Understanding the Issues/ Troubleshooting Problems in V.90 and x2

Updated: November 29, 1998

Testing shows that a vast majority of analog lines in the U.S., Europe, and the Pacific Rim support V.90/x2, but certain conditions in the network or the local loop prevent V.90 or x2, either intermittently to a certain destination or at any time from certain analog lines. Improvements have been made, and will continue to be made, to increase the number of lines and network paths where V.90 speeds can be achieved.

This paper explains the circumstances under which V.90/x2 speeds cannot be achieved and gives troubleshooting advice. It is intended to help the majority of customers whose lines support V.90/x2 speeds and to impart an understanding of why a small minority cannot achieve V.90/x2 speeds.

Please understand that this document is based on 3Com implementations, and many of the commands are 3Com specific. V.90 is a standard, and the concepts described here will apply to all implementations of V.90 regardless of the vendor. For assistance on modems not manufactured by 3Com, please consult your user's manual or the manufacturer's support resources.

Expectations

Currently, due to restrictions set on the output power allowed in the U.S., Canada, and other countries, the maximum speed is bounded at approximately 53.3 Kbps in North America. Support for 56 Kbps is contained within the code, but server code being shipped to North America and some other countries today is restricted in power output. 3Com and others are endeavoring to have these regulations modernized, so this restriction may be removed in future releases.

Certain line conditions and network configurations also produce impairments that may restrict the actual rates achieved, with V.90/x2, V.34, and V.34+. As of today, the majority of users with 3Com client modems are finding their rates in the 46–48 Kbps range. Very few (we believe less than 5 percent) will not achieve V.90/x2 speeds at all. This paper is intended to help the 95 percent get V.90/x2 running as it should, and to impart an understanding of why the remaining 5 percent do not achieve V.90/x2.

It should also be understood that continuous improvements will be made to the code, and that future code releases may increase performance and reduce the occurrences of V.90/x2 not functioning in certain environments.

Requirements

V.90/x2 requires the following:

A digital connection at one end

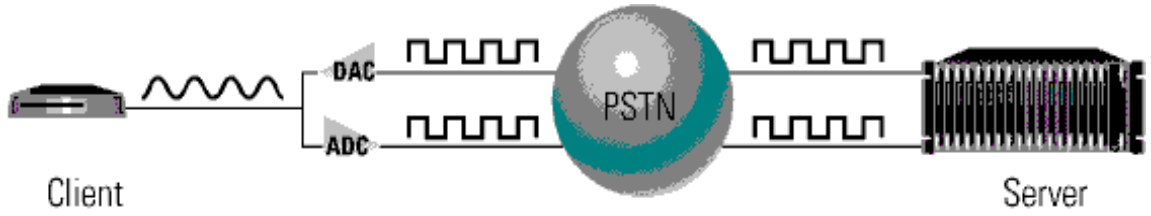
One end of a V.90/x2 connection must terminate at a digital circuit, meaning a trunk-side channelized T1, ISDN PRI, or ISDN BRI. Line-side T1 will not work because an extra analog section is added. In a trunk-side configuration, once the user's analog call is converted to digital and sent through the carrier's network, the call stays digital until it reaches a V.90/x2 server modem through a T1, PRI or BRI circuit.

V.90/x2 support at both ends

V.90 or x2 must be supported on both ends of the connection—by the client modem and the remote access server or modem pool at the host end. Typically, the remote user will be using a V.90/x2 Sportster, Courier, or Megahertz modem dialing into an MP I-modem, NETServer I-modem, Courier I-modem, or Total Control Enterprise Network Hub remote access server. Note that a V.90/x2 client will not operate at V.90 speeds to a server that is only capable of K56flex™; it requires V.90 or x2 support at the head-end.

Only one analog section

There can only be one analog section in the phone network along the path of the call between the V.90/x2 server modem and the client's modem, and it should be at the client's local loop. If the digital connection at the server side is channelized T1, it must be trunk-side and not line-side. With line-side service from the telephone company, there typically is an additional analog section.



