1. Purpose

This document describes V.90 analog modem performance and support with GoDigital's XCel POTS Systems.

2. Overview of V.90 Modems and Modem Operation

Standard V.90 or "56K" modems are designed to provide downstream modem speeds greater than V.34 (V.34 defined maximum of 33.6 kbps) over normal POTS lines. Because of network designs and impairment factors, there are millions of subscribers with V.90 modems not attaining high V.90 connections. The requirements for achieving a V.90 subscriber connection are:

- A digital connection at one end (the ISP end);
- V.90 modem support at both ends; and
- Only one analog-to-digital (A-D) conversion in the direction from the source (ISP) to the subscriber

Digital pair gain systems add a second analog-to-digital conversion that limit modem connections to V.34 speeds. GoDigital's new GDSL XCel Systems with V.90 capability is designed to help restore the subscriber's ability to attain V.90 modem speeds when a second A-D conversion is present.

3. V.90 Modem Speeds

The maximum downstream V.90 speed available in North America is approximately 53.3 kbps, based on current FCC restrictions. Any connection greater than 33.6 kbps (V.34) is considered a V.90 connection. It is important to note that the initial connect speed that a modem and server establish can be significantly different from the data throughput that is actually experienced due to bit error rates experienced in the link. Actual connection rates vary with each modem call and are subject to several key impairment factors including:

- Robbed-bit signaling links in the circuit
- Load coils in the local loop
- Long local loops which gradually decrease the maximum attainable speed
- Copper wire gauge
- External noise disturbances on the loop
- Electrical disturbances and defects in the house wiring
- Subscriber modem compatibility with the ISP remote access server (RAS)
- Digital switch attenuation pad settings (db) in the central office switch

3.1. V.90 Connection Process

- As soon as the modem attempts to connect to an ISP, a dialogue or "handshake" is established between the modem and RAS
- During this handshake, the modem and RAS attempt to establish the fastest speed that they agree is reliable for data transmission.
- If the first speed attempted does not appear reliable, the modem will attempt to drop back to a slightly lower V.90 speed until an agreeable speed is reached.
- If a "V.90 connection" is not attained within a reasonable period of time, the modem will step down to V.34 operation.

3.2. V.90 Impairment Factors

As mentioned above, there are numerous impairment factors that can limit the connect speeds and throughput rates, or completely prevent a successful V.90 modem connection. Some factors are controllable by the telephone company or the subscriber while others may not be. These factors include:

- Individual subscriber modem characteristics
- Individual remote access server (RAS) characteristics

- Individual CO switch and switch port characteristics (pads)
- Specific modem and RAS compatibility
- Number of A-D conversions in the loop
- V.90 support at the RAS – dialed port must support V.90
- Quality of the network between the modem and server, including influence from:
  - CO switch ports and switch systems
  - External noise, which may contribute to bit errors in any part of the network or local loop
  - Length and cable gauge of the loop between the subscriber and the CO

3.3. V.90 Modem Variability

Some modems work better with specific servers and have difficulty with others. If a call does not result in a quick and solid "handshake", then the modems themselves can get confused during handshake causing the call to fall back to V.34. In some instances due to the many factors listed above, the modem may become so confused, or the bit error rate is so high, that either the server or modem will drop the connection entirely. A redial will usually result in re-establishing the connection. This is the nature of V.90 calling between the modem and the server.

There are hundreds of makes and models of V.90 or "56K"modems in use, although the vast majority use one of the three predominate modem chip sets from either Lucent, Conexant (Rockwell) or USR (3Com). The different models all operate with variations in the way the manufacturer has chosen to implement the V.90 protocol and standard. Older or early versions of "56K" modems that have been introduced ahead of the V.90 standards may not support their best speeds on all new servers. In addition, new versions of V.90 modems are constantly being introduced with variations in their implementation of the standard (with the objective of maximum standard compatibility).

3.4. V.90 Performance

V.90 or "56K" modems provide downstream speeds that are greater than V.34 (33.6 kbps) when POTS lines are delivered *directly from the CO switch* (Figure 1) or from a *digital loop carrier (DLC) that has an integrated digital switch interface* (Figure 2). In both of these cases a single analog-to-digital network conversion occurs.

