptual vision
- Viewing distance will be closer (3H)
- Largest CRT Tubes limited by size
- Projectors are expensive and Bulky
- Flat Panel Display Technology seen as the HDTV display technology of the future
  - Producing large flat panels is difficult

Plasma Panel Displays

- PDPs from Fujitsu & Mitsubishi look like providing HDTV Display solution.
- Latest innovations such as ALiS have doubled the vertical resolution to over 1000 lines.



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Staging & Sets

- HDTV resolution & Aspect ratio will mean changes to production:
  - Greater attention to detail
  - Set construction
  - Set painting more accurate
  - Makeup
  - Lighting (more light)
  - Framing of Shots (4:3, 14:9, 16:9, 2.21:1)
  - Use of Zoom & Pan

Studio/Field Storage

- Digital Video Tape probably 270 Mb/s.
- D5 & D1 have been used up to now.
  - 3-4 times compression applied to the HDTV material for storage => Need HD encoder between camera & Storage device
- Disk Video Servers
- Compressed transport stream storage (20-50 Mb/s) on SX, D-Bcam, DVC-PRO etc.
- New formats will be developed, not here yet.

What Are the Next Steps?

- Standards Australia - RC/5 committees
  - Starting now
  - Develop transmission standards
  - Develop reception equipment standards
  - Draft standards ready by end of 1998

On Air Testing

- NTA VHF & UHF trials
  - 2K & 8K operation
  - Planning
  - SFNs
  - Gap fillers
- Ch 12 VHF @ 2.5 kW
- CH 29 UHF @ 1.25 kW

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Channel 9A

- SBS want to use band III 6 MHz channel 9A in metro areas
  options:
  - Truncation of 7 MHz COFDM
  - Transmission of 6 MHz COFDM
  - Offsetting digital/analog transmissions

Propagation Investigations

- Indoor reception tests
  - Multipath propagation
  - Building attenuation
  - Impulse sensitivity

- Adjacent area co-channel simulcast operation

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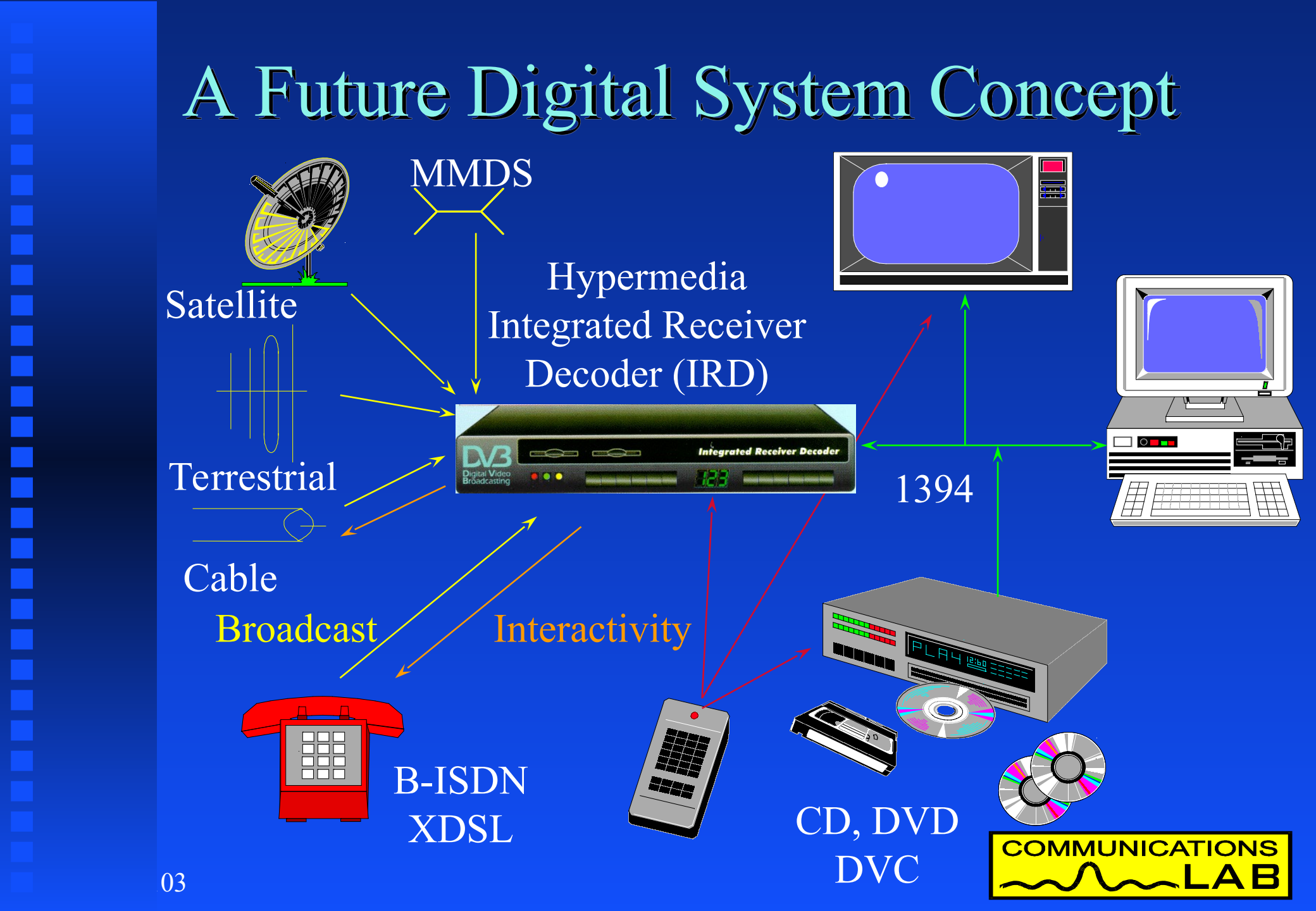
A Future Digital System Concept



The End

Thankyou for your attention

Any questions?

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