Essential Components of an V.90/x2 Connection:
Digital at One End, V.90/x2 at Both Ends, and Only One Analog Section

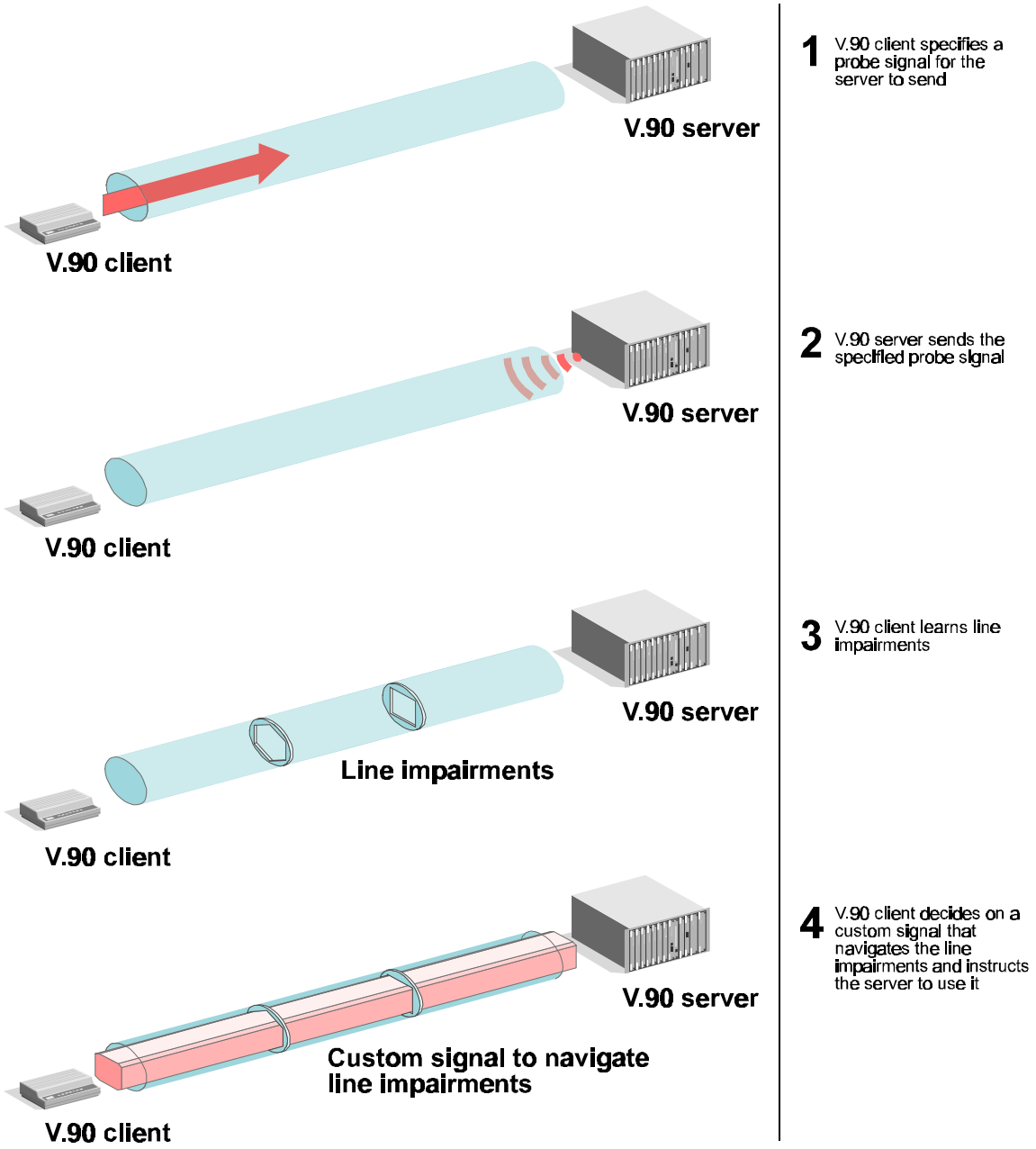
Understanding the client and server roles

In any modem technology the receiver is in control of the link, and is responsible for dealing with any impairment. In a V.90 connection, the analog client is responsible for the download direction (the V.90 direction) and the digital server is responsible for the upload direction. As the download direction is the trickiest and most susceptible to failure, we will focus on that. What you will find is, assuming the path does not have an additional Analog to Digital conversion, performance problems will generally follow the client/analog modem. The digital server is actually passive in the process.