Figure 1: Subscriber Served Directly from Switch

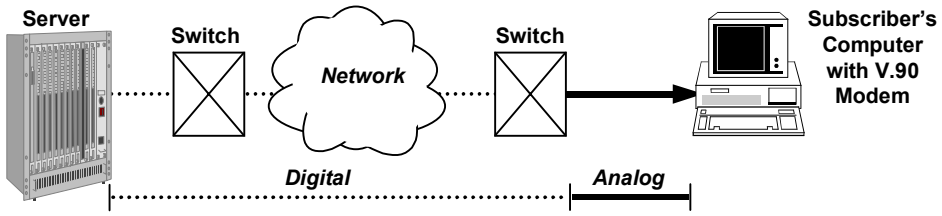
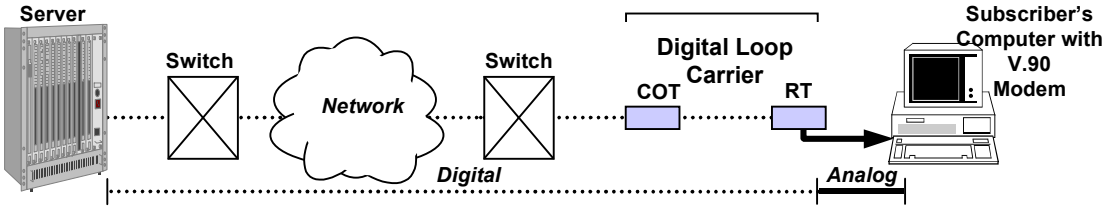


Figure 2: DLC with Integrated Interface

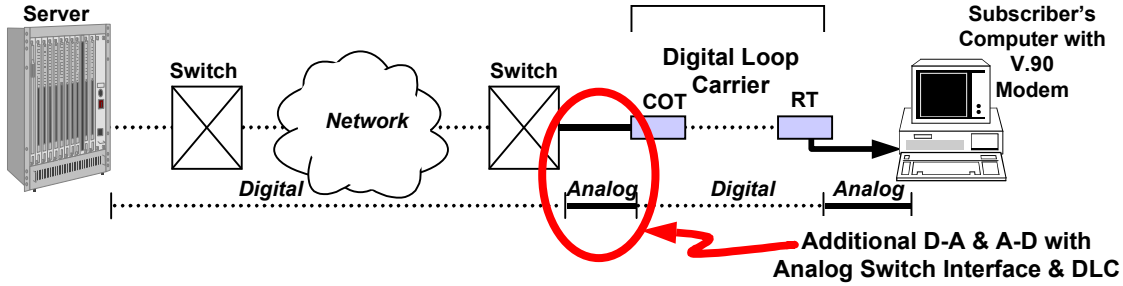


When a digital pair-gain or DLC system has a universal or analog switch interface, an additional analog to digital (A-D) conversion occurs. This second A-D conversion limits modem speed to a V.34 connection speed. See Figure 3.

4. GoDigital XCel™ V.90 Technology

GoDigital's new XCel and GDSL Systems with V.90 capability, help restore a subscriber's ability to attain V.90 speeds by focusing on the impairment caused by the second analog-to-digital conversion found in pair gain systems.

Figure 3: DLC with Analog Switch Interface



Using patent pending Digital Signal Processing (DSP) technology in the XCel CTU line card, the XCel System automatically corrects for the second analog to digital conversion at the switch and enables V.90 connections. A GDSL XCel CTU implements this functionality for each of the eight (or 12) individual POTS lines delivered from the switch. The XCel DSP does this by "training" the individual line to the characteristics of the specific POTS switch port that it is being served from. See Figure 4 and Figure 5.

