Video on Frame Relay

Tandberg

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1. Introduction

This document is designed as an 'eye-opener' to video over frame relay and the idea is to show a solution that works. The equipment described in this document is the VFX-250S, a framer unit from Science Dynamics Corporation. Tandberg video conferencing codecs are being used over frame relay together with this equipment and according to the setup described here. The setup has been tested and found reliable and it works well. For abbreviations throughout the document a glossary is provided in the back.

The costs and savings of using frame relay network for video transmissions are taken from calculations by Science Dynamics and should be considered examples only. Tandberg disclaims any responsibility for inaccuracies or subsequent changes in the tariffs used in developing the above costs and savings.

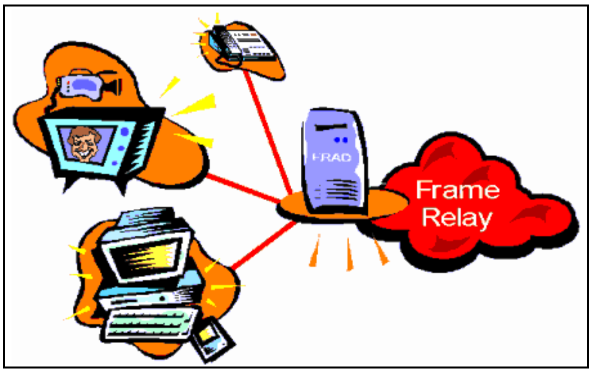
Here's what it takes to make videoconferencing work on frame relays today:

- Unfailing QoS (Quality of Service). The single most important factor in the delivery of acceptable videoconferencing over frame relay is protection of the video stream from frame drops.
- Adequate bandwidth. You'll need 384 Kbps or more for room-based systems, 128 to 256 Kbps for desktop systems and up to 56 Kbps for surveillance systems. This is comparable to the requirements for circuit-switched connections such as ISDN (Integrated Services Digital Network).
- CIR(Committed Information Rate) in the frame relay WAN(Wide Area Network). It must be 1 percent to 3 percent higher than selected bandwidth; you'll need additional transmission space to carry frame relay packet overhead without impeding delivery of the payload.

Tests have shown that even when flooding the concurrently running Ethernet with so much traffic that 98 percent of data packets were thrown away, the video stream rolled merrily along at 30 frames per second with no evidence of tiling faults or frame drops.

2. Background on transmission of video over frame relay

The successful transmission of digitised voice over public frame relay data services the past few years has drawn attention to the question of whether video services can be transmitted over the same link.



Voice, data & video over frame relay

Digitised Video is not new. It has been used for several years by a myriad of users on ISDN or leased line connections. The common international standard for the compression of video and accompanying voice is H.320. Frame relay is not new either. It has been in existence for several years, and is now one of the most widely deployed data transmission means in the world. What is new, and revolutionary, is the ability to take a standard H.320 video stream, "packetise it", and route it over a frame relay network.

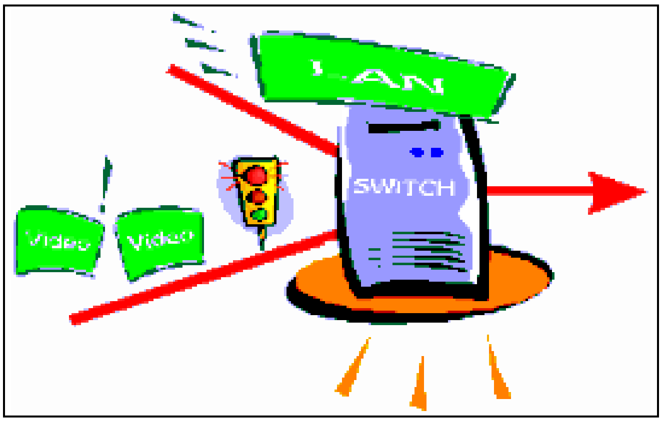
Historically, frame relay has been developed and sold primarily as a data transport technology and service solution. This should be viewed primarily as a marketing and positioning technique, not a fundamental technical limitation. All of the technical challenges of using frame relay to transport video have been met. The marketing challenge is to expand the perceived scope of frame relay beyond a "data only" image.

3. Technical issues

There are two potential technical issues, which may affect the quality of packetised, digitised video. One is delay, or more properly jitter. Jitter is the variation in delay from one frame to the next. This is critical for video, as video requires a constant bit stream in order to maintain an image. The second is dropped frames. If a video frame is lost, it may cause a click or pop in the audio and some pixelation on the video. Too many lost frames and the video quality is impaired.