The V.90 spec describes how to inter-operate, not how to operate or overcome impairments in the link. The process of identifying and overcoming impairments is left to the designers of the analog client modems.

The structure to have the server assist in the process is defined in the V.90 spec and is basically as follows:

- The client instructs the server to produce a tone that allows the client to analyze the network path.
- The server dutifully sends out that tone.
- The client analyzes the tone that is actually received, determines what the telephone network impairments are in the path, and instructs the server how to code the data to compensate for the detected impairments.



The Telephone Network

The analog telephone network is designed primarily for voice, not data. Many tradeoffs must be balanced when implementing a telephone network, and decisions are often made with providing reliable and efficient voice service as the primary focus. Data traffic often benefits from these efficiencies, but there are circumstances where certain equipment is employed that is perfectly logical for voice, yet interferes with high-speed data transmission.

Let's assume that the first two requirements of V.90/x2 are met—one end of the connection is digital and both ends support V.90/x2—and focus on the third requirement.

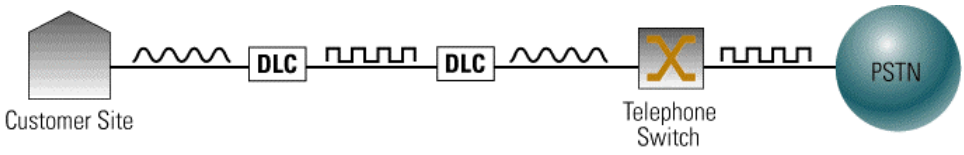
V.90/x2 technology is based on the assumption that there is only one analog section in the path between the analog modem and the V.90/x2 digital host equipment. This analog-to-digital converter (ADC, or codec) is commonly found at the local switching office where the subscriber's analog line is attached to the telephone switching equipment. From that point on, it must remain digital all the way to the V.90/x2 digital host equipment.

The local analog loop between your modem and the switching office

As mentioned above, a typical situation is where the line remains analog from the analog modem to the local switching equipment. It is also common for some of the circuits to be provided over digital circuits (such as over T1/E1 circuits or fiber) to equipment located in the neighborhood. In many cases it is provided as a digital extension of the switching equipment.

This is good for V.90/x2 because it extends the digital portion of the network to the neighborhood and reduces the length of the analog portion (the portion most susceptible to interference and distortion). The equipment that aggregates lines and performs signal conversion is often called a digital loop carrier (DLC).

There are other cases, often when the switching equipment is not capable of digital extensions, in which analog lines are provided from the switching equipment. In these cases, the analog signals are converted to digital for transmission over the digital carrier to the neighborhood, then converted back to analog for delivery to the subscriber's home or business.



Although this is a simple method of modernizing the local loop, providing higher quality voice transmission and more lines over fewer copper wires (reducing the need to tear up streets to add capacity), the additional analog-to-digital conversion prevents the operation of V.90/x2.

There are also other conditions that affect the local loop and either prevent V.90/x2 or reduce the maximum speed. The farther a customer's site is from the switching equipment, the more likely that load coils are installed on the line. Load coils are typically employed on longer wire lengths, and are used to offset some of the negative effects of these longer loop lengths on voice transmission. They will often reduce the speed, affecting V.34 and other modulation techniques as well as V.90/x2. Other problems may include poor wiring either in the telephone network or inside homes and businesses.

Problems within the network

Many problems that occur within the network are likely be intermittent and vary from call to call. The reason these are intermittent is that the path a call takes varies from call to call. A call from one point to another may take a different path each time the call is placed depending on the current utilization of inter-office trunks and other switching gear in the path of the call.

The most common issue is a digital pad where the digital bits (PCM) are manipulated to reduce the volume. This causes problems for V.90/x2 and other modem implementations, but in many cases they are overcome using complex mathematical computations within the modems at each end.