Figure 4: GoDigital COT and CTUs

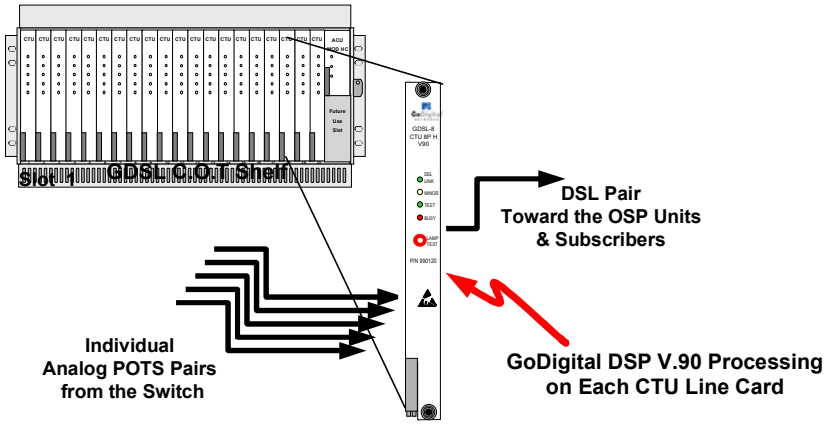
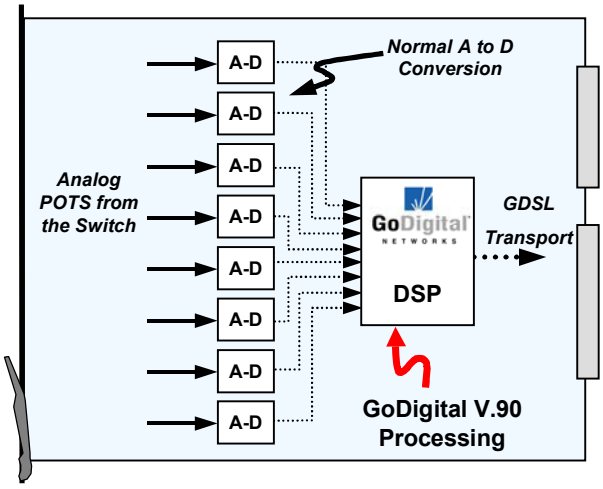


Figure 5: GDSL CTU with V.90 Processing



5. XCel System Expected Performance and Interoperability

NOTE: The information in this section is current as of the date of printing. Updates to this document will be made as additional capabilities are added and further interoperability testing is completed.

5.1. XCel System V.90Expected Performance

Release 2 of the XCel DSP code achieves approximately 70% of connection speeds at V.90 (33.6kbps and higher) as tested in the field in various environments. Characterization of Rls1 and Rls2 in real field environments have demonstrated 23% and 42%, respectively, of connections above 40kbps i.e. Rls2 delivers approximately twice the number of connections over 40kbps as compared to Rls1. As described above, specific results will vary based on the environment in which a system is deployed Rls2 as well as Rls1 provides significant improvement over the 26-28.8 kbps (V.34) speeds that V.90 modem customers have typically been experiencing on digital pair gain systems or on long local loops.

NOTE: The XCel/GDSL Shelf should normally be mounted within 300 feet (total POTS cabling distance) of the central office POTS switch. The maximum distance should not exceed 500 feet. If the shelf is mounted too far from the switch service ports, the GoDigital V.90 signal processing capability on analog POTS lines may be reduced or disabled.

NOTE: The CTU capability to support V.90 modem performance may not be as effective when the XCel or GDSL shelf is installed in a remote DLC location as it would in the Central Office. The CTU's V.90 processing capability will normally correct for modem speed loss at the C.O. switch. If an GoDigital System is placed at the end of a DLC, and that DLC has an analog POTS front end, the combination of two D-A conversions (at the switch and on the POTS card at the DLC's RT) can preclude optimum modem throughput capabilities.

5.2. XCel System CO Switch Compatibility

GoDigital has tested and verified compatibility of the GDSL XCel Technology with the following switches:

XCel - Switch Interoperability(Note 1)		
GREEN	**YELLOW**	**RED**
LUCENT 5ESS	ERICSSON(Note 2)	LUCENT 1AESS (Analog)
SIEMENS EWSD	NORTEL DMS-100(Note 2)	
GTD5 (Rls2)	NORTEL DMS-10(Note 2)	
STROMBERG-CARLSON		

Note 1: GREEN → Demonstrated V.90 Interoperability > 60% of calls with V.90 Connect Rates
YELLOW → Limited V.90 Interoperability and/or Test Results; V.34 achieved
RED → No V90 Interoperability Demonstrated; V.34 achieved
XCel V.34 fallback functionality remains in tack regardless of the switch.
Note 2: Speed limiting modems for these switches provides >60% of calls with V.90 Connect Rates. In the DMS-100 and DMS-10 cases, this significantly increases the V.90 performance.

