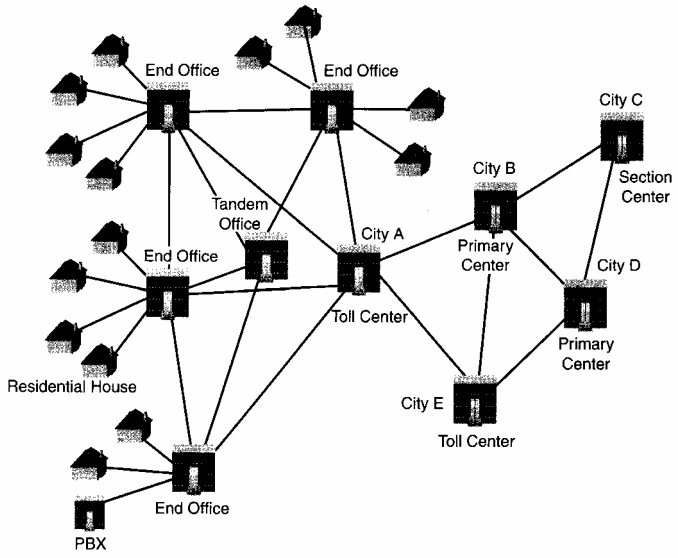
Telecommunication systems

Telecommunication system

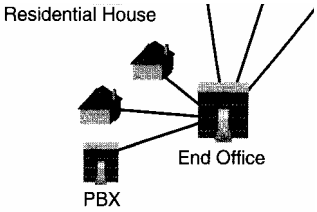
- The ***public-switched telephone network*** (PSTN) was originally analogue, but during the last 30 years it has been transformed into an almost fully digital system.
- One strong motivation for the change from analogue to digital system is that analogue signals become distorted when transported over long distances, i.e., the signal is subject for attenuation and interference.
- In analogue systems the signal is amplified repeatedly when transported over long distances, unfortunately one also amplify the interference at each amplifier.
- In digital systems we can regenerate the bit pattern repeatedly instead of just amplify the signal.
- The digital information is regenerated and can be transported without increased interference over long distance.

Telecommunication system



Telecommunication system

Subscriber – Central Office



- ***Central Office*** (CO)
- *end COs*
- < 10000 subscribers for one CO switching machine.
- The twisted pair telephone loop connecting a subscriber to an end CO is called ***subscriber loop*** (analogue).
- Large business customers are served through a ***Private Branch Exchange*** (PBX)

Telecommunication system

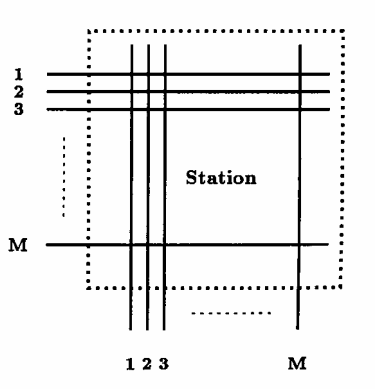
- COs in local regions are connected through ***interoffice trunks*** or ***tandem trunks*** and ***tandem COs*** by the means of a still evolving digital communication hierarchy.
- Telephone connections beyond the local region are made possible through the toll centers
- Above the toll center level are the ***primary centers***.
- ***Sectional center***.
- ***Regional center***.
- Centers are all connected through ***toll trunks***.

Telecommunication system

- Analogue voice channels are digitized once they are terminated at end CO.
- Digital channel banks, which consists of ***subscriber loop line cards*** and a high speed ***Time Division Multiplexing bus*** convert analogue ***voice signal*** as well as ***signaling information*** (such as source and destination address) into digital format. The resulting digital signal is combined into ***a single digital bit stream*** which is going to be integrated into the digital hierarchy.

Telecommunication system

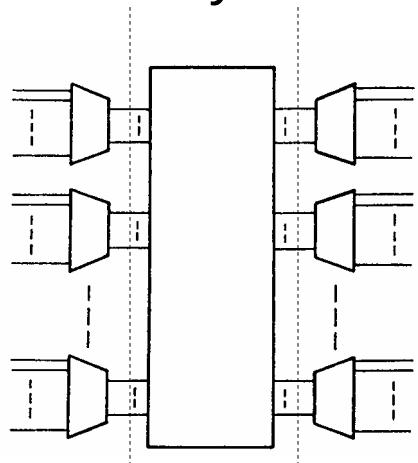
- Since the local station CO should be able to connect any subscriber to any other subscriber in the local area one can see that the station is consisting of a switching matrix.
- The matrix would then have *M* (number of subscribers) rows and columns.
- When subscriber *i* want to reach subscriber *j* the connection *c*(*i*,*j*) is activated.
- This is however not an realistic solution but can be seen as a model, since the utilization of each subscriber loop is very low.