The presence of digital pads causes a minor speed reduction, but it should not prevent V.90/x2 from being achieved altogether. 3Com's V.90 clients (requires V.90 modems on both ends to be effective) have a flexible detection scheme intended to detect and overcome pads and other digital impairments. Other manufacturer's client modems appear to be relying on knowing about each and every pad that may occur in the path, and are therefore more susceptible to problems when a pad (or pads) are encountered in the network that the modem code is not built to overcome. If you suspect this is the case, users should contact the technical support of the manufacturer of their analog modem.

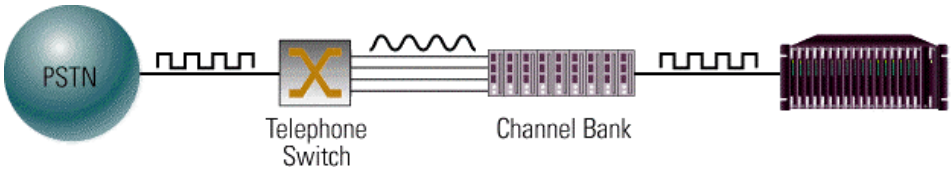
T1 or PRI Lines and Trunk-Side Service

The V.90/x2 server requires a trunk interface—a T1 (channelized or PRI) or E1 (R2 or PRI) trunk connected directly to the chassis, or a BRI line connected to an I-modem.

In a trunk-side configuration, once the user's analog call is converted to digital and sent over digital trunks through the carrier network, the call stays digital until it reaches the Total Control chassis through a T1 or PRI trunk.

Trunk-Side Configuration

A line-side configuration is not suitable for V.90/x2 because the call undergoes more than one analog to digital conversion. An example of line-side service: some central offices (COs) implement channel banks that break T1 signals down, carry the signals over two-wire connections and bring those connections back into another T1 through a second channel bank. Line-side service might be used in a CO where there is older equipment. Line-side service also causes a phenomenon called near-end echo, which introduces impairments.



Line-Side (T1) Configuration

Troubleshooting Calls (V.90/x2 Client)

NOTE: If the client is not a 3Com/U.S. Robotics modem some of this section may be useful, but the best source of information is the manufacturer of the modem.

Troubleshooting Courier Calls

Follow these steps methodically to avoid any oversights.

1. Examine the Courier status messages.

NOTE: The initial release of Courier V.90 code (dated 3/13/98) does not include status messages. These are being revamped to include V.90 and x2 operation and will return to operation in a maintenance release.

- From a terminal screen, call a V.90/x2 server. For example in the U.S., call the USR BBS at 847-982-5092.
- After connecting, hang up. Use either the disconnect feature on your terminal program, or type **+++,** and then type **ATH**.

- Type **ATI11**. In the field **V.90status** a few words appear that give excellent clues for solving the problem. If you see a bunch of coded letters and numbers, you achieved V.90/x2.
- Type **ATI6** to confirm.

NOTE: Follow the remaining steps if you do not have a courier or if you need to dig further.

2. Verify that the host is V.90/x2-capable.

From a terminal screen, call a known-good V.90/x2 host. For example in the U.S., call the USR BBS at 847-262-6000.

3. Ensure that the modem is enabled and has proper V.90/x2 software.

From a terminal screen, type **ATI7**. V.90/x2 should appear as one of the Options.

```
USRobotics Courier V.Everything Configuration Profile...
Product type          US/Canada External
Options               HST,V32bis,Terbo,VFC,V34+,x2, V90
Fax Options           Class 1,Class 2.0
Clock Freq            20.16Mhz
Flash ROM             512k
```

If V.90 or x2 are not shown as an option, but they have the correct code, it needs to be enabled. With the exception of some promotions, V.90/x2 is an extra-cost feature in the U.S. and is not enabled by default unless a V.90/x2 modem was purchased (not just an V.90/x2-upgradeable). See *http://www.3com.com/56K* for more details.

4. Ensure that the S-registers are set properly.

For troubleshooting and other control reasons there are S-Registers employed that shut off V.90/x2 or features that are required for V.90/x2. Essentially, you need to ensure that:

a) V.90/x2 is not disabled and
b) V.8 is enabled.

