Capítulo 5. – Radiodifusión Terrestre

Chapter 5. - Terrestrial Broadcasting

5. Kapitulua.- Lurreko Irrati-difusioa

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V0.1

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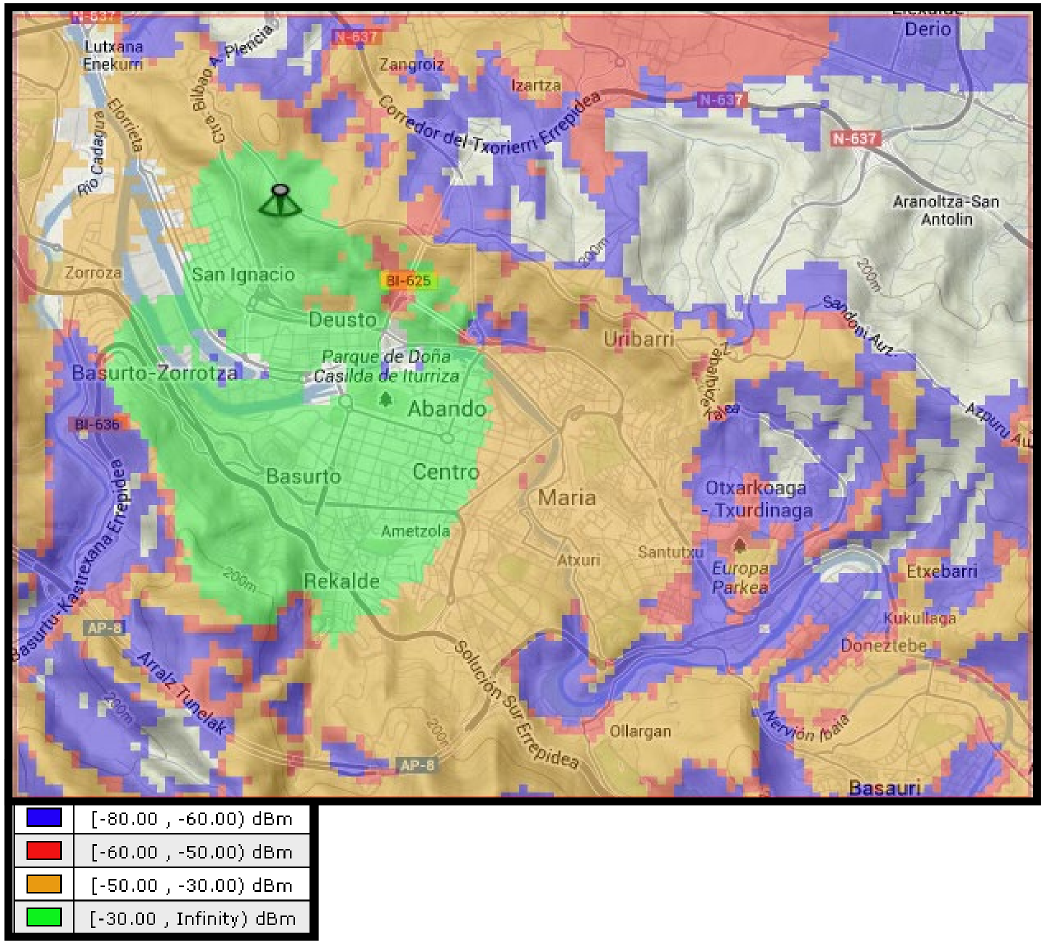
Introduction

- **Term** : broadcasting (service)
- **Definition** : Rec. ITU-R V.662-3 - Radiocommunication in which transmissions are intended for direct reception by the general public. These may include sound transmissions, television transmissions and other types of transmission. Note - By common usage in French and Spanish the meaning of "radiodiffusion" and "radiodifusión" is frequently restricted to "sound broadcasting".
- 3 types:
  - **Terrestrial (radio)**
  - Satellite (radio)
  - Cable

Introduction

Main Characteristics:

- Point to multipoint transmission.
- Large coverage areas: Cities, provinces, etc.
- Unidirectional: Only downlink (from transmitting towers to receivers). Sometimes a return channel is provided for interactivity.
- Digital and analog systems.



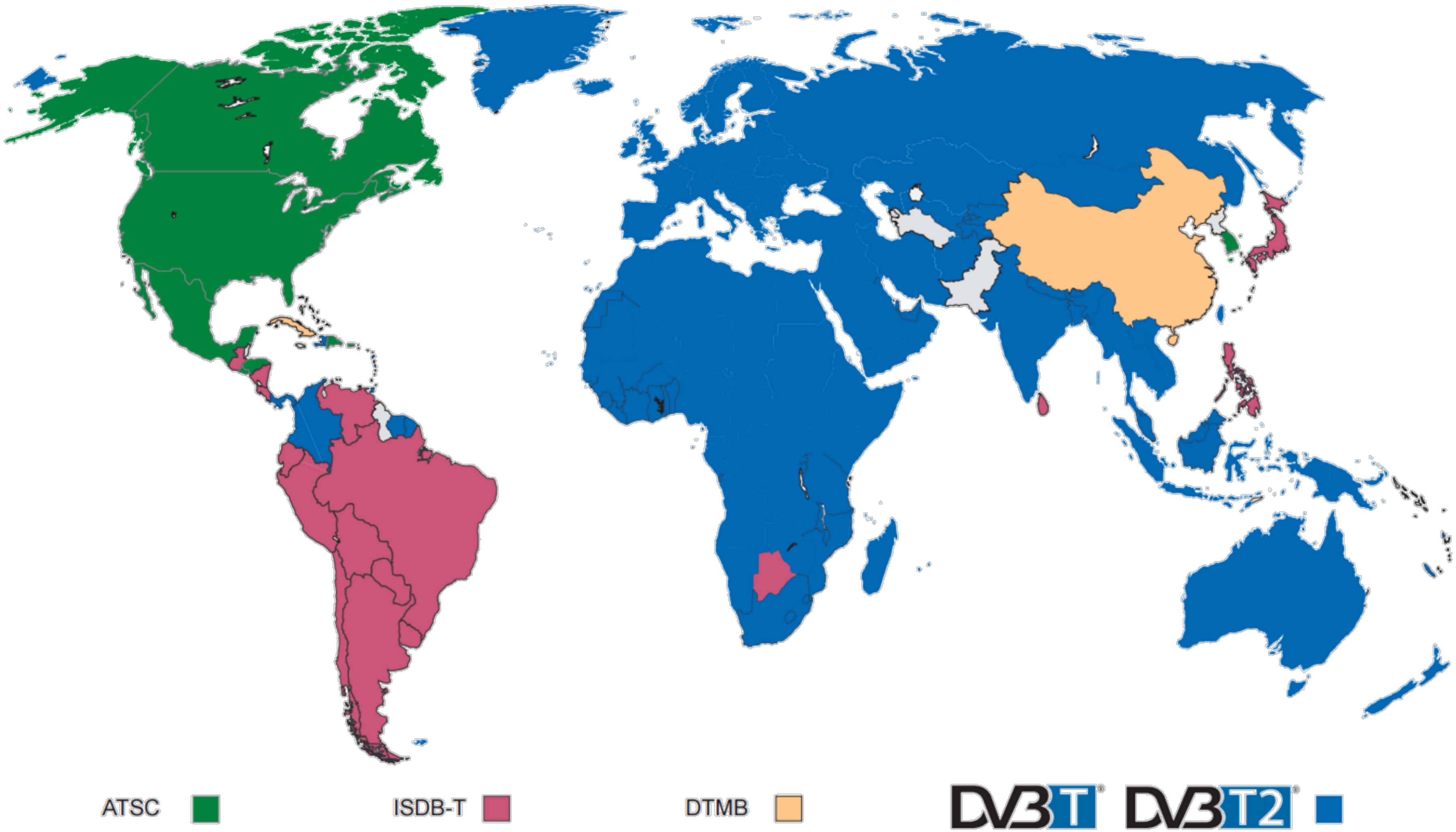
Applications

- **Sound transmissions (radio):**
  - Analog:
    - AM
    - SW
    - FM
  - Digital:
    - DAB/DAB+
    - DRM/DRM+
- **Television transmissions**
- **Other applications: education,…**

Applications

- **Television transmissions:**
  - Analog Terrestrial TV (not used any more in many countries, like Spain)
  - Digital Terrestrial TV (DTT/TDT in Spanish).
    - DVB-T/ DVB-T2 in Europe and many countries of the world.
    - ATSC (Advanced Television Systems Committee), USA.
    - ISDB-T (Integrated Service Digital Broadcasting – Terrestrial", Japan and South America (SBTVD, Sistema Brasileiro de Televisão Digital)
    - DTMB (Digital Terrestrial Multimedia Broadcast) and (DTMB-A) Digital Television Terrestrial Multimedia Broadcasting-Advanced, China.

