MODEM 101: An Introductory Lesson in High-Speed Modems

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Jim, an avid bulletin board caller, wanted to upgrade from his 2400 baud modem to a high-speed modem. He went to his computer dealer and asked for the best 9600 baud modem, and purchased a Hayes V-series® Ultra Smartmodem 9600™, which is indeed one of the best on the market. Jim felt that getting the best justified spending $800 on the modem. However, when Jim got his new modem home and set it up, he found that all of his connections were still at 2400 baud. Many of the system operators who ran the bulletin boards Jim called were as confused as he, but one of them targeted the problem. While Jim's modem was an excellent V.32 modem, the bulletin boards were using HST™ modems. Jim wasn't quite sure what this meant, but returned to his computer dealer and explained the problem. His vendor made him a fair compromise offer: for returning the Hayes and $100, he sold Jim a U.S. Robotics Dual Standard™, which, although more expensive than the Hayes Ultra, can connect to both V.32 and HST modems at high speed. Jim was very happy with his new modem. However, he was not so happy when he saw a V.42bis modem priced at $179, much less than he had paid for his V.32. Jim called the system operator who had understood his first problem and was told that this time he had no problem, because a V.42bis modem with no other designation was a 2400 baud modem, no faster than Jim's older 2400 baud.

Although the name was changed, Jim's story is true, and illustrates one of the most common areas of confusion in today's telecommunication field. Jim faced several sources of confusion. The designations V.32, V.42bis and HST indicate the modem's abilities, but do not describe them to the uninitiated. Jim was also using the word "baud" imprecisely without knowing it. If a modem buyer doesn't understand the jargon of modem descriptions, it is easy to spend a large amount of money and purchase a modem that doesn't function with any more efficiency than a $79 modem from a warehouse store.

What makes two modems compatible?

Modems speak to other modems. In order to do so, the two modems in question must speak the same "language", otherwise they cannot communicate. In the early days of modems, the "language" used by the Hayes Microcomputer Products company was taken as a standard by most modem manufacturers. For medium speed modems (1200 and 2400 bits per second, or bps), this is still the case. Most of these modems use the Hayes "AT" command set and speak freely to one another.

When manufacturers first began making high speed modems (9600 bps and above), no clear standard evolved. Several manufacturers developed proprietary protocols. Such protocols are owned by the company which developed them, and are incompatible with each other. Thus none of these modems could communicate with any of the other types at 9600 bps, because none of them spoke the same "language."

The United Nations, through the Comité Consultatif International de Telegraphie et Telephonie (known as the CCITT), is charged with establishing a recognized standard for high speed telecommunication. The CCITT, based in Geneva, has defined many telecommunication standards, some relating to modems, others to facsimile transmission, and still others to packet-switching and other telecommunications. All of the CCITT standards pertinent to modems are recognizable by their "V.nn" designation. One thing to keep in mind as you are reading is that the "V-dot" protocols such as V.32, V.42, and V.42bis are totally different standards, although they are commonly confused. The -bis suffix also causes confusion. It is easiest to think of -bis as meaning "another protocol". We'll describe each CCITT standard in turn, then summarize the differences.

Before beginning, you should know that "baud" does not technically refer to the speed of a modem, but to an aspect of how the transmission occurs (more precisely, the number of changes of state in the communication line per second). The smallest unit of binary data (0 or 1) is called a "bit", short for BInary digiT. A 300 baud modem utilizing a method known as frequency shift keying sends one bit per baud and is therefore also a 300 bps modem. A 1200 bps modem is usually a 300 baud modem using a different method in order to transmit four bits per baud. Confused? Just forget you ever heard the word "baud" and use the initials "bps".

Another term used in modem descriptions is "duplex". This term, when used in reference to a modem, indicates whether or not data is transmitted out and received in simultaneously at the designated speed. Modems using full duplex protocols can transfer data both directions simultaneously at their rated speed. Half duplex protocols allow data to be sent in only one direction at a time. A signal on the end of the information tells the receiving modem that it is now free to transmit. "Asymmetrical" duplex indicates that information flows in both directions simultaneously, but at different speeds. "Adaptive" duplex means that the modems may transmit anything from full to half duplex, depending on the situation.

