Extra Material

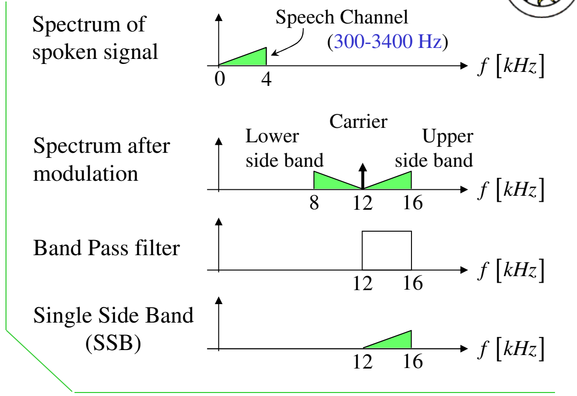
- FMD, FMDA
- TDM
- PDH (Plesiochronous Digital Hierarchy)
- Cross coupling
- Frame structure
- Hierarchy
- SONET and SDH (Synchronous Digital Hierarchy)

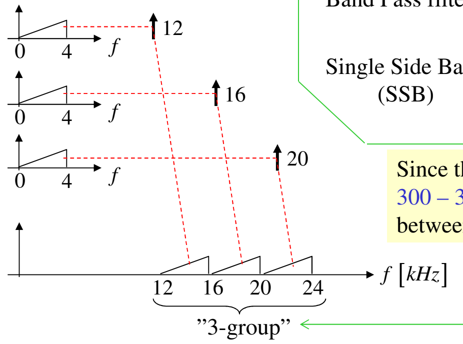
- Visionary future
- Teracom (old pages)
- DAB
- MPEG-2
- Standardization organizations

FDM (analog telephony - old)

FDM =

Frequency **D**ivision **M**ultiplex



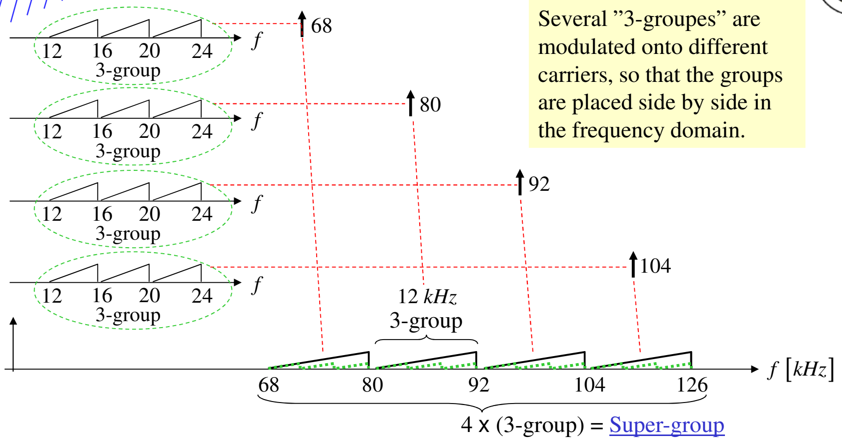


Since the speech channel is between 300 – 3400 Hz there are small spaces between the channels for easier filtering.

3 speech channels are modulated on 3 different carriers.

FDM hierarchy (analog telephony – old)

Several "3-groupes" are modulated onto different carriers, so that the groups are placed side by side in the frequency domain.



[N x Super-group = Master-group]

The grouping and different carrier frequencies are different for different systems (parts of the world). Compare e.g. with the North American system:

http://telecom.tbi.net/index.html "Telecom corner" - Here is a lot of good stuff!

FDM and FDMA

Frequency Division Multiplexing (FDM) is a technique where the carrier bandwidth is divided into sub-channels of different frequency widths, each carrying a signal at the same time in parallel. Each channel is 30 kHz. All the signals may be amplified, conducted, translated in frequency and routed toward a destination as a single signal, resulting in economies which are the motivation for multiplexing. Receivers at the receiving end separates the multiplexed signals by means of frequency passing or rejecting filters, and demodulates the results individually, each in the manner appropriate for the modulation scheme used for that band or group.