Broadcasting service (Digital television)



Digital Terrestrial Television Systems. Blue indicates countries that have adopted or deployed DVB-T and DVB-T2. September 2016

Broadcasting service (Digital television)

- ATSC (Advanced Television Systems Committee), USA.

  *ATSC 3.0 (**NEXTGEN TV**) is the next generation terrestrial broadcast system designed from the ground up to improve the television viewing experience with higher audio and video quality, improved compression efficiency, robust transmission for reception on both fixed and mobile devices, and more accessibility, personalization and interactivity. Major broadcasters are launching NEXTGEN TV on television stations in USA.*

  ATSC 2.0 was a planned major new revision of the standard which would have been backward compatible with ATSC 1.0. ATSC 2.0 was never actually launched, as it was essentially outdated before it could be launched. All of the changes that were a part of the ATSC 2.0 revision were adopted into ATSC 3.0.

  "ATSC 1.0" is the designation used (retroactively) to describe the first digital television standard developed by the ATSC.

ATSC 1.0 (First digital ATSC standard)	ATSC 3.0 (Newest digital ATSC standard)
Supports one bit rate of 19.4 Mbps	high data rate ranging from 28 to 36Mbps or higher than this over 6 MHz bandwidth.
Supports HDTV, multicast and data transmission.	It uses OFDM technique to deliver high data rate ranging from 28 to 36Mbps or higher than this over 6 MHz bandwidth.
Provides coverage with 15dB CNR at rooftop.	It supports flexible bit rates and various coverage areas.
It uses 8VSB modulation	It uses OFDM technique to deliver

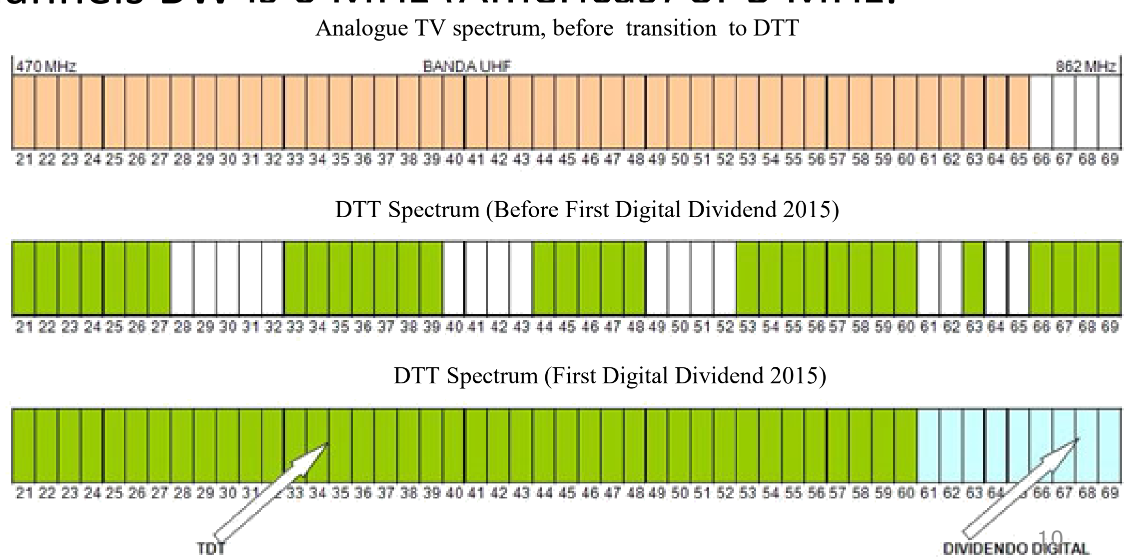
Broadcasting service (Digital television)

- Comparison
  - *Bitrate*
    - *Channel coding efficiency*
    - *High modulations*
  - *Required CNR*
  - *Spectrum efficiency bit/s/Hz*

	ATSC 3.0	DVB-T	DVB-T2	ISDB-T family	DTMB-A
Net data rates	Depending on modulation and code rate Maximum 1.24-77.2 Mbit/s	Depending on modulation and code rate Maximum 3.74 to 31.67 Mbit/s	7.5- 50.5 Mbit/s	Depending on modulation, code and frame header: maximum 5.0-50.73 Mbit/s	4.8 to 38Mbit/s
Spectrum efficiency (bit/s/Hz)	0.26-10.36	0.28-2.44 0.46-1.86	0.98-6.50	0.66-4.17	0.66-6.52
Single frequency networks	Supported	Supported	Supported	Supported	Supported
Modulation	OFDM	OFDM	OFDM	OFDM	OFDM

Radio spectrum

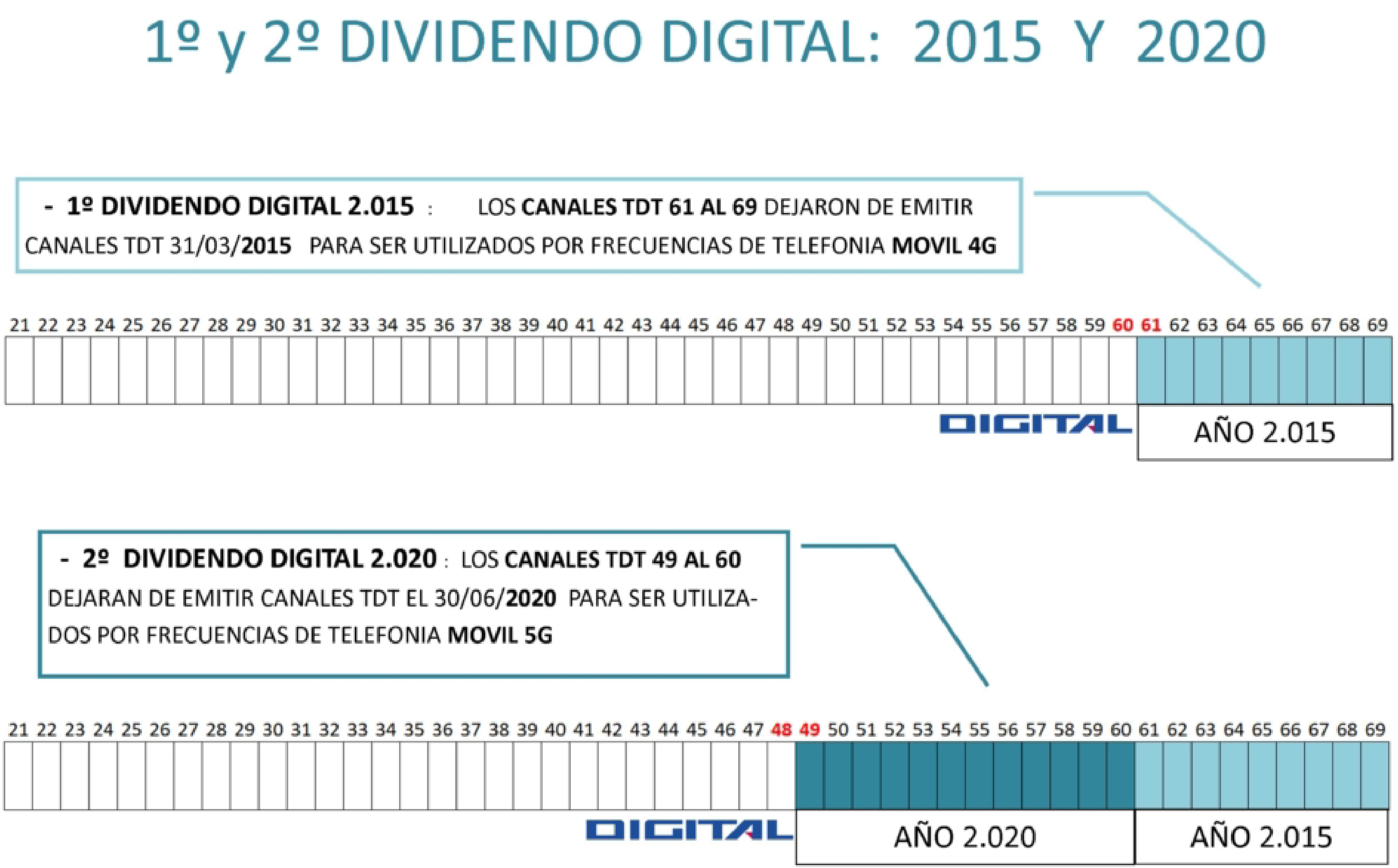
- TV Spectrum
  - ITU Region 1
    - Mainly UHF band: 49 channels (BW=8 MHz) numbered 21 (474 MHz) to 69 (858 MHz)
    - In Europe (2007) the Digital dividend allocated the end of the TV band to mobile services. Channels 61 (794 MHz) to 69 are lost for TV broadcasting. (In Spain deadline has been January 2015)
    - VHF band: 8 MHz or 7 MHz Channels numbered 5 (177.5 MHz) to 12 (226.5 MHz). In Spain this band was reallocated for DAB some years ago.
  - In Other ITU Regions TV channels BW is 6 MHz (Americas) or 5 MHz.
  - Spain:
    - Digital Dividend



