Modem

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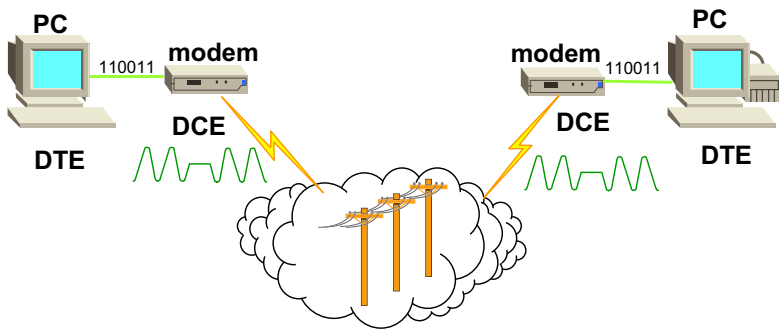
Modem connection



A modem is a communication device that converts binary signal into analog acoustic signals for transmission over telephone lines and converts these acoustics signals back into binary form at the receiving end.

Conversion to analog signal is known as *modulation*; conversion back to binary signal is known as *demodulation.*

In the terminology used in the RS-232C communication standard, modems are DCEs, which mean the connected at one end to a DTE (e.g. computer) device.

Modem type

- **Asynchronous, Synchronous**
- **Half-Duplex, Full-Duplex**

Low-speed modems are designed to operate asynchronously. Each data frame conforms an asynchronous transmission mechanism..

High-speed modems as well as leased-lines modems use synchronous transmission. The two modems use a common time base and operate continuously at substantially the same frequency and phase relationship by circuit that monitor the connection.

A half-duplex modem must alternately send and received signals. Half-duplex allows more of the channel bandwidth to be put to use but slows data communications.

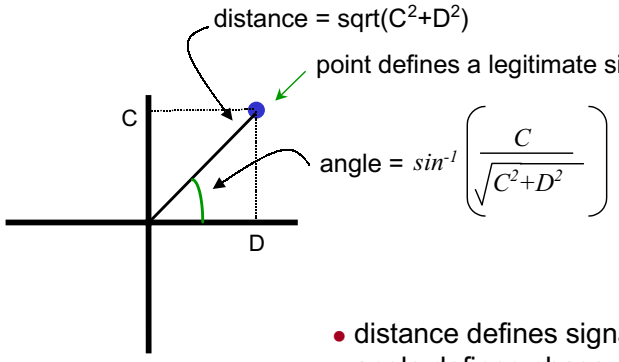
A full-duplex modem can simultaneously handle two signals using two carriers to transmit and receive data. Each carrier uses a half of the bandwidth available to it and its modulation.

Modulation method

- **FSK**
  1 bit per baud. max speed =2400 bps
- **PSK, DPSK**
  up 3 bit per baud
- **QAM**
  combines ASK and PSK, encoding 4-7 bits per baud
- **TCM**
  same as QAM, but adds extra bits for error correction

ASK is not used for data communications because it is very susceptible to electrical noise interference. Low-speed modems use FSK, higher speed modems use PSK, and the very high speed modems use a conjunction of ASK and PSK, and also TCM

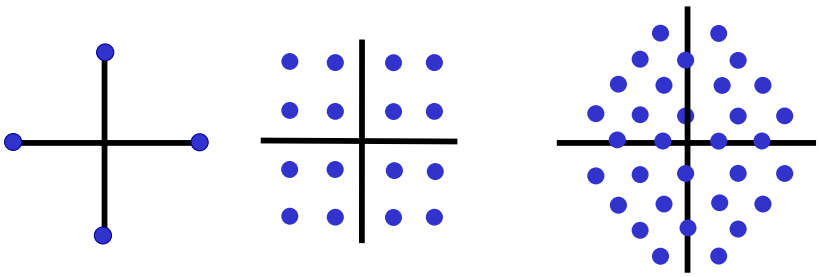
Signal Constellation



- distance defines signal's amplitude
- angle defines phase shift

Modems that use ASK and PSK have a signal constellation, a diagram that uses points plotted on a co-ordinate system to define all signal changes.

Constellation samples



V.22
600 baud 1200 bps
PSK

V.22bis
600 baud 2400 bps
QAM

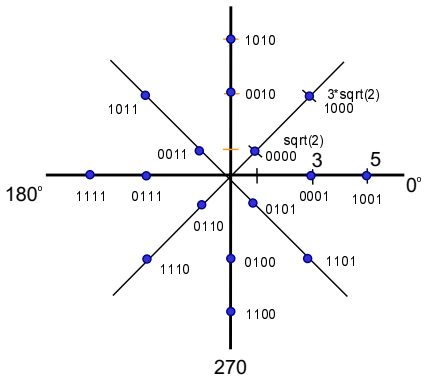
V.32
2400 baud 9600 bps
TCM

V.22 modem uses PSK, four points all the same distance from the origin.