Telecommunication system

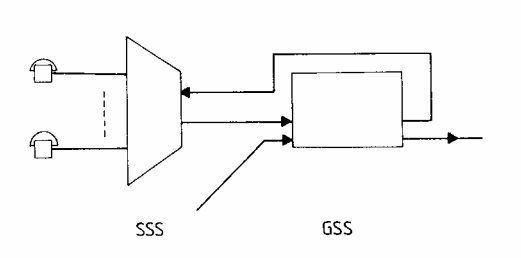
In order to increase the utilization of the connection points, the incoming subscriber loops are concentrated (multiplexed), i.e., the *M* incoming cabels sharing *m* channels where *m*<*M*.

In the switching core, the second stage of the station's fundamental parts, the connection is set up between two subscribers.



Subscriber subsystem (SSS) | Group subsystem (GSS) | Subscriber subsystem (SSS)

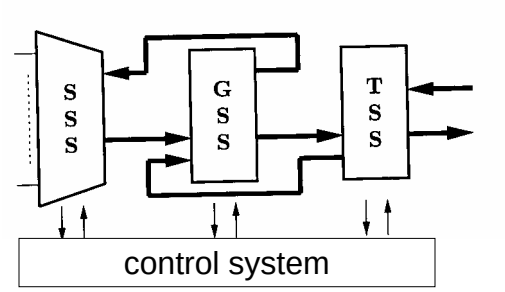
Telecommunication system



Traffic from other stations are already concentrated and is treated as any local group by the group switch.

Since the expansion step is an inverted concentration stage it can actually be the same stage.

Telecommunication system



Here a trunc and signaling system (TSS) is introduced, which controls the connections to other stations.

A control system is also added, which tasks are to detect new calls, calculate new connection paths, perform number analysis for further connections through the switch, set up connections and remove connections etc.

Telecommunication system

- The current digital hierarchy has transmission rates of 64 Kpbs (1 channel), 2.048 Mbps (30 channels), 8.448 Mbps (120 channels), 34.368Mbps (480 channels), 139.264Mbps (1920 channels) and 564.992 (7680 channels).
- These transmission throughputs are mainly implemented by E1, E2, E3 and E4 carrier systems based on a variety of transmission media, such as digital radio links, coaxial cable, twisted pair cables and fiber-optic cable.
- The evolving higher speed digital hierarchy synchronous digital hierarchy (SDH) provides even higher throughputs.

Telecommunication system

Signal	Digital Bit Rate	Channels
E0	64 kbit/s	One 64 kbit/s
E1	2.048 Mbit/s	32 E0
E2	8.448 Mbit/s	128 E0
E3	34.368 Mbit/s	16 E1
E4	139.264 Mbit/s	64 E1

Bit Rate	Abbreviated	SDH	SDH Capacity
51.84 Mbit/s	51 Mbit/s	STM-0	21 E1
155.52 Mbit/s	155 Mbit/s	STM-1	63 E1 or 1 E4
622.08 Mbit/s	622 Mbit/s	STM-4	252 E1 or 4 E4
2488.32 Mbit/s	2.4 Gbit/s	STM-16	1008 E1 or 16 E4
9953.28 Mbit/s	10 Gbit/s	STM-64	4032 E1 or 64 E4
39813.12 Mbit/s	40 Gbit/s	STM-256	16128 E1 or 256 E4

STM = Synchronous Transport Module

Telecommunication system

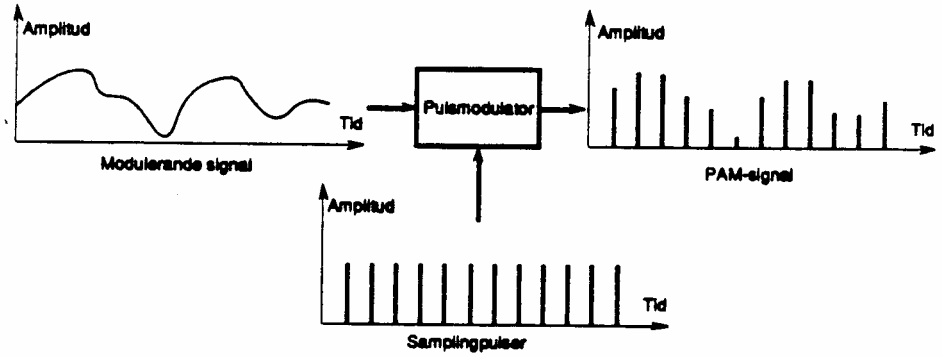
- This digital hierarchy is built upon the pulse coded modulation (PCM) system.
- The basic operations PCM system builds upon are sampling, quantizing, coding and channel multiplexing.

Pulse Coded Modulation System

Sampling

Voice is a continuous signal where the amplitude varies over time.