Radio spectrum

Spain:

- First Digital Dividend, 2015
- Second Digital Dividend, 2020, 694-790 MHz for mobile



Radio spectrum

- Radio Spectrum (Spain)
  - AM: 9 kHz channels from 526.5 to 1606.5 kHz. Usually a guard channel is left unused between used channels.
  - FM: 100 kHz overlapping channels 87.5 to 108. Channel BW 150 kHz.
  - DAB/DAB+: VHF band: 38 channels (BW=1.7 MHz). Channels are name after the old 7 MHz VHF TV channels. For example former channel 5 is divided in 4 DAB/DAB+ channels (5A, 5B, 5C, 5D).
  - DAB/DAB+: L band: Used for terrestrial and satellite

Band III

5A	174.928 MHz	8A	195.936 MHz	11A	216.928 MHz
5B	176.640 MHz	8B	197.648 MHz	11B	218.640 MHz
5C	178.352 MHz	8C	199.360 MHz	11C	220.352 MHz
5D	180.064 MHz	8D	201.072 MHz	11D	222.064 MHz
6A	181.936 MHz	9A	202.928 MHz	12A	223.936 MHz
6B	183.648 MHz	9B	204.640 MHz	12B	225.648 MHz
6C	185.360 MHz	9C	206.352 MHz	12C	227.360 MHz
6D	187.072 MHz	9D	208.064 MHz	12D	229.072 MHz
7A	188.928 MHz	10A	209.936 MHz	13A	230.784 MHz
7B	190.640 MHz	10B	211.648 MHz	13B	232.496 MHz
7C	192.352 MHz	10C	213.360 MHz	13C	234.208 MHz
7D	194.064 MHz	10D	215.072 MHz	13D	235.776 MHz
				13E	237.488 MHz
				13F	239.200 MHz

L-band

T-DAB		S-DAB			
LA	1452.960 MHz	LJ	1468.368 MHz	LS	1483.776 MHz
LB	1454.672 MHz	LK	1470.080 MHz	LT	1485.488 MHz
LC	1456.384 MHz	LL	1471.792 MHz	LU	1487.200 MHz
LD	1458.096 MHz	LM	1473.504 MHz	LV	1488.912 MHz
LE	1459.808 MHz	LN	1475.216 MHz	LW	1490.624 MHz
LF	1461.520 MHz	LO	1476.928 MHz		
LG	1463.232 MHz	LP	1478.640 MHz		
LH	1464.944 MHz	LQ	1480.352 MHz		
LI	1466.656 MHz	LR	1482.064 MHz		

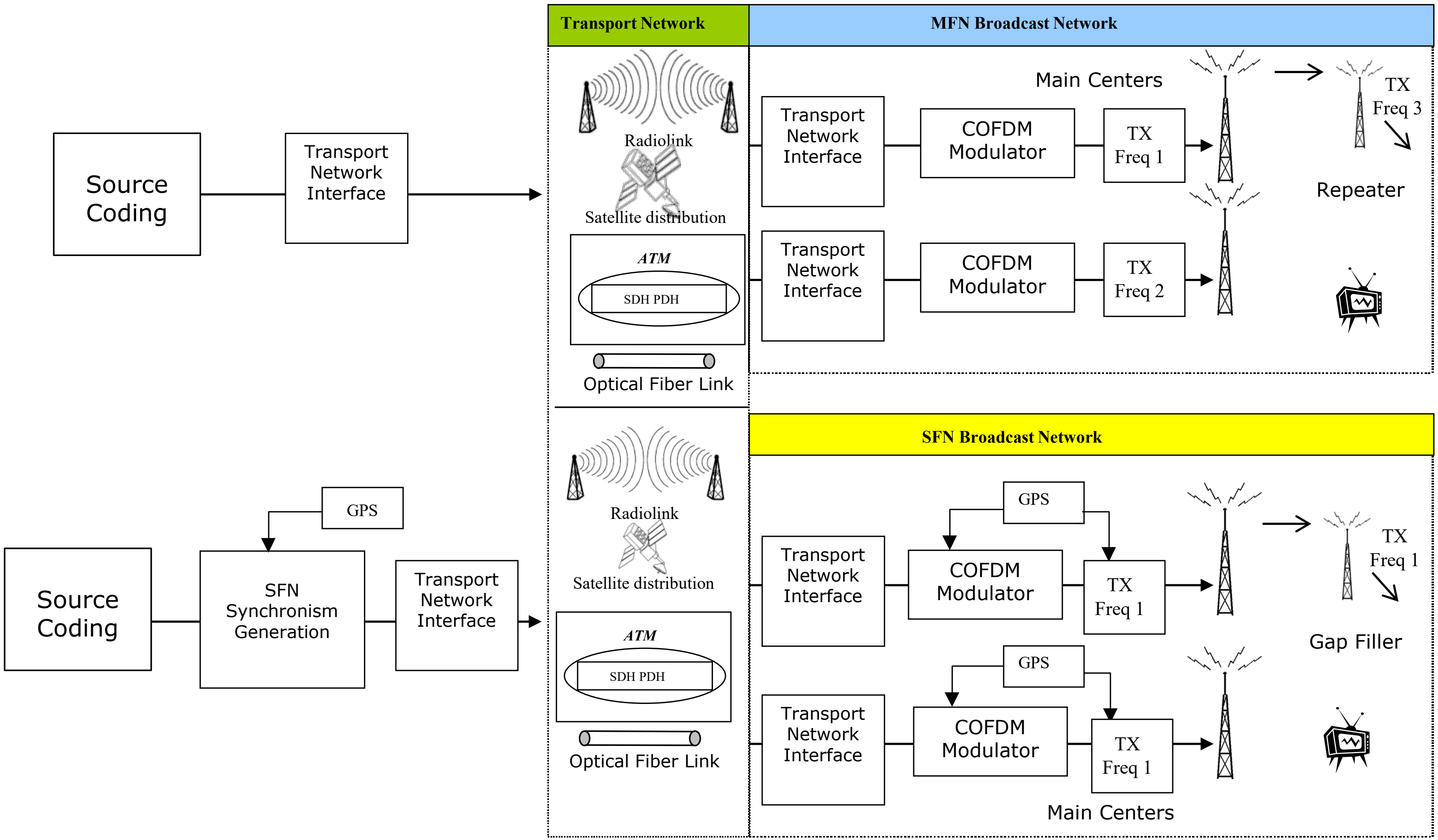
Radio spectrum

- Interferences
  - They are mainly caused by transmitters of the same systems using the same (or similar) frequency, but intended to cover different geographical area.
  - Careful frequency planning must be done to avoid interferences. The used frequencies can not be reused in a certain distance (reuse distance)
  - Coverage area borders are the most critical ones.
  - With digital systems using OFDM, two possible network configurations:
    - Multiple Frequency Networks (MFN).
    - Single Frequency Networks (SFN).
  - Protection ratios are defined to ensure correct reception.
    - The RF protection ratio is the minimum value of wanted-to-unwanted signal ratio, usually expressed in decibels at the receiver input.

Network architecture

- Two parts:
  - Distribution Network: To transport the contents from where they are generated to main transmitters. Point to point. Normally large capacity radio links, or optical fiber links. Some transmission centers are also used as relay nodes for links.
  - Broadcast Network: From transmitter to receivers. Point to multipoint
- Less important transmitters receive the signal from the broadcast network:
  - MFN configuration: Receive the broadcasted signal, change the frequency and amplify it to re-radiate. Repeaters or Transposers.
  - SFN configuration: Receive the broadcasted signal, amplify and re-radiate it at the same frequency. High isolation between Rx and TX antennas and echo cancelation needed to avoid feed-back due to parasitic coupling. Gap-fillers

Network architecture



SFN (Single Frequency Network)

- SFN configuration:
  - Based on COFDM modulation properties, the Digital Video Broadcasting introduced a way to optimize spectrum & bandwidth for DVB-T, namely Single Frequency Network (SFN).
  - Within a Single Frequency Network, all the transmitters from one SFN cell will broadcast over the same frequency, enabling spectrum & bandwidth optimization.
  - It works whenever maximum delay is lower than guard interval. For example: 682 MHz, reception point at 30 km from transmitter1, 40 km from transmitter2, 50 km from transmitter1. Maximum delay (speed of light): (50 km – 30 km)/3e8=66,6 us. Guard interval > 6,66 us