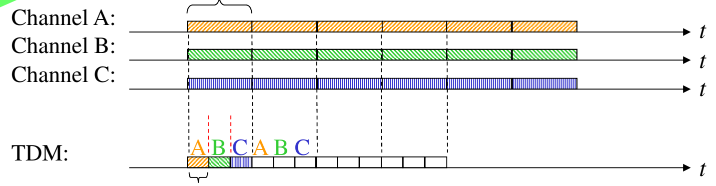
Wavelength Division Multiplex (WDM) and Frequency Division multiplex (FDM) are both based on the same principles but WDM applies to digitized wavelengths of light in optical fiber while FDM is used in analog transmission such as twisted pair telephone line, cable access, cellular, radio and TV communications. TDMA and CDMA are always used in combination with FDMA, i.e., a given frequency channel may be used for either TDMA or CDMA independently of signals on other frequency channels.

Where frequency division multiplexing is used as to allow multiple users to share a physical communications channel, it is called frequency division multiple access (FDMA). FDMA analog transmissions are the least efficient networks since each analog channel can only be used one user at a time. Analog channels don't take full advantage of band-width. Not only are these FDMA channels larger than necessary given modern digital compression, but they are also wasted whenever there is silence during communication. Analog signals are especially susceptible to noise and the extra noise cannot get filtered out.

TDM, PCM First level

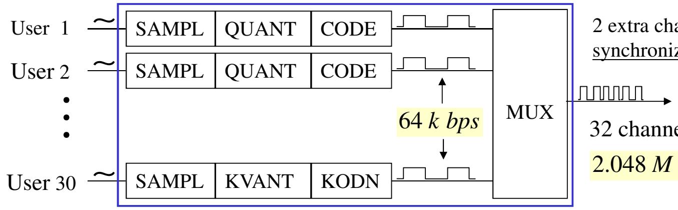
Principle:

$T \approx 15.6\ \mu s \quad \Leftrightarrow \quad 64\ k\ bps$



$\frac{T}{3} \quad \Leftrightarrow \quad 3 \cdot 64\ k\ bps = 192\ k\ bps$

PCM 1st level (or 1st order):



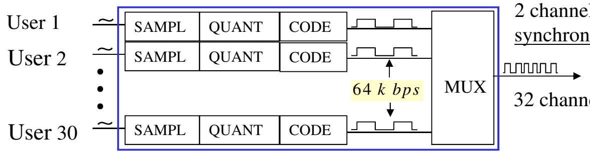
2 extra channels for synchronization and signaling.

32 channels

$2.048\ M\ bps$

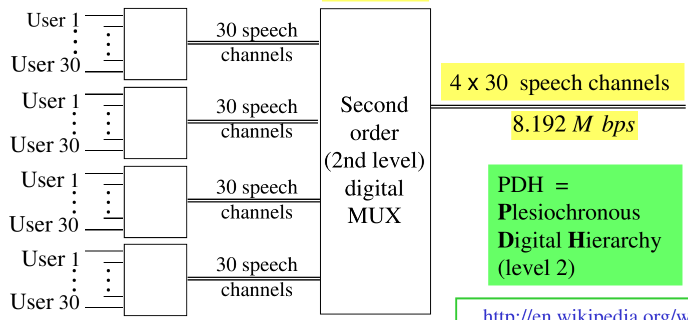
PDH, 2nd order multiplex

PCM First level (or first order):



2 channels used for synchronization and signaling.

32 channels $2.048\ M\ bps$



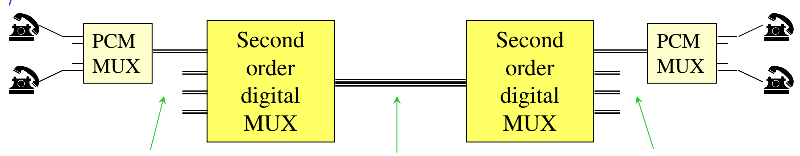
PDH = **P**lesiochronous **D**igital **H**ierarchy (level 2)

