3Com Technical Papers

# 3Com V.90 Technology

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## 3Com V.90 Technology

*V.90, a data transmission recommendation developed by Study Group 16 of the International Telecommunications Union (ITU), provides a specification for achieving line speeds of up to 56 Kbps. This paper explains V.90 in detail.*

V.90 technology allows modems to receive data at up to 56 Kbps over the standard public switched telephone network (PSTN). V.90 overcomes the theoretical limitations imposed on standard analog modems by exploiting the digital server connections that most Internet and online service providers use at their end to connect to the PSTN.

Typically, the only analog portion of the phone network is the phone line that connects the remote site to the telephone company's central office (CO). Over the past two decades, local telephone companies have been replacing portions of their original analog networks with digital circuits. But the slowest portion of the network to change has been the connection from the home to the CO. That connection will likely remain analog for some years to come.

A software upgrade converts a service provider's 3Com Total Control™ remote access concentrator, SuperStack® II Remote Access System 1500 with Universal Connect™ technology, NETServer I-modems, or U.S. Robotics® MP I-modems to V.90 operation. 3Com calls the modems that have a direct digital connection to the PSTN V.90 *digital modems*. Likewise, converting a U.S. Robotics Courier™ V.Everything® analog modem to a V.90 *analog modem* is as simple as downloading new software.

**V.34 Encoding in More Detail**

The PSTN was designed for voice communications (Figure 1). By artificially limiting the sound spectrum to just those frequencies relevant to human speech, network engineers found they could reduce the bandwidth needed per call, increasing the number of potential simultaneous calls. While this works well for voice, it imposes limits on data communications.

V.34 modems are optimized for the situation where both ends connect by analog lines to the PSTN. Even though most of the network is digital, V.34 modems treat it as if it were entirely analog. V.34 modems are incredibly robust, but they cannot make the most of the bandwidth that becomes available when one end of the connection is completely digital. V.34 was built on the assumption that both ends of the connection suffer impairment due to quantization noise introduced by analog-to-digital converters (ADCs).

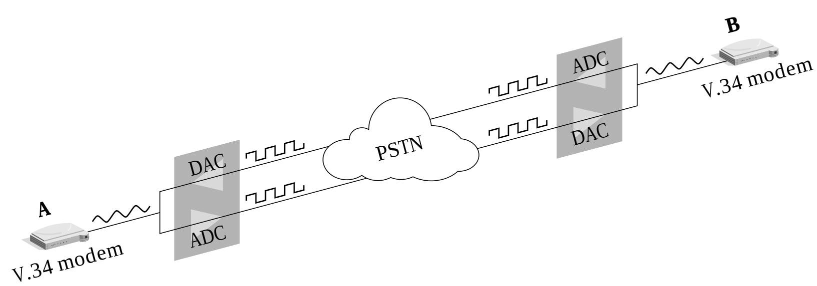


**Figure 1.** *Anatomy of a V.34 Connection*

**Signal-to-Noise Ratio (SNR)**

Signal-to-noise ratio is a measure of link performance arrived at by dividing signal power by noise power. The higher the ratio, the clearer the connection, and the more data can be passed across it. Even under the best conditions, when a signal undergoes analog-to-digital conversion, there is a 38 to 39 dB signal-to-noise ratio (the "noise floor"), which limits practical V.34 speeds to 33.6 Kbps.

**Upstream and Downstream Channels: Asymmetric Operation**

V.90 connections employ one bidirectional channel, upstream and downstream. The V.90 analog modem's downstream (receive) channel is capable of higher speeds because no information is lost in the digital-to-analog conversion. The V.90 analog modem's upstream (send) channel goes through an analog-to-digital conversion, which limits it to V.34 speeds.

***Noise Introduced by Quantization of Analog Signals***

Analog information must be transformed to binary digits in order to be sent over the PSTN. The incoming analog waveform is sampled 8,000 times per second, and each time its amplitude is recorded as a pulse code modulation (PCM) code. The sampling system uses 256 discrete 8-bit PCM codes.

Because analog waveforms are continuous and binary numbers are discrete, the digits that are sent across the PSTN and reconstructed at the other end can only approximate the original analog waveform. The difference between the original waveform and the reconstructed quantized waveform is called quantization noise, and it limits modem speed.