V.22bis uses signal constellation of 16 points. The standard calls for 600 baud and 4 bit per baud, giving a data rate of 2400 bps. There are 3 different amplitudes and 12 possible phase shifts. Full duplex operation is achieved by a low-channel carrier frequency of 1200 Hz and a high-channel carrier frequency of 2400 Hz

Another signal constellation corresponds to the V.32 standard. It is a 32-point constellation, using 2400 baud and 5 bits per baud (Trellis Code Modulation). V.32 provides the data rate of 4*2400=9600 bps. The extra bit is used in error correction.

V.29 Signal Constellation



- **16 points QAM signal constellation**
- **8 phases with 4 amplitudes QAM**
- **2400 baud, 9600 bps synchronous data transmission over four-wire leased line**

V.29 uses a single carrier frequency at 1700 Hz, and it operates at 2400 baud. This modem is specified to operate at 9600 bps. V.29 uses 16-point QAM signal constellation with 8 phases and 4 amplitudes.

Data is represented by sets of four bits. The first bit of each quadbit determines the amplitude and the remaining three bits determine the phase shift.

Some standards

- **V.32** : 9,600 bps, Sync, FDX, 2400 baud, 4:1 bpb, QAM, STN, PP2W
- **V.32bis**: 14,400 bps, Sync, FDX, 2400 baud, 7:1 bpb, TCM, STN, PP2W
- **V.32ter** : 14,400 bps, Sync, FDX, 2400 baud, 9:1 bpb, TCM, STN, PP2W
- **V.33** : 14,400 bps, Sync, FDX, 2400 baud, 7:1 bpb, TCM, PP4W
- **V.34 (V.fast)** : 28,800 bps, Sync, FDX, 2400 baud, 12:1 bpb, TCM, STN, PP2W

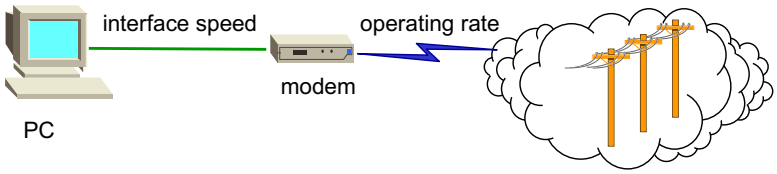
Sync = **Synchornous**
FDX = **Full Duplex**
bpb = **bit per baud**
STN = **for use on Switched Telephone Network**
PP2W = **for use on point-to-point two wire leased circuits**
PP4W = **for use on point-to-point four wire leased circuits**

V.32bis modem operates on six bit at a time and adds a redundant bit for TCM, resulting 64-point signal constellations. It provides data rate of 6x2400=14.4 Kbps. V32bis modems can fall back to 12,200, 9600 or 4800 bps if the line quality degrades and includes an automatic fall forward to a higher speed when the line quality improves.

V.32ter uses a 2-dimensional TCM with 512 points in a signal constellation. It provides transmission rates of up to 19.2 Kbps

V.34 modem has a capability to perform compression when communicate with another V.34 modem. When compression is enabled, the modem can receive data from an attached DTE at 115.2 Kbps to support operating speed 28.8 Kbps. However, the UART built into the serial port of the PC have to support this data rate. The 8250 UART starts to lose characters at data rates beyond 19.2 Kbps. The 16400 UART can result in lost data at operating rates above 57.6 Kbps.

Interface V.S. Operating rate



To effectively use data compression requires users to set modem's interface data rate to exceed its operating rate.

If the interface speed equals the operating rate, data compression will not increase the throughput of modem. To increase the modem's throughput, users must set the interface rate to at least twice the modem's operating rate. For example, if the modem operates at 2400 bps, user should set the interface rate to at least 4800 bps. This setting allows more bits in the form of characters to enter the modem per unit of time that can be transmitted. Then, data compression can attempt to reduce the bits entering the modem so that they can be transmitted at the modem's operating rate, increasing the modem's throughput. [Held, G., Understanding Data communications , Sam Publishing, 1994]

Error correcting

- LAPD (Link Access Protocol D)
  - based on HDLC synchronous protocol
- MNP (Microcom Networking protocol)
  - trademark of Microcom
- TCM
  - modulation with error detecting code
- V.42
  - CRC error correcting standard

MNP protocol

- **Microcom Networking Protocol (MNP)**
  - **Modem protocol developed by Microcom, Inc.**
- **Divided into classes 1-10**
  - **MNP modems negotiate to operate at the highest supported class**
- **Considered a de facto industry standard**

The MNP provide reliable data transmissions using error correction and data compression techniques. Many vendors have licensed the MNP for use in their modem. Today, ITU V series standards are commonly implemented; however, some modem vendors use both V series and MNP.