5.3. XCel System CO Switch Pad (Attenuation) Compatibility

The XCel processing software is designed and tested to support the following individual CO switch line pad settings:

XCel - CO Switch Pad Interoperability(Note 2)		
ANALOG PADS	All (within 0 to 8 dB)	
DIGITAL PADS	0 dB	
	3 dB	
	4 dB	
	5 dB	
	6 dB	

Note 2: Pad Settings, other than those listed, are not currently supported for V90 operation. GoDigital Recommends setting pads to the designated levels to enhance interoperability.
Pad settings do not effect reliability of the XCel V.34 fallback functionality.

5.4. XCel System Remote Access Server Compatibility

GoDigital has tested and verified compatibility of the XCel Technology with the following remote access servers:

XCel - RAS Interoperability (Note 3)		
GREEN	**YELLOW**	**RED**
Lucent / Ascend MAX		
Nortel CVX-1800		
Lucent / Livingston PortMaster		
3COM SuperStack		
Multitech		
Cisco AS5200 (Rls2)		
Cisco AS5300 (Rls2)		
Cisco AS5800 (Rls2)		
3Com Total Control (Rls2)		

Note 3: GREEN → Demonstrated V.90 Interoperability > 60% of calls with V.90 Connect Rates
YELLOW → Limited V.90 Interoperability and/or Test Results; V.34 achieved
RED → No V90 Interoperability Demonstrated; V.34 achieved
XCel V.34 fallback functionality remains intact regardless of the RAC/RAS.

Reliable V.90 interconnections have been attained for these servers in numerous field trials. In the event, a V.90 modem-server handshake does not result in a successful V.90 connection, the XCel CTU will cause the modem connection to fall back to a reliable V.34 connection.

5.5. XCel System Modem Compatibility

Specific modem performance with various ISPs and servers will vary depending on the conditions and impairments present, as described previously. Provided that ISP connections were established with one of the RAS listed in the previous section, these modems (listed below) have all demonstrated multiple V.90 connections over the XCel System with several major ISPs including AOL, Earthlink, MSN and Prodigy. The list of compatible modems shown below will be periodically updated, and is not meant to imply guaranteed performance. If a modem does not appear on this list, it does not mean that it will not operate at V.90 speeds over an XCel System, but more likely that it has not been tested by GoDigital.

The following modems have been tested and verified for V.90 compatibility with XCel Systems (in all RAS combinations, per the RAS Table in the section above):

XCel – Client Modem Interoperability (Note 4)		
GREEN	**YELLOW**	**RED**
External Modems		
USR Courier		Global Village Teleport56
3Com Sportster		(All 56K "FLEX" Modems)
Modem Blaster 5620-2		
Modem Blaster 5620-3		
Best Data		
SupraExpress		
OLITEC		
Lucent-Zoom		
Hayes		
ActionTec		

Internal Modems		
3Com Sportster ISA Faxmodem		
3Com Sportster PCI Win modem		
Best Data PCI Modem		
SupraMax PCI Modem Sup2750		
Zoom PCI Modem		
LT WIN Modem (Rls2)		
Hayes Accura V.90 PCI		
ActionTec		
Xircom PCMCIA Real Port Modem56		
BTC Software Modem		
iMac Internal Modem		

Note 4: GREEN → Demonstrated V.90 Interoperability > 70% Connect Rates
YELLOW → Limited V.90 Interoperability and/or Test Results; V.34 achieved
RED → No V90 Interoperability Demonstrated; V.34 achieved

NOTE: The XCel System is not compatible with the Global Village Teleport 56 modem or any of the 56K FLEX modems. These are older pre-V.90 modems that do not conform to the V.90 standard. Some of these modems may be upgradeable to V.90 with new software available from the modem supplier.

6. Speed Limiting V.90 Modems

Modem instruction manuals recognize the nuances of individual connections, various remote access servers, and network conditions by recommending that, when V.90 speeds are not attained consistently, users should speed limit their modem drivers to a lower connection speed (typically 40-42 kbps) to establish a lower initial connection attempt speed. Speed limiting can significantly increase the probability that a reliable (V.90) connection, is attained prior to the modem "giving up" and dropping to the V.34 mode. Users should consult their modem operating manuals for the proper procedure for speed limiting their modems. (Note: This seems to be particularly the case with Conexant-based modems.)

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