**V.90 Encoding in More Detail**

Quantization noise limits the V.34 communications channel to about 35 Kbps. But quantization noise affects only analog-to-digital conversion—not digital-to-analog. This is the key to V.90: if there are no analog-to-digital conversions between the V.90 digital modem and the PSTN, and if this digitally connected transmitter uses only the 255 discrete signal levels available on the digital portion of the phone network, then this exact digital information reaches the analog modem's receiver, and no information is lost in the conversion processes.

Here's how the process (Figure 2) works:

1. The server connects, in effect, digitally to the telephone company trunk.

2. The server signaling is such that the encoding process uses only the 256 PCM codes used in the digital portion of the phone network. In other words, there is no quantization noise associated with converting analog-type signals to discrete valued PCM codes.

3. These PCM codes are converted to corresponding discrete analog voltages and sent to the analog modem via an analog loop circuit, with no information loss.

4. The client receiver reconstructs the discrete network PCM codes from the analog signals it received, decoding what the transmitter sent.

Data is sent from the V.90 digital modem over the PSTN as binary numbers. But to meet the conditions of step 2 above, the V.90 digital modem transmits data (eight bits at a time) to the client's ADC at the same rate as the telephone network (8,000 Hz). This means the modem's symbol rate must equal the phone network's sample rate.

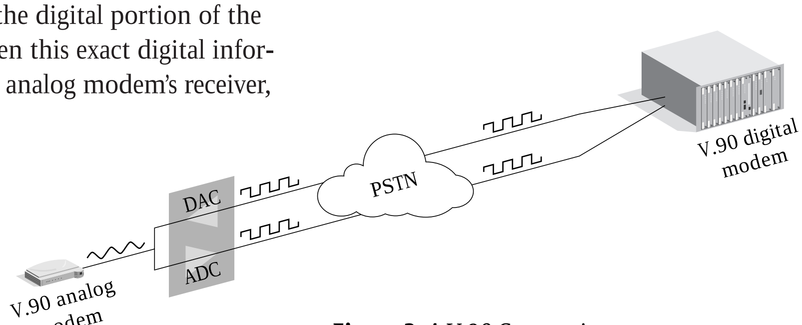


***Figure 2.*** *A V.90 Connection*

**V.90 Modem Connections**

During the training sequence, V.90 modems probe the line to determine whether any downstream analog-to-digital conversions have taken place. If the V.90 modems detect any analog-to-digital conversions, they will simply connect as V.34. The V.90 analog modem also attempts a V.34 connection if the remote modem does not support V.90.

The V.90 analog modem's task is to discriminate among the 256 potential voltages, to recover 8,000 PCM codes per second. If it could do this, then the download speed would be nearly 64 Kbps (8,000 x 8 bits per code). But it turns out that several problems slow things down slightly.

First, even though the network quantization noise floor problem is removed, a second, much lower noise floor is imposed by the network digital-to-analog converter (DAC) equipment and the local loop service to the client's premises. This noise arises from various nonlinear distortions and circuit crosstalk.

Second, network DACs are not linear converters, but follow a conversion rule (μ-law in North America and A-law in many other places). As a result, network PCM codes representing small voltages produce very small DAC output voltage steps, whereas codes representing large voltages produce large voltage steps.

These two problems make it impractical to use all 256 discrete codes, because the corresponding DAC output voltage levels near zero are just too closely spaced to accurately represent data on a noisy loop. (Note: Each network PCM code corresponds to a DAC voltage level.) Therefore, the V.90 encoder uses various subsets of the 256 codes that eliminate DAC output signals most susceptible to noise. For example, the most robust 128 levels are used for 56 Kbps, 92 levels to send 52 Kbps, and so on. Using fewer levels provides more robust operation, but at a lower data rate.

***V.90 Requirements***

V.90 requires the following three conditions for full 56 Kbps transmission:

1. **Digital at one end.** Today, most service providers have digital connections to the PSTN. One end of an V.90 connection must terminate at a digital circuit, meaning a "trunk-side" channelized T1, ISDN PRI, or ISDN BRI. "Line-side" T1 will not work because additional analog-to-digital and digital-to-analog conversions are added. In a trunk-side configuration, once the user's analog call is converted to digital and sent through the carrier network, the call stays digital until it reaches a digital modem through a T1, PRI, or BRI circuit.