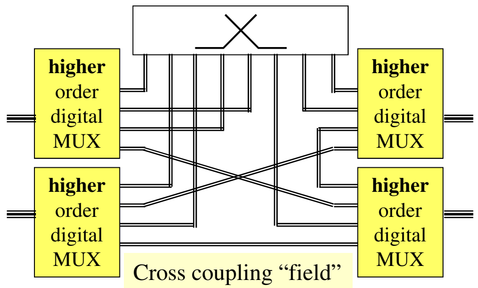
Plesiochronous = Almost but not fully synchronized

http://en.wikipedia.org/wiki/Plesiochronous

Jfr *Att förstå telekom 1* s. 214

Cross coupling





DDF = **D**igital **D**istribution **F**rame

The PDH structure is "stiff". To re-connect or "tap off" a part of the main flow one need to de-multiplex step by step down to the correct level and then multiplex up again to the wanted main flow level.

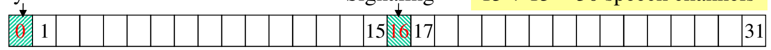
The reconnection is done in a cross coupling field.

Jfr *Att förstå telekom 1* s. 212

Frame structure

European PCM-frame:

Synchronization Signaling 15 + 15 = 30 speech channels



32 time slots x 8 bits x 8 k (sample/sek) = 2048 $k\ bps$ $\rightarrow$ **2-megabit, E1**

North American PCM-frame:

(24 time slots x (8 bits +1)) x 8 k (sample/sek) = 1544 $k\ bps$ $\rightarrow$ **1.5-megabit, T1**

1 frame synchronization bit per sample

Jfr *Att förstå telekom I* s. 213

Hierarchy

Level	Europe	North-America	Japan
4	139 246 *k bps*	139 246 *k bps*	97 728 *k bps*
	x 4	x 3	x 3
3	34 368 *k bps*	44 736 *k bps*	32 064 *k bps*
	x 4	x 7	x 5
2	8 448 *k bps*	6 312 *k bps*	6 312 *k bps*
	x 4	x 4	x 4
1	2 048 *k bps*	1 544 *k bps*	1 544 *k bps*
	x 32	x 24	x 24
0	64 *k bps*	64 *k bps*	64 *k bps*

SONET and SDH, [web]

http://en.wikipedia.org/wiki/Plesiochronous

The modern tendency in system engineering is towards using systems that are either fundamentally asynchronous (such as Ethernet), or fundamentally synchronous (such as Synchronous optical networking, SONET), and layering these where necessary, rather than using a mixture between the two in a single technology.

https://en.wikipedia.org/wiki/Synchronous_optical_networking

Synchronous optical networking (SONET) and
Synchronous digital hierarchy (SDH) are
standardized multiplexing protocols that transfer multiple digital bit streams over optical fiber using lasers or light-emitting diodes (LEDs).
Lower rates can also be transferred via an electrical interface.
The method was developed to replace the plesiochronous digital hierarchy (PDH) system for transporting larger amounts of telephone calls and data traffic over the same fibre wire without synchronization problems.

Future Wireless Communication

From *Elektronik i Norden*, nr 10/2011, p 11. (Reporter Jan Zettergren)

VISONARY Professor Ken Sakamura (Tokyo)

Vision **from** 1988:
In 25 years all persons will ”have ” 100 processors each.
[A quite ”aggressive” vision.]
[At that time there was, say, 1 processor per 10 000 persons, in average.]
This seemed to be an exaggerating prediction,
but for our part of the world it is at least almost so.

Vision for 2035: Ubiquitous, global wireless communication.
We have the sensors, the calculation capacity,
but we still miss a unifying robust and open wireless communication ”platform”
– something that is robust enough to withstand catastrophic situations.

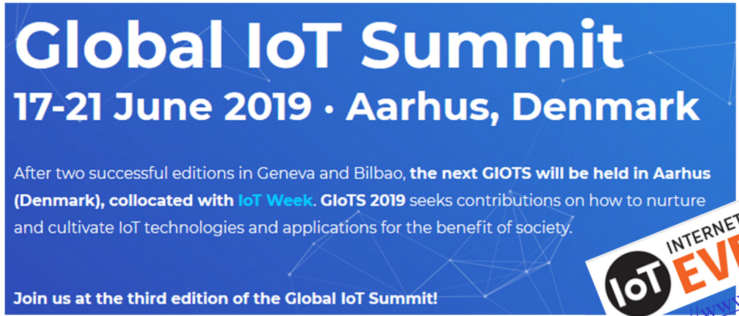
From *Elektronik i Norden*, nr 10/2011, p 11.