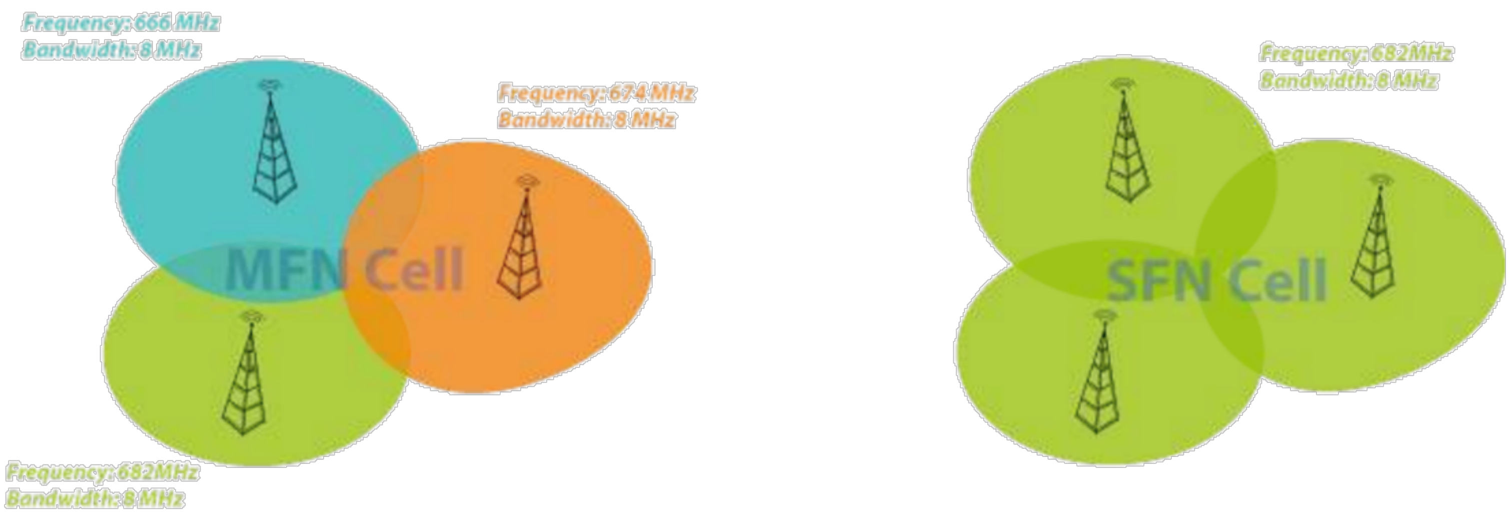
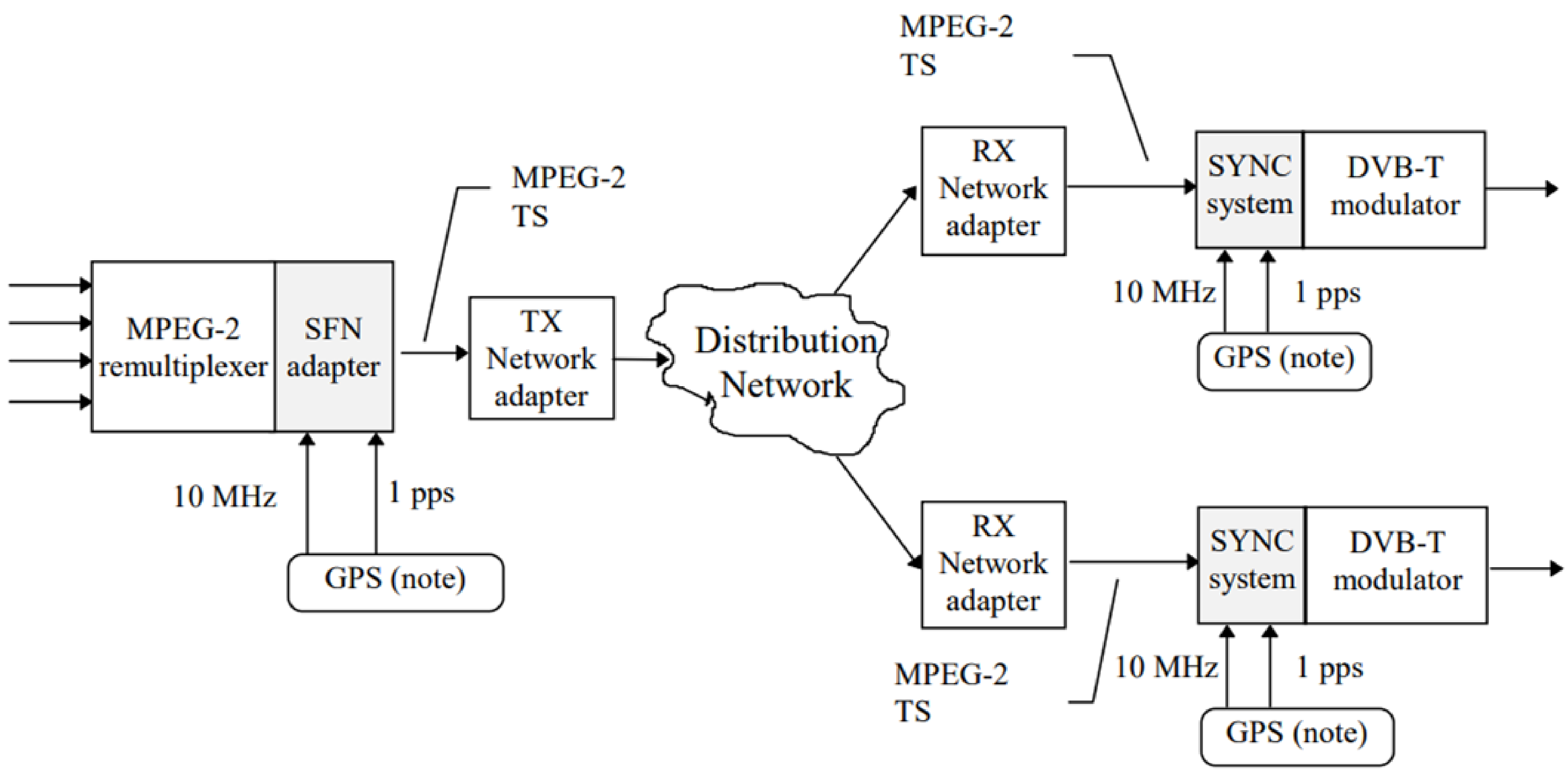


figure 1: Comparison between MFN and SFN topology

Source: Enensys (https://www.enensys.com/)

SFN (Single Frequency Network)

- SFN configuration:
  - Transmitters belonging to one SFN cell shall radiate: 1. over the same frequency 2. at the same time 3. the same OFDM symbols. 2. and 3. imply to provide transmitters with extra information: synchronization and transmission parameters. (SFN adapter + GPS)



Source: Enensys (https://www.enensys.com/)

Propagation: AM Radio and DRM

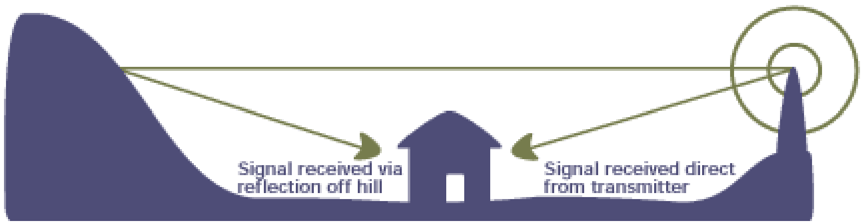
- MF band (526.5 to 1606.5 kHz). **Surface wave propagation.**
- Can propagate over long distances (30 – 200 km)
- Depends on ground constants (conductivity, permittivity)
  - The best propagation medium is sea
  - The worst case are desserts and urban areas (low conductivity and low permittivity values)
  - ITU-R World Map of Conductivities
- Horizontally polarized waves are attenuated significantly
- Practical systems are vertically polarized
- Transmitting antennas vertical dipoles ($\lambda/4$ on earth)
- During the night also sky wave propagation (Ionosphere). E layer, that absorbs these frequencies, vanishes at night. This can cause interferences between transmitters located very far away.

Propagation FM, DRM+, DAB, TV: Space Waves

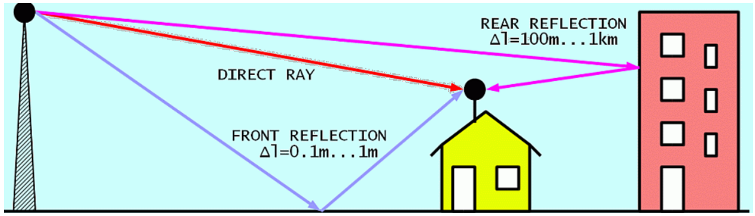
- At these frequency the radio wave propagates as “rays”
- Rays are not infinitesimal but a zone around the transmitter – receiver LOS line (Fresnel ellipsoids)
- Refraction, diffraction, scattering and absorption are relevant phenomena.
- For TV/Radio fixed reception, directive roof-top antennas, LOS. Main propagation phenomena is FSL and multipath.
- For TV/Radio mobile or portable reception, non directive potable antennas, NLOS. Main phenomena is multipath.