Under normal circumstances, typing **AT&F1&W** will enable this. If you are working with an upgraded Courier, ensure that the higher registers (such as S69 and S70) are not 255, they should usually be 0. This is a common issue with upgrades.

On U.S. Robotics modems (formerly known as Sportster) S32 should equal 2. On 3Com Couriers, S58 should equal 0. The current setting can be determined by entering AT I4 in a terminal program. Help on the register options can be obtained online with ATS$.

5. Ensure that the analog line is capable of V.90/x2.

There are a couple ways to ensure that the analog line is capable of V.90/x2, and none are 100% reliable. These techniques represent the best we can do without sophisticated measuring equipment and on-site evaluation.

- Ensure that you are **NOT** dialing from a PBX line. PBXs are less likely to support V.90/x2.

- Dial into the 3Com/U.S. Robotics Line test server at 847-262-6000 (in the U.S. and Canada). Log in as **`x2 test`**. A program analyzes the line and reports **`Yes`** or **`No`** and gives a frequency response from the perspective of the server. Make several calls to ensure a consistent result.

- Dial into a V.90/x2 host from a terminal program. Set S14=0 prior to dialing to prevent disconnecting on escape. At the login prompt (or whatever is displayed after connect) type +++ to get to the modem's command prompt. While still online, enter (and capture the results if possible): **ATI4I6I7I11Y11**

- Send **AT I6 I11**after 45–60 seconds online. This will show the true settle-in speed, as the first thirty seconds or so might be slightly erratic.

```
Freq     Level
 150     20
 300     16
 ...
3300     11
3450     13
3600     17
3750     25
```

Y11 Command Results.

High-End Rolloff

Examine the values of 3300 and 3750 from the Y11 screen. These values indicate the degree of rolloff in signal power at the high end of the frequency spectrum.

Subtract the value for 3300 and from the value of 3750. If the difference is equal to or greater than 25, that is very good evidence of an additional analog-to-digital conversion (codec). An additional codec pair in the path makes achieving V.90/x2 either not possible or extremely unlikely. It should be noted that some lines might see these same conditions if they are a long distance from the telco facilities and are likely to see improvements with newer modem code.

Signal Attenuation at 3750 Hz

Another criteria to look at is the value of 3750. If it is greater than 50–55, this is a sign of a long local loop, and it is likely to cause poor performance or possibly prevent V.90/x2 from being achieved.

Other Important Values

Other values to collect, if it is not practical to obtain the I-screens in their entirety, are SNR and round-trip delay (from I11) and 150 and 300 (from Y11).

6. Disconnect any other devices that share the analog line and check for line noise or "hum".

Although the following actions should not be necessary for normal operation, they will aid troubleshooting.

- Disconnect (not just hang up) all other phones, answering machines, caller ID boxes, and modems, from all telephone wall jacks at the location. Use only one standard telephone cable (usually silver and 7ft long) between the modem and a wall jack.

- Telephone cable extenders and Y-adapters, if defective, have adverse affects on V.90/x2 (and V.34 for that matter) connections. Multiple devices sharing the same line may affect V.90/x2 performance, especially if they are daisy-chained. Disconnect the other devices and connect the modem directly to the wall jack.

- Another issue that occurs frequently is noise from electrical wires and appliances. Plug a telephone into the same jack your modem is connected to and press (or dial) a single number ("1" works well in the U.S.) to get rid of the dial tone, then listen carefully. If you hear a low frequency "hum" on the line, that is caused by the phone wires coming near electrical wires or appliances. Often this is right near the modem. Try to make sure the phone wire is separated from power cables, surge suppressors, etc.

This "hum" or "buzz" may also be introduced somewhere between your home and the telephone company. Most modern installations in the US, and elsewhere, provide a box at the back the home that allows you to disconnect your house wiring and plug in with a standard RJ11 directly to the phone line. If possible, connect a phone to the telephone company's connection box at the back of you home, and do the same test. This will isolate out noise sources within your home. If the excessive noise is present, then you need to contact your telephone company's repair service. They are generally cooperative when the noise problem interferes with voice communications. It is often best to avoid emphasizing the modem problems, focus on the voice problems and they will generally send someone out.