VISONARY Professor Ken Sakamura (Tokyo)

- The ”internet of things” / Intelligent objects. In the future not only people but also machines and objects can talk to each other and will have intelligence. (We see the beginning of this era now already.)
- There has been a focus towards the development of hardware, but in the future there will be a shift towards a focus on the overall systems (the fullness or completeness of the systems).
- Key word: ”Connect, Connect, Connect” (anywhere, whenever, without bounds).
- ”Ubiquitous networking, Ubiquitous objects, Ubiquitous computing.”
- Dynamic allocation/configuration of ‘thin clients’ (light, low power, less hardware to carry) in a variety of ‘cloud services’.
- New protocols to handle information without formal structure. More broadcasting (not point-to-point focus as of today).

Examples of IoT conferences 2019

https://globaliotsummit.org/



INTERNET OF THINGS IoT EVENTS https://www.iotevents.org/

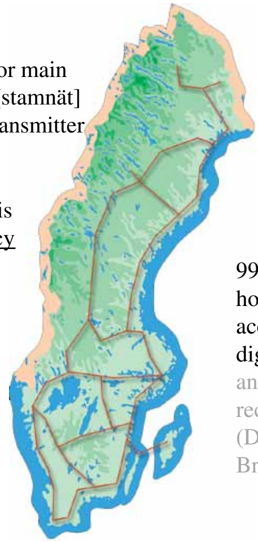
http://www.cse.chalmers.se/~russo/ssiot19/

Teracoms main distribution network

From old pages about Teracom)

Teracom's backbone or main distribution network [stamnät] consists of 54 large transmitter stations.

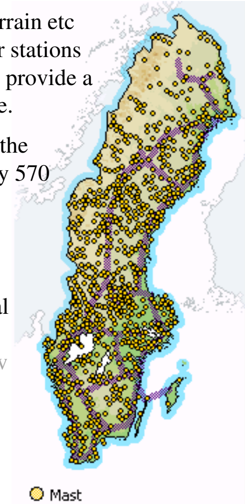
Reliability in the net is secured by redundancy (- alternative distribution links or "highways").



Due to hilly terrain etc a lot of smaller stations is necessary to provide a better coverage.

Together with the backbone, fully 570 stations.

99,8 % of the households have access to terrestrial digital TV and 35 % can now receive DAB (Digital Audio Broadcast).



https://www.teracom.se/privat/radio/frekvenstabeller-radio/

(Information from old page)

	Station	Frequency [MHz]	ERP [Watt]	Polari-zation	Ground height [meter]	Antenna height [meter]
Karlstad, Sörmon	SR P1	90.5	15 000	H	101	139
	Karlstads närradio	92.2	100	V	"	100
	SR P2	94.2	15 000	H	"	139
	SR P3	96.5	15 000	H	"	139
	SR P4 Värmland	103.5	15 000	H	"	139
	RIX FM	104.4	5 000	V	"	100
	Radio City	105.4	5 000	H	"	140
Filipstad, Klockarhöjden (reduced in direction west)	SR P1	88.5	2 500	H	290	262
	SR P2	90.1	2 500	H	"	262
	SR P3	98.8	2 500	H	"	262
	SR P4 Värmland	103.2	2 500	H	"	262
Örebro, Lockhyttan	SR P1	87.9	60 000	H	254	272
	SR P2	91.5	60 000	H	"	272
	SR P4 Örebro	102.8	60 000	H	"	272

"Radio Sweden" (closed down 2009)

Short wave and Medium wave distribution ended in October 2010

NAME	Frequency	Wave-length	Antenna power	Direction of max radiation
Medium wave				
Sölvesborg	1179 kHz	254 m	600 kW	60°, 270°

"Foreign" program (in Swedish) to north Europe

Short wave	Equipment
Hörby	Three 500 kW transmitters, 5 950 - 21 750 kHz Directive "curtain" antennas in the directions 70° , 150°, 190°, 250°, 290°

"Foreign" program (in Swedish) to the whole world

DAB (Digital Audio Broadcast)

DAB coverage in Sweden 2002 (until present)

Sweden was very early with introducing DAB, financed via the Swedish government.
However, very few people adopted the new technology, and the funding was decreased.