CCITT protocols: data transmission or "speed"

V.22: You may rarely see a reference to the V.22 protocol. Modems using V.22 are almost universally called "1200 baud" modems rather than V.22 modems. This is a 1200 bps data transmission protocol. A data transmission protocol specifies the "modulation technique", or method used to transfer the data. It therefore dictates the fastest speed at which information can be transferred. Thus, data transmission protocols are often called "speed" protocols. In addition to the rate of the character stream, data transmission protocols define such things as methods used to limit the effect of telephone line noise, so they are not technically just "speed" protocols.

V.22bis: V.22bis is the data transmission protocol recommended by the CCITT for 2400 bps modems. The modulation technique used by V.22bis modems transmits four bits per baud, and these modems typically are 600 baud modems. Four bits per baud at 600 baud is the same as 2400 bps. These modems are usually called 2400 baud modems, which is technically incorrect. From the consumer's standpoint, it doesn't matter if your modem is a 600 baud modem transmitting four bits per baud, or a 2400 baud modem transmitting one bit per baud. Both have a "speed" of 2400 bps. V.22bis is a full duplex protocol.

V.32: V.32 is also a data transmission protocol. It is a 4800 bps and 9600 bps standard employing a method called trellis coded quadrature amplitude modulation (TCQAM) at 2400 baud. TCQAM encodes 2 or 4 bits per baud and is a full duplex protocol. Until the advent of V.32bis, V.32 was considered to be the standard for high-speed modems. However, it was introduced only after certain proprietary transmission protocols had become well established, and thus has shared, but not dominated the high speed data transmission market.

V.32bis: V.32bis is the newest data transmission protocol from the CCITT, with final approval of the standard expected in spring or summer of 1991. V.32bis is a 14400 bps full duplex protocol, encoding 6 bits per baud at 2400 baud. There are already several modems being marketed which adhere to the proposed V.32bis standard. It is considered unlikely that major changes will occur prior to final approval that would cause these "pre-approval" V.32bis modems to be non-standard.

Thus, the "V-dot" protocols that determine data transmission or "speed" are, in order from slowest to fastest, V.22 (1200 bps), V.22bis (2400 bps), V.32 (4800 bps or 9600 bps), and

V.32bis (14400 bps). All are full duplex protocols. The remaining "V-dot" protocols do not determine "speed", but are concerned with error correction (ensuring that the data received is an exact copy of the data sent) and data compression (coding the data into a smaller form so that it takes less time to send at the rated speed).

CCITT protocols: error correction and data compression

V.42: V.42 is an error correction protocol. V.42 uses a method known as link access protocol for modems, or LAP-M. It helps to ensure that transmission of data is done without error. Unlike the protocols discussed above, V.42 does not relate to the speed of data transmission, only to its correctness. However, V.42 can decrease the actual time for transmission at a given transmission speed.

This requires a little more explanation. One way of measuring the speed of data transmission is by characters per second, or cps. Each character consists of 10 bits, thus a 2400 bps modem has a theoretical character rate of 240 cps (the number of bits per second divided by the number of bits in a character). In reality, this figure is closer to 235 cps, because no transmission is totally efficient. This rate is commonly referred to as the "throughput" because it indicates how many characters the modem can "put through" in a given time. The 10 bits in each character include 8 bits of data plus a "start" bit and a "stop" bit. The V.42 error correction protocol strips off the excess start and stop bits and thus reduces the data load by 20%. The actual throughput increase is less, due to protocol overhead, but is about 15% (270 cps at 2400 bps with excess bits stripped off compared to 235 cps at 2400 bps without).

V.42bis: V.42bis is a data compression standard. Data compression is commonly used to reduce the size of a file for storage or transmission. Smaller files naturally take less time to transmit. V.42bis uses a method of compression called Limpel-Ziv encoding, which typically can achieve a 4:1 compression ratio on an non-compressed ASCII text file, meaning four times as much data can be sent in a given time at a given transmission rate. With V.42bis compression, a V.32 (9600 bps) modem can achieve an effective transfer rate of 19200 bps.

However, many files have been compressed before they are transmitted, usually so that they can be stored in less space on a hard disk or floppy disk. This process, commonly called "archiving", uses one of a variety of proprietary or public domain compression techniques. MS-DOS® files that have been compressed usually have extensions such as .ZIP, .LZH, .ARC or .GIF which identify the compression technique used. If a modem tries to further compress a file that has already been compressed, it actually increases the time needed for transmission. Therefore, the V.42bis standard includes the ability to "sense" pre-compressed files and disable the V.42bis compression for such files.