Using this same technique, if you hear scratchy noise on the line, this will affect modem performance. This may be caused by poor connections in your home or office, but are often caused by poor connections on phone poles or other connecting points on your line. Use the same test methods as above to isolate out whether this is a problem in your house wiring, or with telephone company facilities.

7. Try disabling V.90 (leaving x2 enabled)

Though it will be rare, there are possibly circumstances where x2 could outperform V.90. If you are having trouble with V.90, and the server you are dialing is capable of x2, disable V.90 as a troubleshooting step. In 3Com client modems, V.90 is the preferred modulation, and if it fails due to line problems, x2 will not be attempted. If V.90 is disabled, x2 will be attempted when dialing an x2 capable server. On a U.S. Robotics (Sportster) the command to do this is S32=66. On a Courier it is S58=32.

8. Contact 3Com/U.S. Robotics Technical Support.

NOTE: If your analog modem is not manufactured by 3Com, please contact the support line of the manufacturer of your modem.

To expedite your request, please collect the following data first:

- ❑ The phone number for the POP being called.

From a call to your service provider, preferably while online:

- ❑ From the Y11 screen, the values for 150, 300, 3300, and 3750.
- ❑ From the I11 screen, the round-trip delay and SNR values.

From a call to a known-good V.90/x2 host:

- ❑ From the Y11 screen, the values for 150, 300, 3300, and 3750.
- ❑ From the I11 screen, the round-trip delay and SNR values.

If practical, the full I4, I6, I7, I11, Y11 online screen captures, obtained 45 seconds after connect are best.

Troubleshooting Non-3Com Modem Calls

1. Verify you are using the latest version of code.

Confirm that the modem uses the latest version of code. Below is a list of popular modem manufacturers and their web sites.

Rockwell Based Retail Modems

http://www.bestdata.com/	Best Data
http://www.bocaresearch.com/	Boca
http://www.digicomsys.com/	Creative (Digicom)
http://www.diamondmm.com/	Diamond/Supra
http://www.globalvillage.com/	Global Village
http://www.hayes.com/	Hayes
http://www.maxcorp.com/	Maxtech
http://www.tdksystems.com/	TDK
http://www.vikingcomponents.com/	Viking
http://www.xircom.com/	Xircom
http://www.zoomtel.com/	Zoom

Rockwell Based RAS Products

http://www.ascend.com	Ascend
http://www.cisco.com	Cisco

Lucent Based Retail Modems

http://www.actiontec.com/	Actiontec
http://www.hayes.com/	Hayes Microcomputer Products
http://www.bestdata.com/	Best Data
http://www.linksys.com/	Linksys
http://www.multitech.com/	Multi-Tech
http://www.newmediacorp.com/	New Media
http://www.vikingcomponents.com/	Viking Components
http://www.xircom.com/	Xircom

Lucent Based OEM Modems

http://www.compaq.com/athome/index.html	Compaq Computer Corporation
http://www.fujitsu-pc.com/	Fujitsu PC Corporation
http://www.hp-at-home.com/	Hewlett-Packard Company
http://www.ibm.com/	IBM
http://www.nec-computers.com/	NEC
http://www.quantex.com/sales/	Quantex
http://www.ita.sel.sony.com/index.html	Sony
http://www.toshiba.com/	Toshiba

Lucent Based RAS Products

http://www.ariel.com/	Ariel
http://www.baynetworks.com/	Bay Networks
http://www.hayes.com/	Hayes
http://www.livingston.com/	Livingston
http://www.multitech.com/	Multi-Tech

2. Disconnect any other devices that share the analog line and check for line noise or “hum”.

Although the following actions should not be necessary for normal operation, they will aid troubleshooting.

- Disconnect (not just hang up) all other phones, answering machines, caller ID boxes, and modems, from all telephone wall jacks at the location. Use only one standard telephone cable (usually silver and 7ft long) between the modem and a wall jack.

- Telephone cable extenders and Y-adapters, if defective, have adverse affects on V.90/x2 (and V.34 for that matter) connections. Multiple devices sharing the same line may affect V.90/x2 performance, especially if they are daisy-chained. Disconnect the other devices and connect the modem directly to the wall jack.