Now (from 2002), DAB can be received in the Stockholm, Gothenburg, Malmö and Luleå area only, covering about 35 % of the population,
(compared with 85 % in the late 1990-ies).

DAB advantages compared to FM

DAB (Digital Audio Broadcasting) has many advantages compared to classical FM.

- **More channels.**
Advanced digital signal processing makes it possible to pack more channels (more programs) into a certain bandwidth. Compare with ”Single frequency network”.

- **Sound quality.**
Digital radio gives a noise free sound, comparable with a CD.

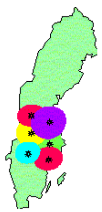
- **Mobile reception.**
Often one listen to radio in the car. Digital radio gives better mobile reception, without ”crackles”.

- **New services.**
Digital radio is able to provide multimedia, pictures, file transfer and streaming.

DAB, Single Frequency Network

Same frequency for the whole country

On transmit there are differences between FM and DAB.
In a single frequency network you can send 4-6 stereo programs covering the whole country, within the same bandwidth as needed for one FM channel.
If you instead choose mono, the number can be doubled.



FM
Nearby transmitters have to use different frequencies in order not to disturb (interfere with) each other.

DAB
All transmitters use the same carrier frequency (Single Frequency Network).

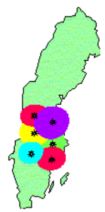
This is possible due to advanced digital signal processing, where signals from different transmitters can be phase shifted to add coherently, thus enhancing each other (instead of interfering destructively with each other).

An important consequence is that the total transmitted power can be reduced.

DAB, Dynamic Range Control

Same frequency for the whole country

On transmit there are differences between FM and DAB.
In a single frequency network you can send 4-6 stereo programs covering the whole country, within the same bandwidth as needed for one FM channel.
If you instead choose mono, the number can be doubled.



FM
Nearby transmitters have to use different frequencies in order not to disturb (interfere with) each other.

DAB
All transmitters use the same carrier frequency (Single Frequency Network).

This is possible due to advanced digital signal processing, where signals from different transmitters can be phase shifted to add coherently, thus enhancing each other (instead of interfering destructively with each other).

An important consequence is that the total transmitted power can be reduced.

DAB, The signal structure

Construction of the signal:
The DAB signal consists of three parts, or transport channels:

- **Syncronization channel (S)** (carries no information)
- **Fast Information Channel (FIC)** contains ”contents”, RDS- data and a data channel with limited capacity.
- **Main Service Channel (MSC)** main channel for information

S	FIC	Main Service Channel

Just after the synchronization, the FIC data is first received.
This is information on how the capacity in the MSC is divided between different services, so-called Multiplex Configuration Information (MCI).
Further, information about name and code for the ensemble and actual services, flags, frequency information and other RDS-like content.

DAB, Generation of signal

http://www.worlddab.org/eureka.aspx (old page)

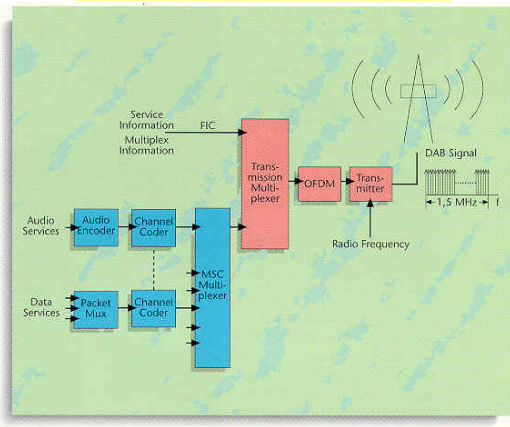


Fig. 1: Generation of the DAB Signal

Generation of the DAB Signal

You will see in Figure 1 how each service signal is coded individually at source level, error protected and time interleaved in the channel coder. Then the services are multiplexed in the Main Service Channel (MSC), according to a pre-determined, but adjustable, multiplex configuration. The multiplexer output is combined with Multiplex Control and Service information, which travel in the fast Information Channel (FIC), to form the transmission frames in the Transmission Multimplexer.