Propagation FM, DRM+, DAB, TV: Space Waves

- Multipath
  - Large Scale → orography



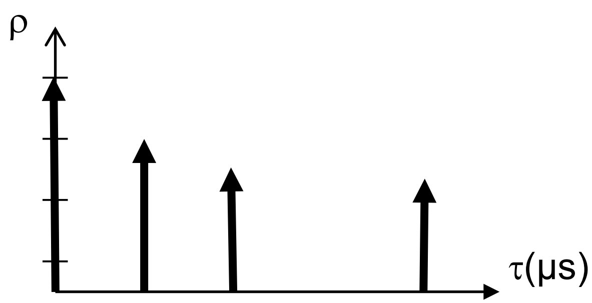
  - Small Scale → obstacles, roofs, urban elements, etc close to the receiver



  - The multipath problem is overcome with antenna directivity (fixed reception) and channel estimation and equalization techniques (mobile and portable)

Propagation FM, DRM+, DAB, TV: Space Waves

- Channels models for fixed reception:
  - Gaussian: Only one path.
  - F1. Ricean: One main path and 20 attenuated and delayed paths. Simulates roof-top antenna reception
  - P1. Rayleigh: Similar to F1, but without main path. Used to describe the fixed portable indoor or outdoor reception conditions.
  - 0 dB echo. This profile only includes two paths. Delay and frequency shift of one path is defined. Used to describe SFN reception



F1 and P1 path definition

i	ρi	τi (µs)	θi (rad)
1	0,057 662	1,003 019	4,855 121
2	0,176 809	5,422 091	3,419 109
3	0,407 163	0,518 650	5,864 470
4	0,303 585	2,751 772	2,215 894
5	0,258 782	0,602 895	3,758 058
6	0,061 831	1,016 585	5,430 202
7	0,150 340	0,143 556	3,952 093
8	0,051 534	0,153 832	1,093 586
9	0,185 074	3,324 866	5,775 198
10	0,400 967	1,935 570	0,154 459
11	0,295 723	0,429 948	5,928 383
12	0,350 825	3,228 872	3,053 023
13	0,262 909	0,848 831	0,628 578
14	0,225 894	0,073 883	2,128 544
15	0,170 996	0,203 952	1,099 463
16	0,149 723	0,194 207	3,462 951
17	0,240 140	0,924 450	3,664 773
18	0,116 587	1,381 320	2,833 799
19	0,221 155	0,640 512	3,334 290
20	0,259 730	1,368 671	0,393 889

Propagation FM, DRM+, DAB, TV: Space Waves

- Channels models for Mobile reception:
  - Doppler effect due to movement. Speed must be defined.
  - TU-6. Typical Urban, 6 paths.
  - Pi and Po: Pedestrian indoor and outdoor.

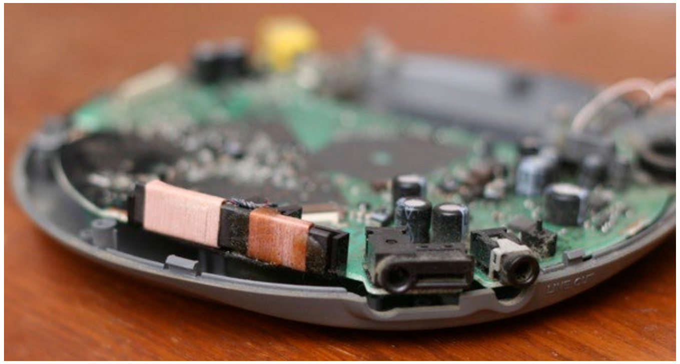
Tap number	Delay (μs)	Power (dB)	Doppler Spectrum
1	0.0	–3	Classical
2	0.2	0	Classical
3	0.5	–2	Classical
4	1.6	–6	Classical
5	2.3	–8	Classical
6	5.0	–10	Classical

TU6 path definition

Design basics: Antennas

- AM/DRM TX Antennas: Vertical Monopoles (λ/4 on earth). Some times forming arrays.

- AM/DRM RX Antennas: Ferrite loop antennas:
  - Small size.
  - Low efficiency.
  - Omnidirectional.

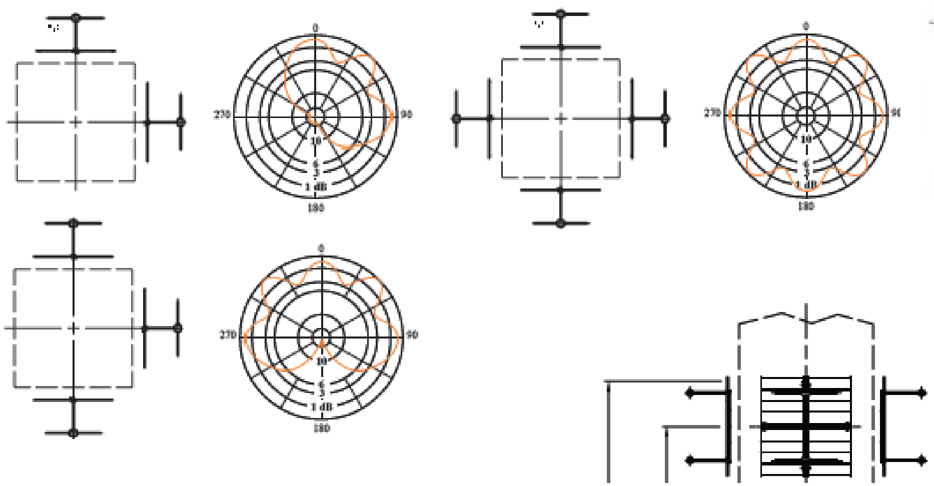


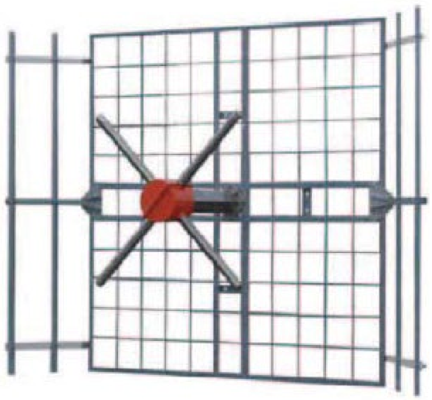
Antennas

- FM Tx Antennas: $\lambda/2$ dipole arrays (panels)
  - Polarization: Horizontal, Vertical or (most common) Mixed (circular).
  - With reflectors to form sectors
  - Gain depends on the number of dipoles and bays: 1 to 15 dBi aprox.
  - Examples: http://www.sira.mi.it/en/products/broadcasting/8

FM-03/32 (8x4)

HORIZONTAL PATTERNS WITH 2, 3 AND 4 FACES AT 98 MHZ



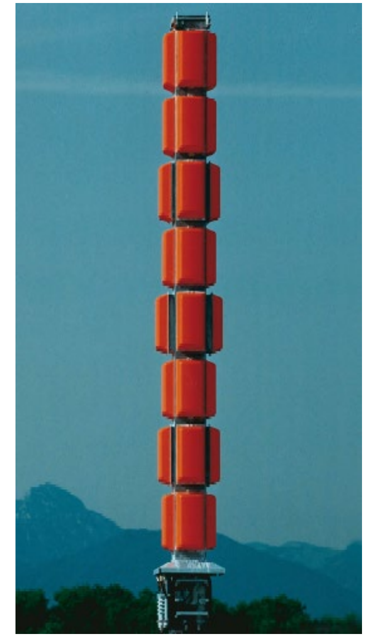


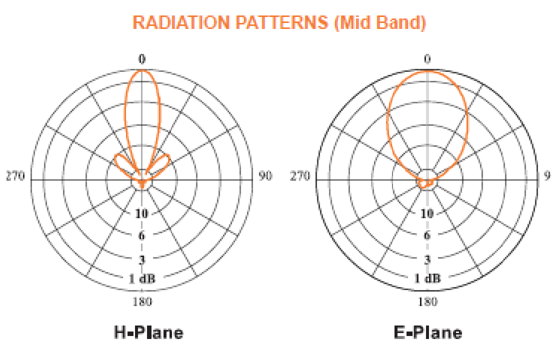
Antennas

- FM Rx Antennas:
  - For roof-top antennas: double folded $\lambda/2$ dipole (circular antenna)
    - Polarization: Horizontal.
    - Omnidirectional (Gain 1 dBi)
    - Examples: http://www.televes.es/en/catalogo/producto/circular-fm-antenna
  - For portable reception: $\approx\lambda/4$ monopoles
    - Telescopic antennas.
    - Many times earphone cable used as antenna.
    - Not very good adaptation, but enough to receive strong signals.