By sampling periodically we can describe the curve as a number of pulses with different amplitudes (samples).



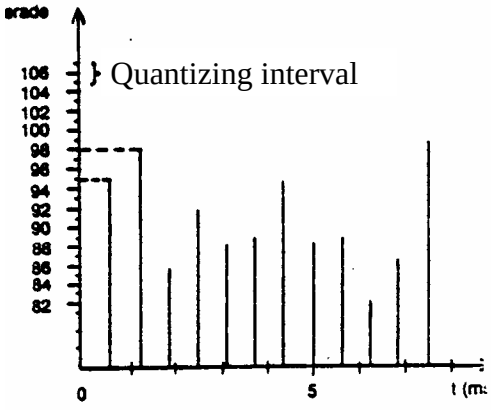
Pulse Coded Modulation System

- As can be seen some of the information is missing the higher rate that we sample the continuous signal the better we can represent it with the samples.
- The sampling rate is 8000 Hz, given by Nyquist's ***sampling theorem*** (f_s=2B) assuming a voice signal is in the 300 – 3400 Hz intervall.
- The result is ***pulse amplitude modulated*** (PAM) signal.

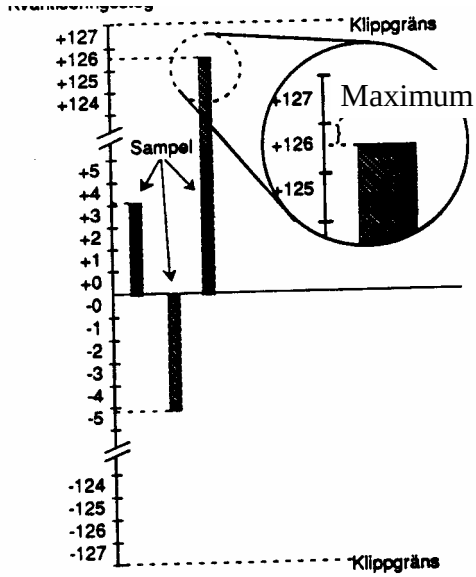
Pulse Coded Modulation System

Quantizing

We measure the height of each pulse in a PAM signal and gives each pulse a value. In order not to have an infinite number of possible values we divide the amplitude into intervalls.



Pulse Coded Modulation System



Maximum error 1/2 a step

Each sample is 8 bits which gives 256 different levels, each sample has a value between +/- 128.

Pulse Coded Modulation System

Since we use only a number of levels in the quantizing process, it gives rise to quantizing distortion.

The maximum error that can occur is half a step, if one decreases the step size, i.e., use more steps, the quantizing distortion should become lower.

However, a more fine-grained quantization requires more bits for transmission which means more bandwidth.

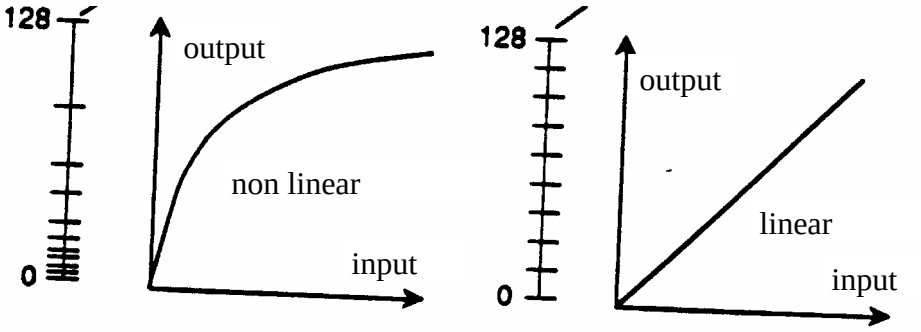
It is not the distortion's absolute value that are important, it is the ratio between the signal and the distortion that is important.

In order to differ distortion from common noise one use S/Q instead of S/N as a quality measure.

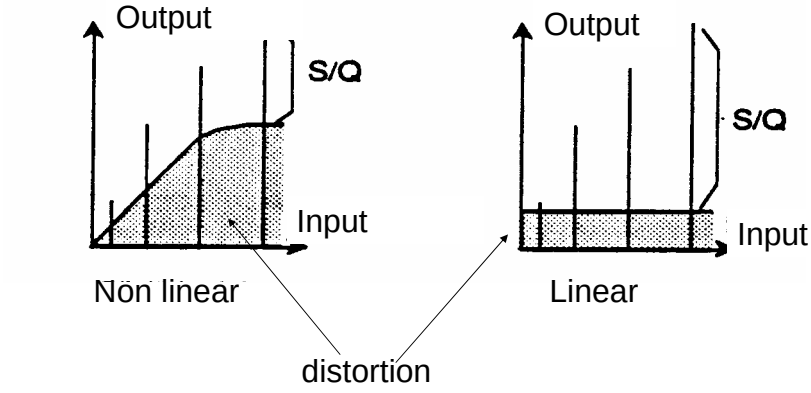
Pulse Coded Modulation System

If the quantization steps are linear, i.e., the quantization steps are equally sized, the S/Q ration become un-necessary good for strong signals and very bad for weak signals.