In leased line applications using TDM (Time Division Multiplexing) jitter is not an issue, as video frames arrive at known, predictable intervals. Concurrently, there is little likelihood of dropped frames unless the line itself malfunctions. However, public frame relay networks introduce issues that do not occur when running the frame relay protocol over private leased lines. Customers who wish to run digitised video over public frame relay services need to understand these issues.

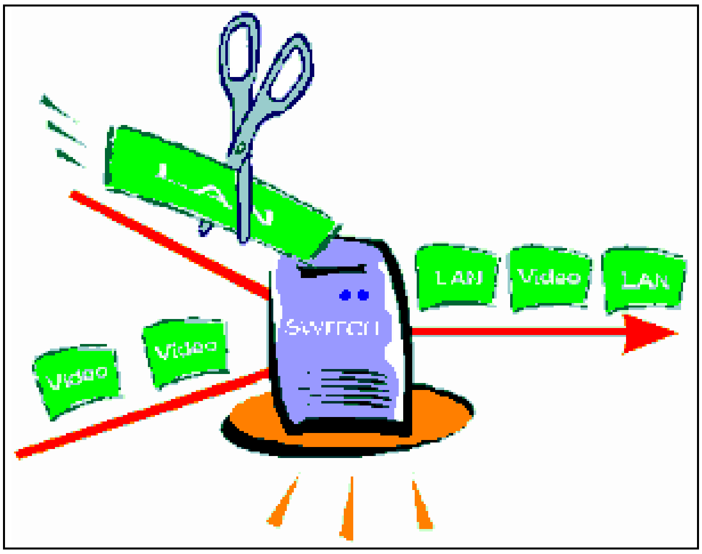
Jitter can occur in public frame networks when an intermediate switch is processing someone else's frame when your frame arrives.



Jitter is created by differences in packet size

The second incoming frame is held in a buffer at the switch until the transmission of the first frame is completed. The delay that results is dependent on the length of the first frame. Since frame relay allows variable length frames, this delay is variable and unpredictable, resulting in jitter. If this jitter exceeds the ability of the receiving device to compensate by buffering, video quality will be degraded.

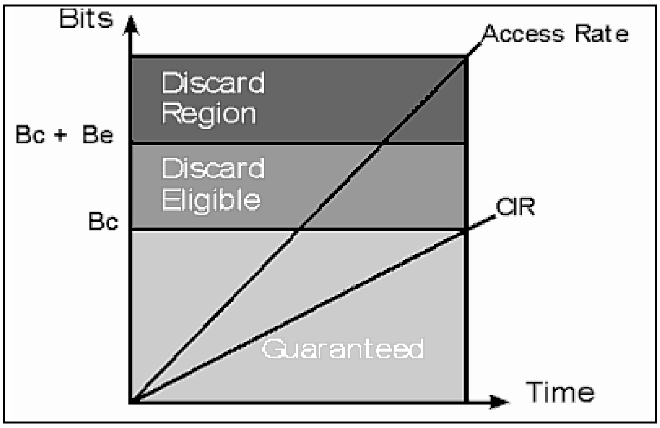
However, for the majority of public frame relay networks, jitter is more a theoretical problem than a real problem. Public services run on high-speed backbones. Since delay is inversely proportional to speed, this means that delay at intermediate nodes is highly unlikely. Also, many of today's Public frame relay networks use a cell (fixed frame length) based architecture between nodes, which also reduces the likelihood of jitter.



Cell based systems cut packet into fixed sizes

Dropped frames are potentially a more serious problem. The frame relay standard allows the network service provider to control congestion by simply disposing of any frames which exceed the users CIR. In other words, if you contract for a CIR of 128 kbps but send a burst at 192 kbps, frames which exceed the 128 kbps CIR will have a DE (Discard Eligible) bit set. If some intermediate switch on the network becomes congested, these frames may be discarded. While an occasional lost frame will not seriously degrade video quality, too many will cause a noticeable loss of video quality.

In most networks, dropped frames are unlikely to occur. This depends, of course, on the capacity of the network, the actual traffic load at any given time, how the load varies, and other factors beyond the control of the end user.



The only certain way is to have enough CIR to cover all usage.