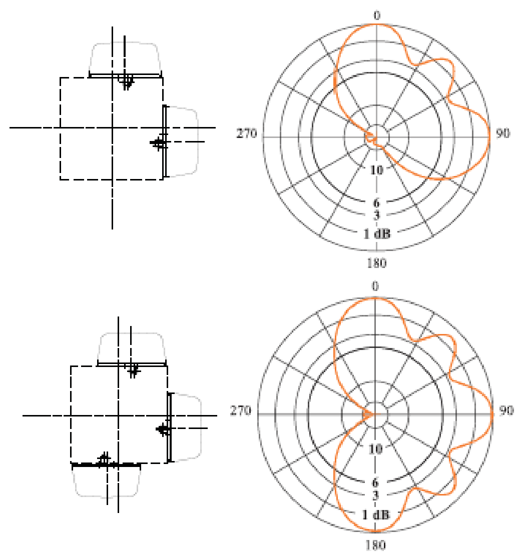
Antennas for TV Broadcasting

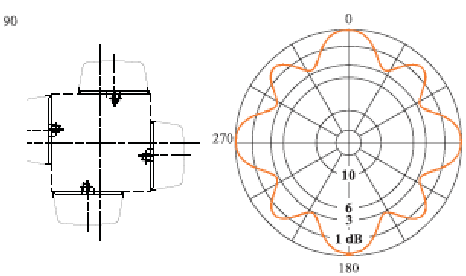
- TV Tx Antennas: $\lambda/2$ dipole arrays (panels)
  - Polarization: Horizontal (most common) or Vertical
  - With reflectors to form sectors
  - Gain depends on the number of dipoles and bays: normal values 12-16 dBi.
  - As frequency is higher than FM, antennas are smaller and dipole arrays are enclosed inside radomes
  - Examples: http://www.sira.mi.it/en/products/broadcasting/8/uhf-antennas/207





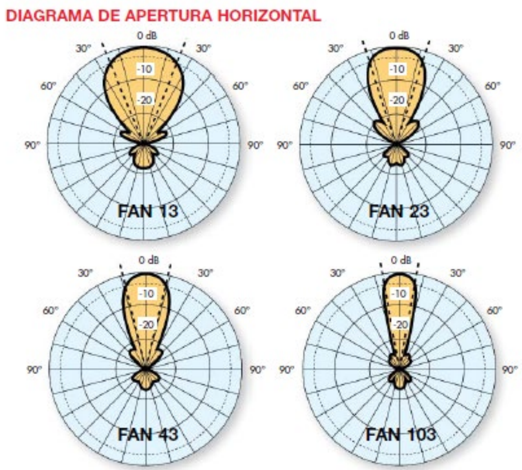
Horizontal antenna example

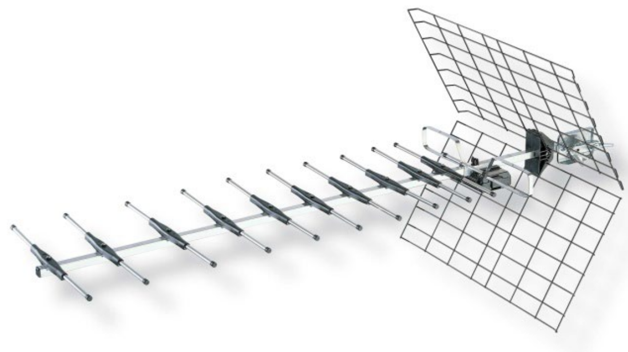




Antennas for TV Broadcasting

- TV Rx Antennas:
  - For roof-top antennas: Uda-Yagi or Log-periodic antennas
    - Polarization: Horizontal or Vertical
    - Directive antennas (Gain 5-17 dBi)
    - Examples: https://www.fagorelectronica.com/es/recepcion-tv

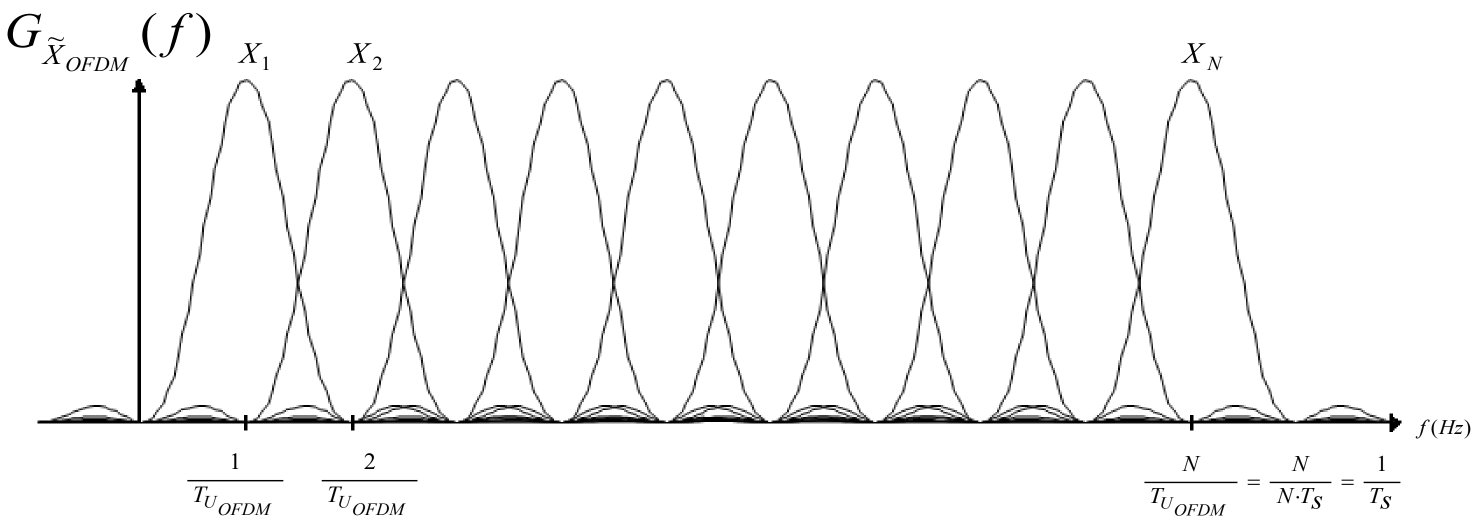




  - For portable reception: $\approx\lambda/4$ monopoles or $\approx\lambda/2$ dipoles
    - Telescopic antennas.
    - Some times with amplifier included (active antennas).
    - Not very good adaptation, but enough to receive strong signals.

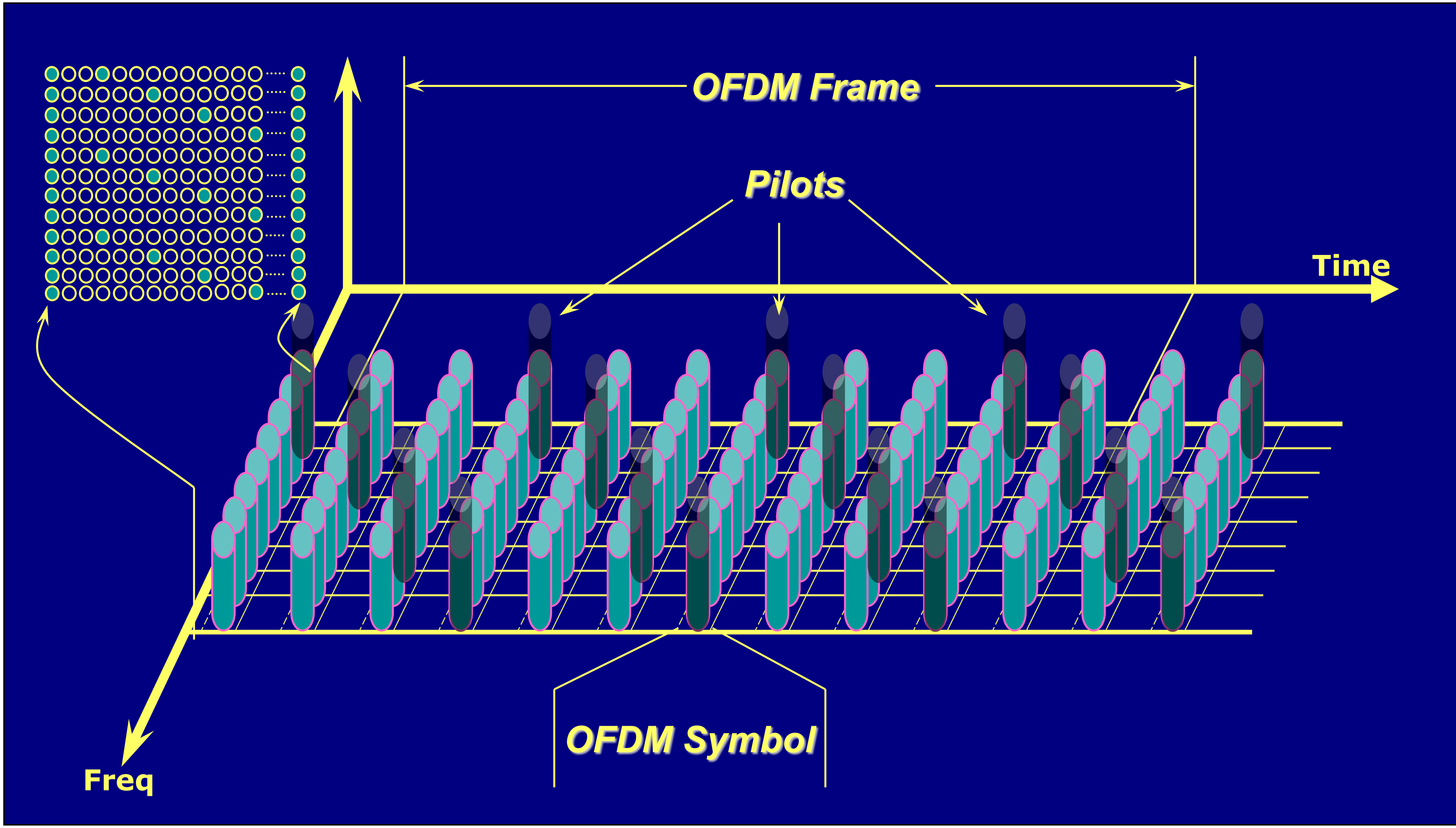
OFDM

- Orthogonal Frequency Division Modulation
- Used in digital Radio and TV broadcasting
- Information is sent in multiple orthogonal carriers (ie DTT in Spain about 8000 carriers)