- Another issue that occurs frequently is noise from electrical wires and appliances. Plug a telephone into the same jack your modem is connected to and press (or dial) a single number (“1” works well in the U.S.) to get rid of the dial tone, then listen carefully. If you hear a low frequency “hum” on the line, that is caused by the phone wires coming near electrical wires or appliances. Often this is right near the modem. Try to make sure the phone wire is separated from power cables, surge suppressors, etc.

  This "hum" or "buzz" may also be introduced somewhere between your home and the telephone company. Most modern installations in the US, and elsewhere, provide a box at the back the home that allows you to disconnect your house wiring and plug in with a standard RJ11 directly to the phone line. If possible, connect a phone to the telephone company's connection box at the back of you home, and do the same test. This will isolate out noise sources within your home. If the excessive noise is present, then you need to contact your telephone company's repair service. They are generally cooperative when the noise problem interferes with voice communications. It is often best to avoid emphasizing the modem problems, focus on the voice problems and they will generally send someone out.

  Using this same technique, if you hear scratchy noise on the line, this will affect modem performance. This may be caused by poor connections in your home or office, but are often caused by poor connections on phone poles or other connecting points on your line. Use the same test methods as above to isolate out whether this is a problem in your house wiring, or with telephone company facilities.

3. Gather diagnostic information from a call into the host.

Most modems include commands to gather some diagnostic information from a call. Gather the following information from a call into the Total Control V.90 host.

Lucent Based Modems
ATI11
ATI3

Rockwell Based Modems
AT&V1
ATI3

It is best to retrieve this data a good minute or two into a call. If possible, gather the same info dialing into a Rockwell or Lucent based host.

4. Disable V.90

As a troubleshooting step disable V.90 on your client modem. The following commands will work for most modems.

Lucent-based Windows Modems
AT-V90=0

Lucent-based Hayes and other related Modems (most externals and some internals)
Check with your modem vendor's documentation. Usually S109 is used to do this.

Rockwell-based Modems
AT+MS=V34 disables V.90 and K56
AT+MS=K56 disables only V.90

5. Disable AD converter detection on Rockwell based modems.

Some Rockwell modems will incorrectly detect multiple analog to digital converters in the path to a 3Com V.90 host. On some Rockwell modems you can disable the detection of analog to digital converters and the modem will always attempt a V.90 connection.

The command to disable A/D detection is:
ATS202=32

6. Contact your modem manufacturer's Technical Support team.

If you are still experiencing problems establishing V.90 connections with your modem, a call should be placed into the modem manufacturer's technical support team. You may also want to visit their web site for additional troubleshooting information.

Troubleshooting V.90/x2 Servers (I-modem family and Total Control Hubs)

Troubleshooting V.90/x2 servers is an extension of the V.90/x2 client troubleshooting steps. Consider client issues discussed in the previous section and do not assume anything. As mentioned earlier in this document, as long as the server is properly configured for V.90 and x2, the vast bulk of problems are likely to reside in the analog client modem.

1. Call the V.90/x2 server from a known-good analog line.

Call from a known V.90/x2-capable analog line and check for an V.90/x2 connect message. If you get a V.90/x2 connect message, the correct software is installed and enabled.

This does not mean V.90/x2 is fully operational (there could be other issues). If V.90/x2 works from a known-good line, but does not work from a particular line, go through the client troubleshooting steps for that line and test from a wide base (at least several) of different locations.

2. Ensure that the host has proper V.90/x2 software and that it's enabled.

Courier I-modem
At the I-modem, enter **ATI7**. V.90 and/or x2 should appear under **Options** as a supported option. If not, obtain the correct software, install it, and enable it.

V.90 and x2 are NOT an extra-cost feature of I-modems. X2 code required the modem to be enabled, but V.90 code does not have this requirement.

Total Control Quad Modem Cards

Confirm that the cards are up-to-date and the feature is enabled on the NMC. Feature enable is determined from the NMC, not the I7 screen of the quads.

Total Control Manager SNMP Software

- From Total Control Manager, select the **NMC**.
- Select **Programmed Settings**, and then select **Added Cost Features**. V.90 and/or x2 should be shown as enabled.