2. V.90 support at both ends. V.90 must be supported on both ends of the connection, by the analog modem as well as by the remote access server or modem pool at the host end. Typically, the remote user will be using a 3Com Courier, U.S. Robotics, Megahertz®, or other brand V.90 modem dialing into a 3Com U.S. Robotics MP I-modem, NETServer I-modem, Courier I-modem, SuperStack II Remote Access System 1500, Total Control remote access concentrator, or other brand V.90 digital modem.

3. One analog-to-digital conversion. There can be only one analog-to-digital conversion in the phone network along the path of the call between the V.90 digital modem and the analog modem. If the line is a channelized T1, it must be "trunk-side" and not "line-side." With line-side service from the phone company, there is typically an additional analog-to-digital conversion.

### 3Com x2™ Technology vs. 3Com V.90 Technology

Until recently, proprietary implementations were the only options for 56 Kbps access. However, in February 1998 the ITU reached a determination for 56 Kbps technology, providing for one universally compatible solution—the V.90 standard. 3Com's V.90 solution will remain compatible with 3Com's proprietary transmission scheme for 56 Kbps access, x2™ technology.

As Table 1 illustrates, all 3Com x2 modems, both client and server, will continue to support x2 technology when they are upgraded to V.90. Users who do not upgrade to the new standard will be able to connect to digital modems with 3Com's x2 technology for high-speed downloads. Client x2 modems that are not upgraded to the standard will receive a V.34 connection when they call a digital modem that was originally K56flex, even if it has been upgraded to the standard.

### The Difference Is in the Details

The data modes of x2 technology and V.90 are essentially the same. The technical differences between x2 technology and V.90 are primarily in two areas of the "handshake" or initialization sequences:

- **V.8 Signaling Protocol.** V.8 is an international standard that determines the capabilities of the modems on both ends of the call. The V.8 signaling protocol used in V.90 differs from the proprietary signaling method used in x2 technology.
- **Digital Impairment Learning (DIL).** Digital Impairment Learning is a mechanism employed in V.90 technology that allows each manufacturer to determine the digital impairments in its own way. This method allows for flexibility and future improvements without a change to the protocol.

**Table 1.** *Modem Compatibility Matrix*

| | x2 Server | K56flex Server | 3Com V.90 Server | Other V.90 Server | V.34 Server |
|---|---|---|---|---|---|
| x2 Client | 56K | V.34 | 56K | V.34 | V.34 |
| K56flex Client | V.34 | 56K | V.34 | ?* | V.34 |
| 3Com V.90 Client | 56K | V.34 | 56K | 56K | V.34 |
| Other V.90 Client | V.34 | ?* | 56K | 56K | V.34 |
| V.34 Client | V.34 | V.34 | V.34 | V.34 | V.34 |

** Backward compatibility is up to individual manufacturers*

**V.90 Technology from 3Com**

There are a number of important benefits to choosing 3Com's V.90 modem technology:

- **Digital connections today.** 3Com digital modems, such as those in the Total Control remote access concentrator, already process digital signals straight from digital lines, and can be upgraded to V.90 operation via a software upgrade.
- **Programmable platform.** 3Com has a long history of delivering software-based implementations based on digital signal processors (DSPs), and was the first to deliver 56 Kbps products to the market with U.S. Robotics x2 technology. 3Com has taken advantage of this lead to refine, enhance, and improve its 56 Kbps product line in order to deliver top performing products and easy upgrades for its customers.
- **Overcoming digital impairments/universal PAD detection.** 3Com has repeatedly developed technology that overcomes impairments on the telephone network. In previous protocols—V.34, for example—the industry faced analog impairments such as echo, line noise, and cross-talk. Common digital impairments include network signals (such as robbed bits), transcoding (A-law to μ-law conversion), and digital devices called packet assembler/disassemblers (PADs). If not properly compensated for in PCM modem algorithms, these digital impairments can change the digital bit stream enough to impact performance. The V.90 specification sets a framework and mechanism to allow for discovering and compensating for digital impairments, but it leaves the task of overcoming them to individual vendors.

3Com has designed and built true digital modems for years. Our engineers have spent the past year researching obscure impairments and variations and identifying solutions. 3Com has developed technology to overcome digital impairments and achieve maximum performance on the widest variety of transmission lines across the globe. V.90 modems from 3Com and its licensees will deliver the benefits of this research and development.