Therefore non linear quatization in used in PCM systems.

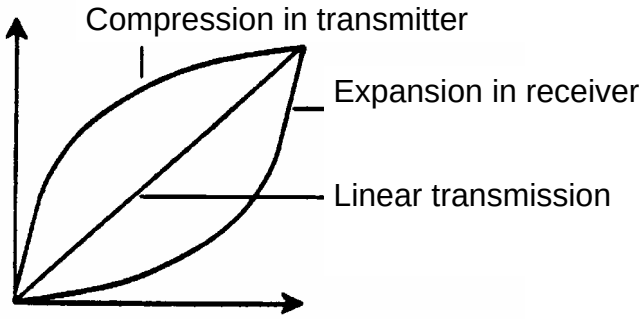


Pulse Coded Modulation System

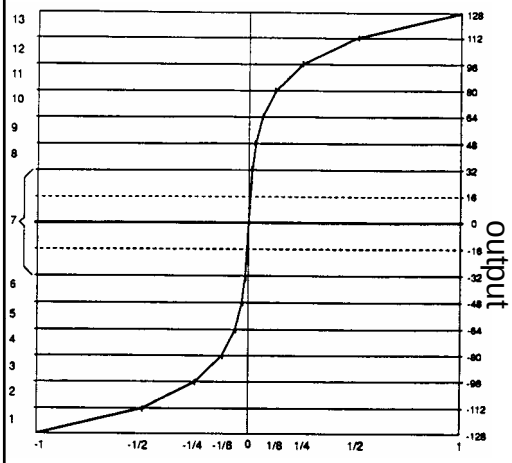


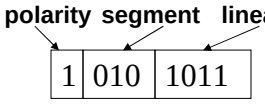
Pulse Coded Modulation System

The relative amplitude error is constant when the signal is ***compressed*** in the transmitter and ***expanded*** in the receiver



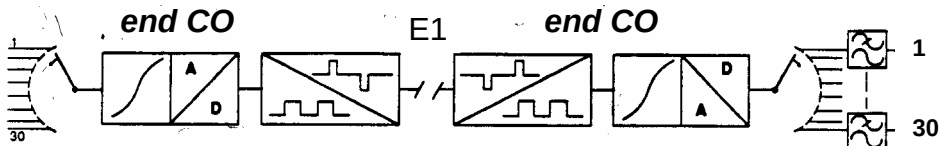
Pulse Coded Modulation System





- The PCM system uses a compression law called A-law.
- The output signal from the coder is a digital word of 8 bits.
- The first bit tells the polarity.
- The following three bits tells which segment the sample contains.
- The last four bits are linear coding inside the segment.

Pulse Coded Modulation System

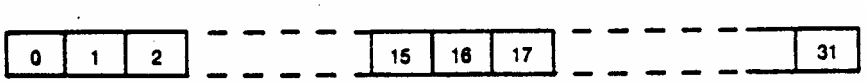


Sampling frequency 8000 Hz

Frame length 125 μs

Each sample is 8 bits times a sample rate of 8000 Hz equals a throughput of 64 Kbps per channel.

Pulse Coded Modulation System



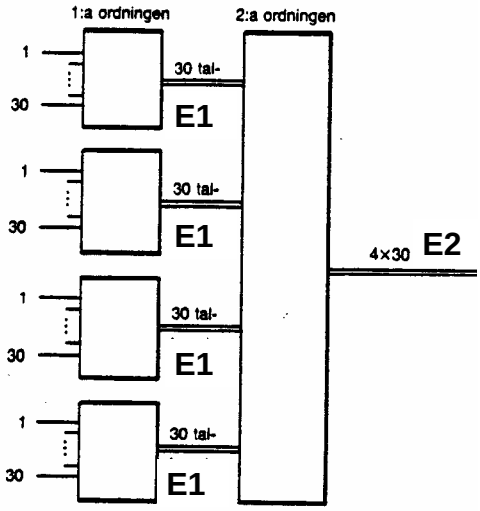
Each sample sequence generates one frame containing: 30 voice channels, one ***preamble*** for synchronization and ***one slot for signaling***.

Each frame contains the 30 PCM code words from 30 ongoing telephone calls.

Each channel is 64 Kbps which means that the total throughput for a **E1 trunk line** is 2048 Kbps.

Pulse Coded Modulation System

Second level PCM multiplexing



Pulse Coded Modulation System