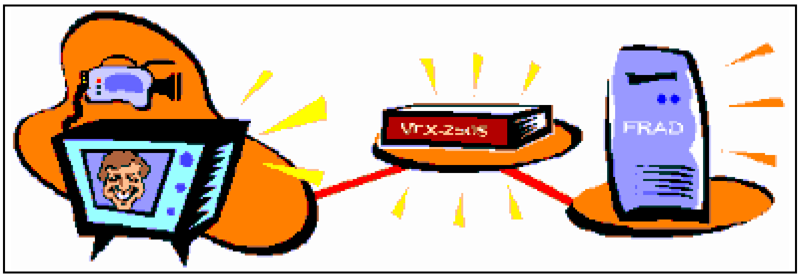
This is unnecessary in most cases, as the majority of installed public networks are not oversubscribed. Most carriers are now offering QoS (Quality of Service) or SLA (Service Level Agreement) guarantees, which categorically provide an end user with confidence that more than 99% of frames will arrive at their destination. For the Video over Frame Relay user, there are other ways of reducing the threat of frame loss.

1. The first is the configuration of the frame size. Frame relay allows the payload portion of the frame to be adjusted to carry larger or smaller amounts of information. This allows network administrators to adjust the frame size for optimal network performance. If a small frame packet is lost, it is not carrying too much information as to critically impair video function.

2. The second method is to establish a traffic prioritisation scheme for any channels carrying video through a FRAD (Frame Relay Access Devices) on a defined DLCI. This ensures that video frames are first out. Therefore, intelligent buffer management ensures video frames, which are less tolerant of delay, have priority over data frames which can usually tolerate some delay.

4. Equipment for Video over Frame Relay

There are many H.320 compliant systems on the market which users may wish to place on a frame relay network. This may be accomplished by an external H.320 to frame relay conversion unit such as the VFX-250S.



Using an external converter

This is a simple solution, which maintains existing investment in video equipment, while providing the benefits of operating over a frame relay network.

Note: Some video codec manufactures claim their product to be frame relay compatible by outputting HDLC, which can then be carried transparently by a FRAD. This is not a 'true' frame relay solution and certain limitations apply.

4.1 Framing the Picture

Preparing video for the frame network requires a framer that packetises output from the codec: Suggested equipment could be a video framer from Memotec working in front of its CX900e, and an AVI-2000 from ACT to complement the ACT SDM-9300 FRAD. Both FRAD manufacturers use the Science Dynamics VFX-250S to become "video-capable."

The video framer interacts with the RS449 output of Data Terminal Equipment (DTE)-> the codec. The VFX-250S provides clock to the DTE at 64, 96, 128, 192, 256, 384, 512, 768, 1.024 or 1.536 Kbps. It supports continuous full-duplex data transfers at up to 2.048 Kbps.

Normally, the VFX-250S's selected clock is locked to a submultiple of the network clock. When running 384 Kbps with the Memotec CX900e, the ACT's SDM-9300 FRAD requires to drop to 256 Kbps. Another option allows the VFX-250S automatically to vary the output clock rate to the DTE by slight increments as required to maintain slip-free data transfer.

The VFX-250S creates standard frame relay frames with 6-byte headers and user-selected packet lengths. Short packets (for example, 256 bytes) add frame overhead but have less impact on the audio/video stream if they get lost. Long packets (up to 1.580 bytes) are more efficient but increase the delay. It is possible to run the VFX-250S framer both at the ACT-recommended setting of 256 bytes and at 1.500 bytes (which is in line with the recommendations of other framer users) without any difference in the overall performance.