Finally, **Orthogonal Frequency Division Multiplexing** (**OFDM**) is applied to shape the DAB signal, which consists of a large number of carriers. The signal is then transposed to the appropriate radio frequency band, amplified and transmitted.

DAB, Reception of signal

Reception of a DAB signal

Figure 2 demonstrates a conceptual DAB receiver.

The DAB ensemble is selected in the analogue tuner, the digitised output of which is fed to the OFDM demodulator and channel decoder to eliminate transmission errors.

The information contained in the FIC is passed to the user interface for service selection and is used to set the receiver appropriately. The MSC data is further processed in an audio decoder to produce the left and right audio signals or in a data decoder (Packet Demux) as appropriate.

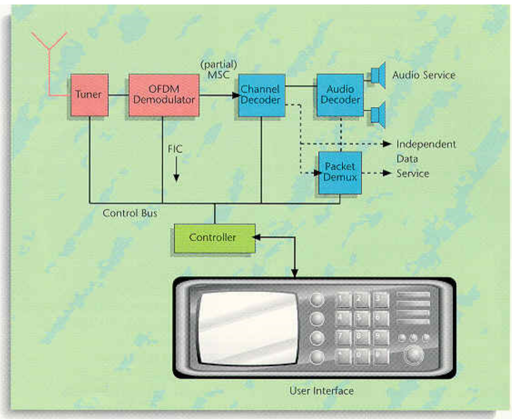


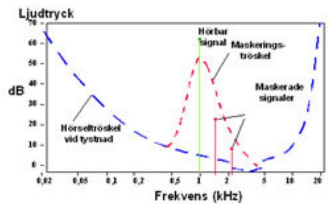
Fig. 2 : Conceptual DAB Receiver

DAB, Ljudkodning

Ljudkodning
En av målsättningarna under utvecklingsarbetet var att ljudkvaliteten skulle motsvara CD-kvalitet. På en CD är datahastigheten c:a 1,4 miljoner bitar per sekund, 1,4 Mbit/s. Genom s k perceptuell kodning kan datahastigheten reduceras med c:a 80% utan att ljudkvaliteten subjektivt försämras.

De bitar som tas bort är dels redundans, d v s bitar som inte bär någon information men som är nödvändiga för att till exempel CD-systemet skall fungera, och dels irrelevans, det vill säga bitar som bär information som inte är uppfattbar för den mänskliga hörseln. I det senare fallet är det i första hand örats maskeringseffekter som kan utnyttjas.

Utvecklingen av avancerad ljudkodning har varit mycket snabb under de senaste åren och har funnit en stor mängd användningsområden. Den ljudkodning som används i DAB är standardiserad av ISO/IEC. Standarden medger användning av ett stort antal datahastigheter mellan 32 kbit/s och 384/ kbit/s. Samplingstakten är alltid 48 kHz i DAB och ljudkvaliteten sjunker naturligtvis med lägre hastigheter. En mängd lyssningsprov som genomförts över hela världen har visat att en hastighet på något över 200 kbit/s inte ger någon subjektiv skillnad från en CD.