V.42 and V.42bis are commonly confused with the other V-dot protocols. Unlike V.22, V.22bis, V.32 and V.32bis, all of which define a data transmission speed, V.42 and V.42bis have no effect on speed, but are, respectively, error correction and data compression protocols. The modem Jim saw advertised for $179 was a 2400 bps modem with V.42bis data compression ability.

Proprietary data transmission protocols

The CCITT standards are, by definition, world-wide and non-proprietary. However, other protocols exist that define data transmission, error correction and data compression. Proprietary data transmission protocols in use in modems being sold today include the HST™, DIS™ and PEP™ protocols. Proprietary error correction and data compression protocols in use today include MNP® level 6 and higher and CSP™.

Proprietary high speed data transmission protocols are owned by the companies which developed them and cannot be used by anyone else without a license. The cardinal rule to remember about data transmission protocols is that two modems with different high speed protocols will not be able to communicate with each other at high speed. However, since all these modems have a standard 2400 bps protocol as a "fall-back" protocol, these modems will be able to connect in most cases and communicate at 2400 bps.

HST: The HST™ (High Speed Transmission) modulation is similar to V.32 in the fact it uses a trellis coded quadrature amplitude modulation (TCQAM) technique. Unlike the V.32, it is not full duplex, but instead sends data at a maximum of 14400 bps in one direction with either a 300 or 450 bps frequency shift keyed reverse channel. This makes it an "asymmetrical duplex" modem. The main TCQAM channel encodes up to 7 bits per baud, at 2400 baud, with one bit used as parity, for the theoretical maximum of 14400 bps in one direction. The modem will switch channels as the data demands. The HST protocol is proprietary to U.S. Robotics (USR).

The meanings of the initials USR and HST are often confused. All HST modems are made by U.S. Robotics, but U.S. Robotics makes other modems which do not use the company's proprietary protocol. For instance, U.S. Robotics makes a modem which uses only their proprietary HST protocol, the U.S. Robotics Courier HST™. However, they also make a high speed modem that conforms to the CCITT standard only, the U.S. Robotics Courier™ V.32. A third, and very popular, modem marketed by U.S. Robotics includes both the CCITT V.32 protocol and the proprietary HST protocol. This modem, the U.S. Robotics Dual Standard™ HST V.32, will connect at high speed to an HST only modem or to a modem that has V.32 only, thus the name Dual Standard. The logic for both protocols actually exists side-by-side in the Dual Standard modems. Recently, U.S. Robotics has begun producing modems that utilize the new V.32bis protocol, both in a single protocol modem and in a Dual Standard modem.

DIS: The DIS™ (Dynamic Impedance Stabilization™) protocol, like the V.32, V.32bis and HST protocols, uses quadrature amplitude modulation to achieve a data transmission rate of 9600 bps. The major difference between DIS modems and others, however, is the method used to control "noise", or unwanted signals on the telephone line. A "noisy" telephone line can cause errors in data transmission or even cause loss of carrier before the transmission is finished. The CCITT standards call for use of echo cancellation to filter out unwanted line noise. Echo cancellation requires a digital signal processor, which greatly increases the cost of the modem. DIS uses a method of improving the signal-to-noise ratio which does not require the processor. Thus, modems using the DIS protocol are significantly less expensive than V.32, V.32bis, or HST modems. DIS is a proprietary product of CompuCom Corporation.

PEP: The PEP™ (Packetized Ensemble Protocol™) modulation technique, which is a proprietary product of the Telebit Corporation, is totally dissimilar to the protocols described above. It uses a method called dynamic adaptive quadrature amplitude modulation (DAQAM). Effectively, it splits the phone line into 511 sections and puts a 34 baud carrier on each section. By encoding up to 4 bits per baud, PEP achieves maximum speeds of 18000 bps (non-non-compressed). Each channel can be going only one direction, so full duplex operation can be had at 9000 bps. PEP also utilizes adaptive duplex, which means that the speed over the various channels will be determined by the data being sent. If data is being sent in only one direction, it will transmit at 18000 bps in that direction. However, if full duplex is needed, data will be sent at 9000 bps in both directions. If traffic is heavier in one direction than the other, the PEP protocol adjusts to ensure a maximum data transmission rate. Modems using the PEP protocol are common in systems using the UNIX® operating system.