## Glossary

***amplitude***
A measure of the distance between the high and low points of a waveform.

***analog-to-digital converter (ADC)***
A device that samples incoming analog voltage waveforms, rendering them as sequences of binary digital numbers. Passing waveforms through an ADC introduces quantization noise.

***Basic Rate Interface (BRI)***
An ISDN line that provides up to two 64 Kbps B-channels and one 16 Kbps D-channel over an ordinary two-wire telephone line. B-channels carry circuit-oriented data or voice traffic while D-channels carry call-control signals.

***call-control signaling***
Operations associated with establishing and tearing down virtual circuits through a network; for example, dialing.

***central office (CO)***
The facility at which individual telephone lines in a limited geographic area are connected to the public telephone network.

***Digital Impairment Learning (DIL)***
A mechanism during the initial training sequence that allows for uploading and sending tones that allow the client analog modem to detect and learn about digital impairments in the path. This allows the analog modem to build a custom constellation that can avoid or compensate for the discovered impairments.

***digital signal processor (DSP)***
A processor that is optimized for performing the complex mathematical calculations inherent in processing digital signals. A discrete DSP can be reprogrammed; a DSP integrated in a chipset typically contains its own ROM and cannot be reprogrammed.

***digital-to-analog converter (DAC)***
A device that reconstructs analog voltage waveforms from an incoming sequence of binary digits; does not in itself introduce noise.

***Integrated Services Digital Network (ISDN)***
A public switched digital network that provides a wide variety of communications services and integrated access to the network

***line-side T1***
A T1 that undergoes at least one analog-to-digital conversion in the path between the V.90 digital modem and the PSTN.

***Primary Rate Interface (PRI)***
A four-wire ISDN line (or "trunk") with the same capacity as a T1, 1.544 Mbps. PRIs contain 23 64 Kbps B-channels and one 64 Kbps D-channel. The D-channel carries call-control signaling for all the B-channels.

***public switched telephone network (PSTN)***
The public networks that deliver telephone services worldwide.

***pulse code modulation (PCM)***
A technique for converting an analog signal with an infinite number of possible values into discrete binary digital words that have a finite number of values. The waveform is sampled, then the sample is quantized into PCM codes.

***quantization***
The process of representing a voltage with a discrete binary digital number. Approximating an infinite valued signal with a finite number system introduces an error called quantization error.

***signal-to-noise ratio (SNR)***
A measure of link performance arrived at by dividing signal power by noise power. Typically measured in decibels. The higher the ratio, the clearer the connection.

***T1***
A four-wire digital line (or "trunk") with the same capacity as a PRI line, 1.544 Mbps. T1s contain 24 DS-0s, each of which carries 56 Kbps (call-control signaling is carried within the DS-0).

***trunk-side T1***
A T1 line that has a direct digital connection to the phone network, and therefore undergoes no analog conversions in the path between the V.90 digital modem and the PSTN.

***V.90 analog modem***

A modem equipped with V.90 software and attached to a standard analog telephone line. In order to connect at V.90 speeds (32–56 Kbps), the device at the other end of the connection must be a V.90 digital modem that is attached to a trunk-side T1, BRI, or PRI line.

***V.90 digital modem***

A digital modem equipped with V.90 software and attached to a trunk-side T1, BRI, or PRI line. Analog modems must be equipped with V.90 software in order to connect at V.90 speeds (32–56 Kbps). Current 3Com products that can act as V.90 servers include the Total Control remote access concentrator, NETServer I-modem, MP I-modem, and Courier I-modem. The SuperStack II Remote Access System 1500 will support V.90 when it ships in July 1998.