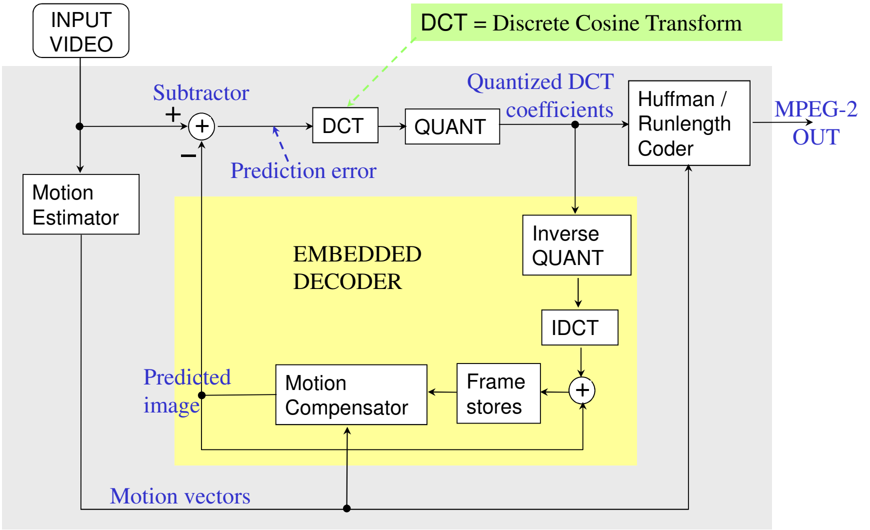


I en utveckling av ISO/IEC-standarden har också s.k. halv samplingstakt standardiserats. Detta ger högre ljudkvalitet vid låga datahastigheter och har införts i den revidering av DAB-standarden som nyligen antagits. Detta möjliggör tal- eller meddelandekanaler med god ljudkvalitet vid 64 eller 32 kbit/s.

MPEG-2 Encoder

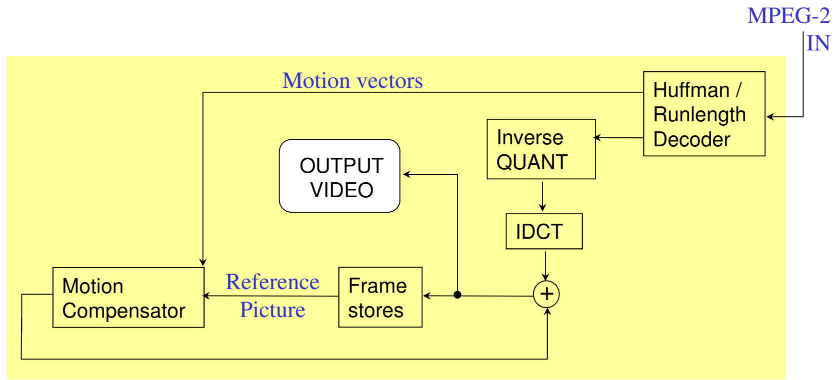
http://www.bretl.com/mpeghtml/codecdia1.htm (old page)

DCT = Discrete Cosine Transform



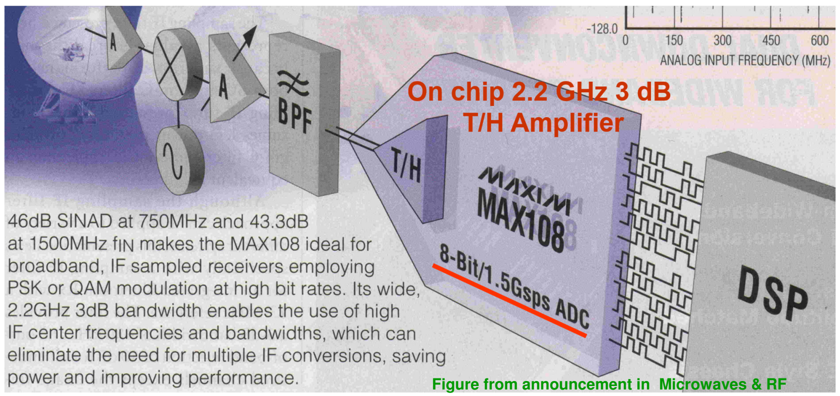
MPEG-2 Decoder

http://www.bretl.com/mpeghtml/codecdia1.htm (old page)



RF/IF sampling (under-sampling)

See eg: https://www.eetimes.com/document.asp?doc_id=1272390



Standardization Organizations

DVB (Digital Video Broadcasting) www.dvb.org

ITU (International Telecommunications Union) www.itu.int

CEPT (European Conference of Postal and Telecommunications Administrations) www.cept.org

ISO/IEC www.iso.ch ISO is a worldwide federation of national standardization organizations from ca 140 countries.

ETSI (the European Telecommunications Standards Institute) www.etsi.org

CENELEC www.cenelec.org [European standardization body]

ITS/SEK www.its.se [organizes Swedish cooperation within ETSI, ITU, ISO/IEC and CENELEC]

RDS Forum www.rds.org.uk

EBU (European Broadcasting Union) www.ebu.ch