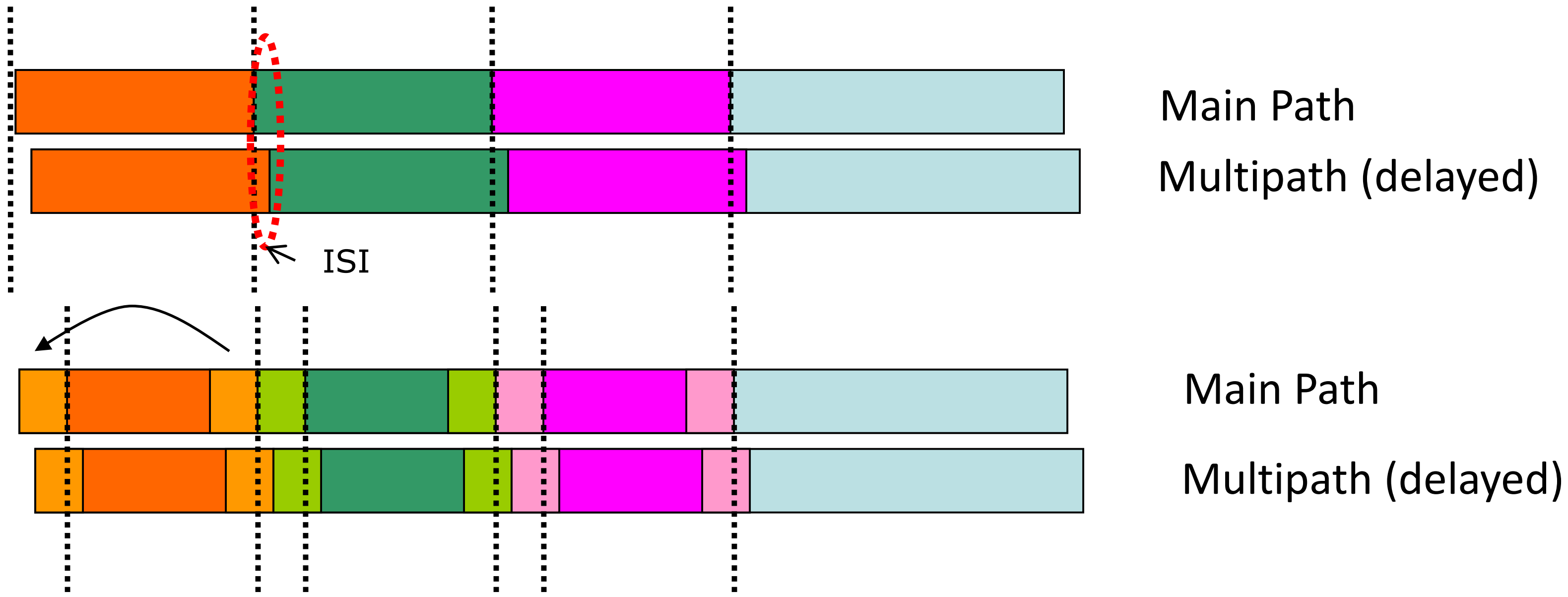
- Pilot Carriers: Usually some of the carriers are not used for data, but for channel estimation needed in the equalization process. DRM(+), DBV-T(2).
- Example: DVB-T

OFDM



OFDM

- Multipath impairment is avoided by guard interval (GI) insertion. Part of the time is wasted for GI, but delay spread does not cause ISI. This technique allows SFN configuration.

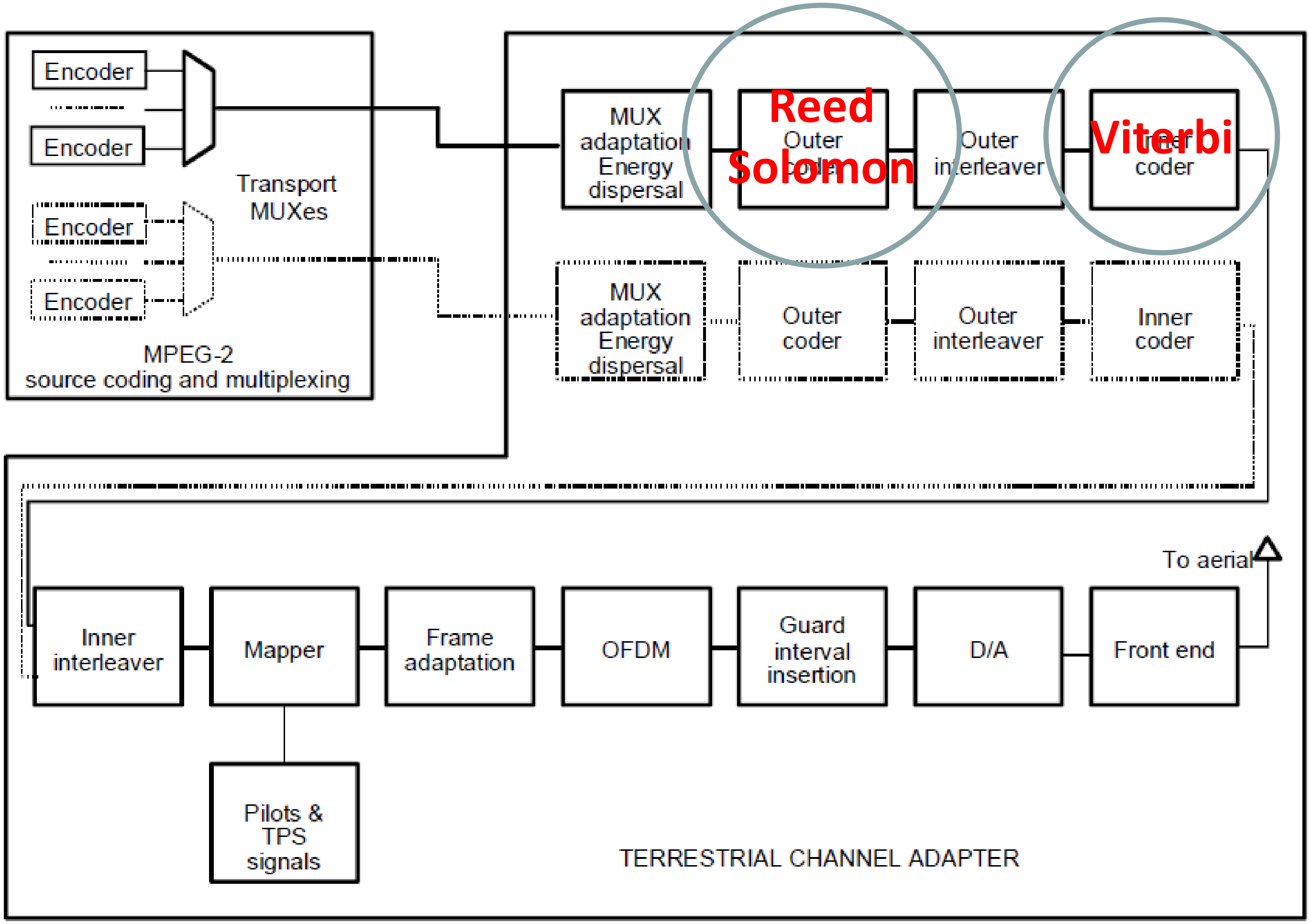


- The length of the GI is set to be a fraction of the symbol duration

Mode	8K mode			
Guard interval Δ / T_U	1/4	1/8	1/16	1/32

Example DVB-T

- Coding: Two concatenated coding:
  - RS (204, 188, t=8): input 188 bytes, output 204
  - Viterbi, code rates= 1/2, 2/3, 3/4, 5/6, 7/8



Example DVB-T

Numerical values for the OFDM parameters for the 8K and 2K modes for 8 MHz channels

Parameter	8K mode	2K mode
Number of carriers K	6 817	1 705
Value of carrier number K_{min}	0	0
Value of carrier number K_{max}	6 816	1 704
Duration T_U (see note 2)	896 μs	224 μs
Carrier spacing $1/T_U$ (see notes 1and 2)	*1 116 Hz*	*4 464 Hz*
Spacing between carriers K_{min} and K_{max} $(K-1)/T_U$ (see note 2)	*7,61 MHz*	*7,61 MHz*
NOTE 1: Values in italics are approximate values. NOTE 2: Values for 8 MHz channels. Values for 6 MHz and 7 MHz channels are given in annex E, tables E.1 and E.2.		