NOTE: Only Total Control Manager provides this information, not the NMC console port.

3. Ensure that the S-registers are set properly.

As with the clients, there are a number of S-Registers controlling how V.90/x2 works and disabling all or some of the functionality. Those registers must be properly set to allow V.90 and x2 calls to be accepted.

IMPORTANT:
After upgrading to V.90, **Restore from Factory Defaults** or **restore from h/w def** and **Save to NVRAM** to ensure that new registers have valid settings. These settings should be made to all modems in the chassis (or pools that are receiving V.90/x2 calls, if pooling functionality is configured). Perform settings using Total Control Manger software or from the RS232 port (on each modem) with an AT&F1&W.

4. Ensure that the lines are trunk-side.

In most cases, assume that there are no analog-to-digital conversions in the network (behind your CO switch), but if all else fails, investigate.

- Set **S14=0** prior to dialing to prevent disconnecting on escape.
- From a terminal program, dial into a V.90/x2 host.
- At the login prompt (or whatever is displayed after connect) type **+++** to get to the modem's command prompt. While still online, type (and capture the results if possible):
  ATI4I6I7I11Y11

```
Freq     Level
 150     20
 300     16
 ...
3300     11
3450     13
3600     17
3750     25
```

Y11 Command Results

Examine the values of 3300 and 3750 from the Y11 screen. These values indicate the degree of rolloff in signal power at the high end of the frequency spectrum. Subtract the value for 3300 and from the value of 3750. If the difference is equal to or greater than 25, that is very good evidence of an additional analog-to-digital conversion (codec). It is likely that it is a line-side T1. The additional codec pair in the path makes achieving V.90/x2 either not possible or extremely unlikely.

It is possible that certain line configurations, switch types, or network environments cause problems. In such cases, please contact 3Com Technical Support. The vast majority of problems will not occur when a 3Com V.90 client is used, as these were tracked and resolved in the 3Com V.90 implementation. This may not be the case with other vendor's V.90 implementations.

Appendix A - Glossary

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.
Codec	Coder-decoder -- a device that converts analog signals on one side to digital signals on the other, or vice versa.
Digital loop carrier (DLC)	A device that, when used in concert with a digital line, provides an alternative to stretching multiple lower-bandwidth analog lines over longer distances.
Digital pad	A sort of fixed “volume control” that attempts to equalize the loudness of signals from various types of lines.
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.
Digital signal processor (DSP)	A processor that is optimized for performing the complex mathematical calculations inherent in processing digital signals. A discrete DSP may be reprogrammed. A DSP integrated in a chipset typically contains its own ROM and cannot be reprogrammed.
High-end rolloff	Reduction in signal power at the upper frequencies of the voiceband.
Line-side T1	A T1 that undergoes at least one analog-to-digital conversion in the path between the x2 server modem and the PSTN.
Load coil	Used to offset some of the negative effects of longer local loop lengths on voice transmission. Load coils improve voice quality but reduce data-carrying capacity, especially at V.34 and x2 speeds.
Local loop	The path (wiring) between a customer location and the local telephone company’s central office. This is often a completely analog connection over two copper wires.
Near-end echo	Interference in the receive signal caused by reflection of the transmit signal from the “hybrid” at the local CO.
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.
Private branch exchange (PBX)	A telephone switch that is privately owned and located on a customer’s premises -- typically a business or hotel.
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 DS0s, each of which carries 56 Kbps (call-control signaling is carried within the DS0).
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 x2 server modem and the PSTN.
x2 client m-8odem	A modem equipped with x2 software that is attached to a standard analog telephone line. In order to connect at x2 speeds (32–56 Kbps), the device at the other end of the connection must be an x2 server modem that is attached to a trunk-side T1, BRI, or PRI line.
x2 server modem	A digital modem equipped with x2 software that is attached to a trunk-side T1, BRI, or PRI line. Client modems must be equipped with x2 software in order to connect at x2 speeds (32–56 Kbps). Current products that can act as x2 servers include the Total Control Enterprise Network Hub, NETServer I-modem, MP I-modem and Courier I-modem.