**3Com Corporation**
P.O. Box 58145
5400 Bayfront Plaza
Santa Clara, CA
95052-8145
Phone: 800-NET-3Com
or 408-764-5000
Fax: 408-764-5001
World Wide Web:
http://www.3com.com

**3Com ANZA**
*Sydney, Australia*
Phone: 61 2 9937 5000
Fax: 61 2 9956 6247
*Melbourne, Australia*
Phone: 61 3 9866 8022
Fax: 61 3 9866 8219

**3Com Asia Limited**
*Beijing, China*
Phone: 8610 6849 2568
Fax: 8610 6849 2789
*Shanghai, China*
Phone: 86 21 63501581
Fax: 86 21 63501531
*Hong Kong*
Phone: 852 2501 1111
Fax: 852 2537 1149
*India*
Phone: 91 11 644 3974
Fax: 91 11 623 3192
*Indonesia*
Phone: 6221 572 2088
Fax: 6221 572 2089
*Korea*
Phone: 82 2 319 4711
Fax: 82 2 319 4710
*Malaysia*
Phone: 60 3 732 7910
Fax: 60 3 732 7912
*Pakistan*
Phone: 92 21 5846240
Fax: 92 21 5840727
*Philippines*
Phone: 632 892 4476
Fax: 632 811 5493
*Singapore*
Phone: 65 538 9368
Fax: 65 538 9369
*Taiwan*
Phone: 886 2 377 5850
Fax: 886 2 377 5860
*Thailand*
Phone: 622 231 8151 5
Fax: 622 231 8158

**3Com Belgium**
*Belgium, Luxembourg*
Phone: 32 2 725 0202
Fax: 32 2 720 1211
*Netherlands*
Phone: 31 30 6029700
Fax: 31 30 6029777

**3Com Canada**
*Calgary*
Phone: 403 265 3266
Fax: 403 265 3268
*Montreal*
Phone: 514 683 3266
Fax: 514 683 5122
*Toronto*
Phone: 416 498 3266
Fax: 416 498 1262
*Vancouver*
Phone: 604 434 3266
Fax: 604 434 3264

**3Com France**
Phone: 33 1 69 86 68 00
Fax: 33 1 69 07 11 54

**3Com GmbH**
*Munich*
Phone: 49 89 627 320
Fax: 49 89 627 32 233
*Austria*
Phone: 43 1 580 17 0
Fax: 43 1 580 17 20
*Berlin*
Phone: 49 30 34 98790
Fax: 49 30 34 987999
*Poland*
Phone: 48 22 645 1351
Fax: 48 22 645 1352
*Switzerland*
Phone: 41 31 996 1414
Fax: 41 31 996 1410

**3Com Ireland**
Phone: 353 1 820 7077
Fax: 353 1 820 7107

**3Com Japan**
Phone: 81 3 3345 7251
Fax: 81 3 3345 7261

**3Com Latin America**
*U.S. Headquarters*
Phone: 408-326-2093
Fax: 408-764-5730
*Argentina*
Phone: 541 312 3266
Fax: 541 314 3 3329
*Brazil*
Phone: 55 11 5181 0869
Fax: 55 11 5182 7399
*Chile*
Phone: 562 633 9242
Fax: 562 633 8935
*Mexico*
Phone: 525 520 7841
Fax: 525 520 7837

**3Com Northern Latin America**
*Miami, Florida*
Phone: 305-261-3266
Fax: 305-261-4901
*Colombia*
Phone: 571 629 4110
Fax: 571 629 4503
*Venezuela*
Phone: 582 953 8122
Fax: 582 953 9686

**3Com Mediterraneo**
*Milano, Italy*
Phone: 39 2 253011
Fax: 39 2 27304244
*Rome, Italy*
Phone: 39 6 5279941
Fax: 39 6 52799423
*Spain*
Phone: 34 1 509 69 00
Fax: 34 1 307 66 63

**3Com Middle East**
Phone: 971 4 349049
Fax: 971 4 349803

**3Com Nordic AB**
*Denmark*
Phone: 45 39 27 85 00
Fax: 45 39 27 08 44
*Finland*
Phone: 358 0 435 420 67
Fax: 358 0 455 51 66
*Norway*
Phone: 47 22 58 47 00
Fax: 47 22 58 47 01
*Sweden*
Phone: 46 8 632 56 00
Fax: 46 8 632 09 05

**3Com Russia**
*Moscow*
Phone: 007 095 258 09 40
Fax: 007 095 258 09 41

**3Com South Africa**
Phone: 27 11 807 4397
Fax: 27 11 803 7405

**3Com UK Ltd.**
*Marlow*
Phone: 44 1628 897000
Fax: 44 1628 897003
*Manchester*
Phone: 44 161 873 7717
Fax: 44 161 873 8053
*Edinburgh*
Phone: 44 131 240 2900
Fax: 44 131 240 2903




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