Other error correction and data compression protocols

The most common non-CCITT error correction and data compression protocols are those developed by Microcom, Inc. These are all indicated by the letters MNP® (Microcom Networking Protocol®) and a number which differentiates between the various MNP protocols. MNP levels 2-4 (error correction) and MNP level 5 (data compression) are in widespread use and are found on most high speed modems, including those that meet CCITT standards.

The reason for this is that both the V.42 standard and the V.42bis standard include an annex which requires that MNP levels 2-4 (for V.42) or MNP level 5 (for V.42bis) be available as "fall-back" protocols. In the case of error correction, this ensures that if both modems are not V.42 compliant, at least MNP level 4 error correction will be used. MNP level 4 is similar to V.42 in that it strips the start and stop bits from each 10-bit character, thus increasing throughput by about 15%. The MNP level 4 protocol includes MNP levels 2 and 3, which are also error correction protocols.

Note that some 2400 bps modems do not have any error correction or data compression ability. These are often referred to as "non-MNP" or "non-error correcting" modems. When such modems are used for data transmission, software (such as the Zmodem file transfer protocol) is used to provide error correction. Modems which have at least MNP level 4 error correction or V.42 error correction (which includes MNP level 4 as a fall-back protocol) can instead use a file transfer protocol such as Ymodem-G, which is faster because it sends the data in a stream with no software-controlled error correction.

MNP level 5 is the most commonly seen non-CCITT data compression protocol, and is included in the CCITT V.42bis standard as a fall-back protocol. MNP level 5 differs from V.42bis in two important ways. First, while V.42bis uses a 4:1 data compression protocol, MNP level 5 uses a method called run length encoding, which is only a 2:1 data compression protocol. Microcom did develop a 4:1 compression protocol (MNP level 9) but that did not provide much of a challenge to V.42bis.

The second difference between V.42bis and MNP level 5 is that, while V.42bis can "sense" previously compressed files and disable V.42bis compression, MNP level 5 does not have this capability. Attempting to further compress an already compressed file slows transmission. Therefore, if a modem with MNP level 5 (but not V.42bis) capabilities is used mostly for previously compressed files, as is the case with most bulletin board file transfers, MNP level 5 should be disabled on that modem, usually by toggling a DIP switch or changing a software setting. If the modem is used for non-compressed text file transfers, MNP level 5 should remain enabled.

MNP level 5 is often erroneously referred to as an error correction protocol. This is partially because modems tend to be referred to by their most sophisticated feature. Thus, an "MNP 5 modem" is considered better than an "MNP 4 modem". In fact, this is true, because the MNP level 5 modems always include MNP levels 2-4. However, it is imprecise to refer to a modem as an "MNP 5 error correcting modem". In such a modem, only MNP levels 2-4 have anything to do with error correction, while MNP level 5 is strictly a data compression protocol. It is more precise to describe such a modem as an "error correcting modem with MNP level 5 compression".

A non-CCITT, non-Microcom error correction and data compression protocol called CSP™ (CompuCom Speed Protocol™) is used with modems employing the DIS data transmission protocol. These same modems offer MNP levels 2-5 as fall-back routines for times when the DIS modem connects to a non-DIS modem (at 2400 bps, as DIS is a proprietary protocol). CSP offers compression of up to 4:1 on non-compressed files without apparent degradation of file transfers on precompressed files. It is a proprietary technology of CompuCom Corporation.

Summing it up

Modem protocols can dictate the data transmission characteristics such as speed and telephone line noise reduction. Examples of this type of protocol include V.22, V.22bis, V.32, V.32bis, HST™, DIS™ and PEP™.

Modem protocols can also provide error correction, at the same time increasing throughput by about 15%. Examples of this type of protocol include V.42 and MNP® levels 2-4.

Finally, modem protocols can compress data that has not been previously compressed, which shortens transmission time by decreasing file size. Examples of this type of protocol are V.42bis and MNP® level 5. The CSP™ protocol handles both error correction and data compression for modems using the DIS™ data transfer protocol.

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