Class 1 : 2400 bps asynchronous byte-oriented half-duplex provides efficiency of approx. 70%. A 2400 bps modem using get a throughput of 1690 bps.

Class 2 : 2400 bps asynchronous byte-oriented half-duplex with 84% efficiency.

Class 3 : 2400 bps full-duplex synchronous transmission with 108% efficiency.

Class 4 : Dynamically adjusted packet sizes and protocol overhead reduction with 120% efficiency.

Class 5 : Improve Class 4 by 2:1 compression ratio. 200% max efficiency.

Class 6 : Same as V.29 with compression; 9600 baud achieves 19.2 kbps.

Class 7 : Same as Class 6 with enhance2-3 times data compression.

Class 8 : Is no longer marketed.

Class 9 : Same as V.32, but triple throughput by using Class 7 data compression techniques.

Class 10 : Use *adverse channel enhancements* that help modems work better with poor telephone connection.

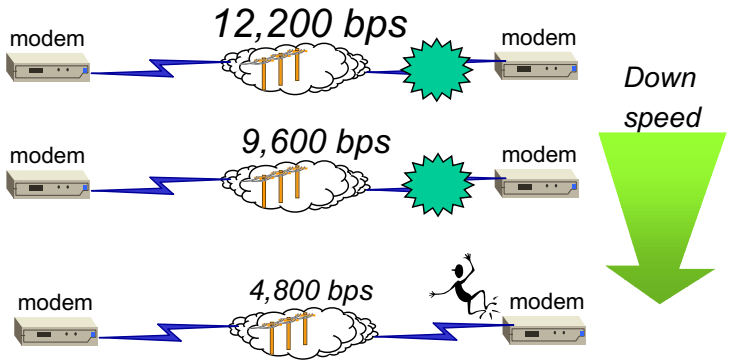
V.42 Recommendation

- V.42
  - Defines error-checking standard
  - uses CRC for each data block
- V.42bis
  - Defines modem compression using the Lempel Ziv method

V.42bis is the data compression standard that provides compression factors up to four on some form of data . The V.42 recommendation defines a protocol in which modems generate and add a cyclic redundancy check (CRC) to each block for error detection.

MNP error detection and correction is supported as a secondary standard. V.42-compatible modem first attempts to communicate in its error-free mode using LAPB. If the far-end modem does not support the V.42 protocol. The V.42 modem attempts to communicate using MNP error control. If it fails, two modems communicate without error correction.

Fallback



Most high-speed modems incorporate fallback capabilities. Two modems try first the highest speed and next try lower speed until reliable communications are established. At lower fallback rate, smaller number of bits per baud are used for encoding.

Most modems fall back and stick with the low speed that proves itself reliable. Some modems constantly sense the connection for any improvement. If the line improves, modems can shift back (fall forward) to a higher speed.

Smart modem

- **Introduces by Hayes Microcomputer Products**
  - **known as Hayes-compatible modems**
- **Properties**
  - **standard modem with microprocessor**
  - **automatic dialing**
  - **provides command in ASCII form**
- **Hayes command**
  - **known as Hayes-compatible modems**
  - **AT DT 9,9985800**

Most modems use a standardized set of instructions called *Hayes command set* (from Hayes company which developed the command). Hayes command set comprises several instructions beginning with a two-character sequence, AT, called *attention characters.* A modem that understands the Hayes command set is said to be *Hayes-compatible.*

Example of Hayes command set :

A	Answer call
A/	Repeat last command
C*n*	Turn modem's carrier on (1) or off(0)
D*n*	Dial a telephone number *n*
E*n*	Enable (1) or disable (0) echo characters
H*n*	Hang up (0) or pick up (1)
P	Pulse dial
S	Set modem register values
T	Touch tone dial
Z	Reset modem

Hayes Response Codes

- 0 OK
- 1 CONNECT
- 2 RING
- 3 NO CARRIER
- 4 ERROR
- 5 CONNECT 1200
- 6 NO DIALTONE
- 7 BUSY
- 8 NO ANSWER
- 10 CONNECT 2400

0	OK	Command executes without error
1	CONNECT	Connection established
2	RING	Phone is ringing
3	NO CARRIER	Carrier lost or never detected
4	ERROR	Error in command line or line to long
5	CONNECT 1200	Connection established at 1200 bps
6	NO DIALTONE	Dialtone not detected in waiting period
7	BUSY	Modem detect a busy signal
8	NO ANSWER	No silence detected while waiting for a quite answer
10	CONNECT 2400	Connection established at 2400 bps