1 512 useful carriers in 2K mode and 6 048 useful carriers in 8K mode

Duration of symbol part for the allowed guard intervals for 8 MHz channels

Mode	8K mode				2K mode			
Guard interval Δ / T_U	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32
Duration of symbol part T_U	$8\ 192 \times T$ 896 μs (see note)				$2\ 048 \times T$ 224 μs (see note)			
Duration of guard interval Δ	$2\ 048 \times T$ 224 μs	$1\ 024 \times T$ 112 μs	$512 \times T$ 56 μs	$256 \times T$ 28 μs	$512 \times T$ 56 μs	$256 \times T$ 28 μs	$128 \times T$ 14 μs	$64 \times T$ 7 μs
Symbol duration $T_S = \Delta + T_U$	$10\ 240 \times T$ 1 120 μs	$9\ 216 \times T$ 1 008 μs	$8\ 704 \times T$ 952 μs	$8\ 448 \times T$ 924 μs	$2\ 560 \times T$ 280 μs	$2\ 304 \times T$ 252 μs	$2\ 176 \times T$ 238 μs	$2\ 112 \times T$ 231 μs
NOTE: Values for 8 MHz channels. Values for 6 MHz and 7 MHz channels are given in tables E.3 and E.4.								

Example DVB-T

- Channels models for fixed reception:
  - Gaussian: Only one path.
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  - P1. Rayleigh: Similar to F1, but without main path. Used to describe the fixed portable indoor or outdoor reception conditions.
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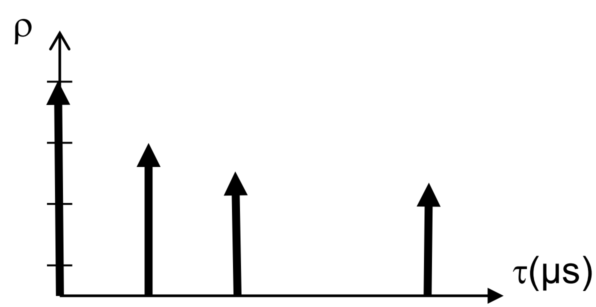

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3	0,407 163	0,518 650	5,864 470
4	0,303 585	2,751 772	2,215 894
5	0,258 782	0,602 895	3,758 058
6	0,061 831	1,016 585	5,430 202
7	0,150 340	0,143 556	3,952 093
8	0,051 534	0,153 832	1,093 586
9	0,185 074	3,324 866	5,775 198
10	0,400 967	1,935 570	0,154 459
11	0,295 723	0,429 948	5,928 383
12	0,350 825	3,228 872	3,053 023
13	0,262 909	0,848 831	0,628 578
14	0,225 894	0,073 883	2,128 544
15	0,170 996	0,203 952	1,099 463
16	0,149 723	0,194 207	3,462 951
17	0,240 140	0,924 450	3,664 773
18	0,116 587	1,381 320	2,833 799
19	0,221 155	0,640 512	3,334 290
20	0,259 730	1,368 671	0,393 889

Example DVB-T

Required C/N for non-hierarchical transmission to achieve a BER = 2×10^{-4} after the Viterbi decoder for all combinations of coding rates and modulation types

		Required C/N for BER = 2×10^{-4} after Viterbi QEF after Reed-Solomon			Bitrate (Mbit/s)			
Modu-lation	Code rate	Gaussian channel	Ricean channel (F_1)	Rayleigh channel (P_1)	Δ/T_U = 1/4	Δ/T_U = 1/8	Δ/T_U = 1/16	Δ/T_U = 1/32
QPSK	1/2	*3,1*	*3,6*	*5,4*	*4,98*	*5,53*	*5,85*	*6,03*
QPSK	2/3	*4,9*	*5,7*	*8,4*	*6,64*	*7,37*	*7,81*	*8,04*
QPSK	3/4	*5,9*	*6,8*	*10,7*	*7,46*	*8,29*	*8,78*	*9,05*
QPSK	5/6	*6,9*	*8,0*	*13,1*	*8,29*	*9,22*	*9,76*	*10,05*
QPSK	7/8	*7,7*	*8,7*	*16,3*	*8,71*	*9,68*	*10,25*	*10,56*
16-QAM	1/2	*8,8*	*9,6*	*11,2*	*9,95*	*11,06*	*11,71*	*12,06*
16-QAM	2/3	*11,1*	*11,6*	*14,2*	*13,27*	*14,75*	*15,61*	*16,09*
16-QAM	3/4	*12,5*	*13,0*	*16,7*	*14,93*	*16,59*	*17,56*	*18,10*
16-QAM	5/6	*13,5*	*14,4*	*19,3*	*16,59*	*18,43*	*19,52*	*20,11*
16-QAM	7/8	*13,9*	*15,0*	*22,8*	*17,42*	*19,35*	*20,49*	*21,11*
64-QAM	1/2	*14,4*	*14,7*	*16,0*	*14,93*	*16,59*	*17,56*	*18,10*
64-QAM	2/3	*16,5*	*17,1*	*19,3*	*19,91*	*22,12*	*23,42*	*24,13*
64-QAM	3/4	*18,0*	*18,6*	*21,7*	*22,39*	*24,88*	*26,35*	*27,14*
64-QAM	5/6	*19,3*	*20,0*	*25,3*	*24,88*	*27,65*	*29,27*	*30,16*
64-QAM	7/8	*20,1*	*21,0*	*27,9*	*26,13*	*29,03*	*30,74*	*31,67*

NOTE 1: Figures in italics are approximate values.
Quasi Error Free (QEF) means less than one uncorrected error event per hour, corresponding to BER = 10^{-11} at the input of the MPEG-2 demultiplexer.

NOTE 2: The net bit rates after the Reed-Solomon decoder are also listed.

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Example DVB-T

Required C/N for non-hierarchical transmission to achieve a BER = 2×10^{-4} after the Viterbi decoder for all combinations of coding rates and modulation types

		Required C/N for BER = 2×10^{-4} after Viterbi QEF after Reed-Solomon			Bitrate (Mbit/s)			
Modu-lation	Code rate	Gaussian channel	Ricean channel (F_1)	Rayleigh channel (P_1)	Δ/T_U = 1/4	Δ/T_U = 1/8	Δ/T_U = 1/16	Δ/T_U = 1/32
QPSK	1/2	*3,1*	*3,6*	*5,4*	*4,98*	*5,53*	*5,85*	*6,03*
QPSK	2/3	*4,9*	*5,7*	*8,4*	*6,64*	*7,37*	*7,81*	*8,04*
QPSK	3/4	*5,9*	*6,8*	*10,7*	*7,46*	*8,29*	*8,78*	*9,05*
QPSK	5/6	*6,9*	*8,0*	*13,1*	*8,29*	*9,22*	*9,76*	*10,05*
QPSK	7/8	*7,7*	*8,7*	*16,3*	*8,71*	*9,68*	*10,25*	*10,56*
16-QAM	1/2	*8,8*	*9,6*	*11,2*	*9,95*	*11,06*	*11,71*	*12,06*
16-QAM	2/3	*11,1*	*11,6*	*14,2*	*13,27*	*14,75*	*15,61*	*16,09*
16-QAM	3/4	*12,5*	*13,0*	*16,7*	*14,93*	*16,59*	*17,56*	*18,10*
16-QAM	5/6	*13,5*	*14,4*	*19,3*	*16,59*	*18,43*	*19,52*	*20,11*
16-QAM	7/8	*13,9*	*15,0*	*22,8*	*17,42*	*19,35*	*20,49*	*21,11*
64-QAM	1/2	*14,4*	*14,7*	*16,0*	*14,93*	*16,59*	*17,56*	*18,10*
64-QAM	2/3	*16,5*	*17,1*	*19,3*	*19,91*	*22,12*	*23,42*	*24,13*
64-QAM	3/4	*18,0*	*18,6*	*21,7*	*22,39*	*24,88*	*26,35*	*27,14*
64-QAM	5/6	*19,3*	*20,0*	*25,3*	*24,88*	*27,65*	*29,27*	*30,16*
64-QAM	7/8	*20,1*	*21,0*	*27,9*	*26,13*	*29,03*	*30,74*	*31,67*

NOTE 1: Figures in italics are approximate values.
Quasi Error Free (QEF) means less than one uncorrected error event per hour, corresponding to BER = 10^{-11} at the input of the MPEG-2 demultiplexer.

NOTE 2: The net bit rates after the Reed-Solomon decoder are also listed.

Conclusions

- Broadcasting – Television:
  - Several standards with similar characteristics
  - Different configurations (modulations, code rate,…)
  - OFDM
  - Single Frequency Networks
  - Guard interval – robust against multipath