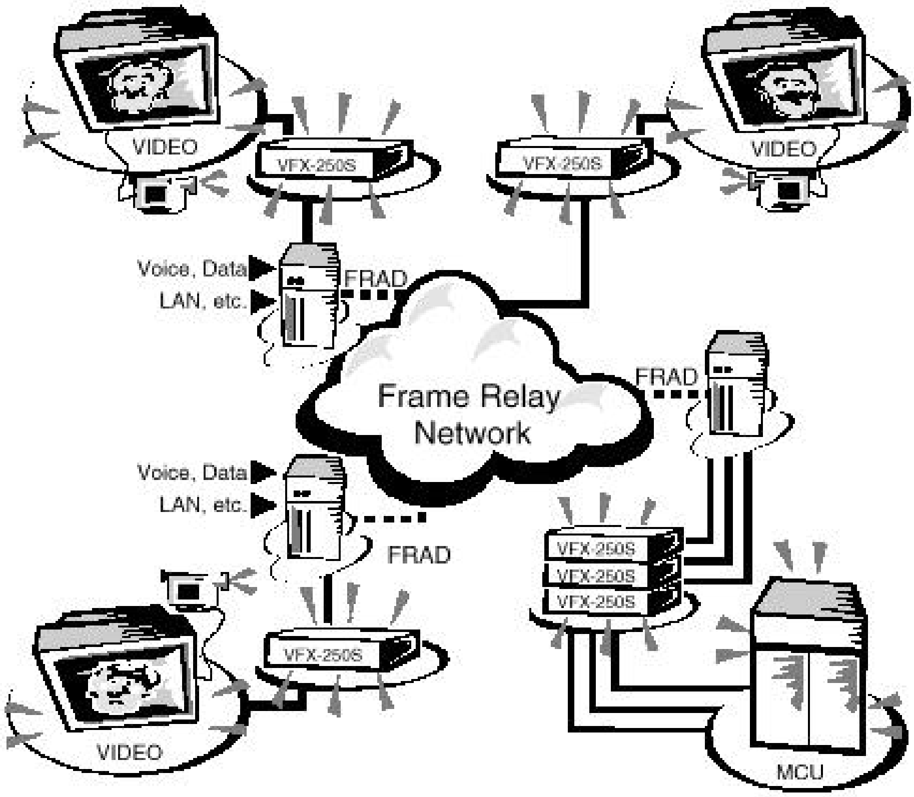
You can connect either the VFX-250S or the ABL VT2C directly to a DSU/CSU on a frame relay network. The two products have another common trait: If you intend to share the video stream with other types of traffic, you'll need to connect the VFX-250S or ABL VT2C to one of the inputs on a FRAD or router acting as a frame relay switch.

5. About the Product VFX-250S

The VFX-250S product series from Science Dynamics Corporation offers a cost-effective solution to the packetisation of continuous data bit-streams. The world of frame relay users is becoming larger day by day, as are the different uses of frame relay services. Corporate customers are adopting frame relay as a medium for many different types of communication. The advent of FRADs has enabled users to integrate LAN-to-LAN connectivity, inter-office voice communications, IBM SNA traffic, etc. over a single frame relay circuit. The advantages of integration are, quite obviously, cost. The transmission of video over any digital network requires the use of video encoders/decoders (referred to as Codecs). Most video codecs, however, are designed to run on "leased line" or ISDN type services which provide a transparent path for continuous bit streams. Now, Science Dynamics brings support for the transportation of continuous data bit-streams (such as H.320) over a frame relay service in the form of a standalone unit. In this application the VFX-250S provides the continuous bit stream required by video codecs and permits continuous bit stream access for frame relay service providers (FRADs). The VFX-250S is a ‘desktop’ enclosure, with AC power, which can be incorporated into an existing network providing an instant upgrade to frame relay networking facilities.

6. Application Overview

The diagram below shows the use of the VFX-250S in a video-conferencing over frame relay application. In this application the VFX-250S takes the H.320 datastream from the end point video-conferencing equipment and packetises it into a frame relay format for transmission over the network. This application also includes a MCU (Multi-point Conferencing Unit) which can interface with multiple VFX-250S units.



7. Technical Specification of VFX-250S

7.1 Network & User Interface

Connector:
Female 37-pin D type to user equipment (Video codec) Male 37-pin D type to network equipment (FRAD)
Interface:
RS449 (X.21, V.35 and others with adapter cables) RS422 balanced drivers and receivers and RS423 receivers

7.2 User Interface

Clock Rates:
VFX-250S can accept external TT clock or it can supply clock to user equipment at the following speeds: 64, 96, 128, 192, 256, 384, 512, and 768 Kbps, plus 1.024, 1.536, and 1.920 Mbps
Transmission:
Supports continuous full duplex data transfer at specified clock rates.

7.3 Network Interface

Clock Rates:
VFX-250S requires clock from network (up to a maximum of 2.048Mbps).
Packet Parameters:
Packet Length: 10 - 4095 bytes
DLCI: 2 byte
FCS: standard 2 bytes

7.4 Enhanced Buffer Management

A unique underlying protocol is used to negotiate a Master/Slave relationship between two communicating VFX-250S units. This allows for an "end-to-end" management of the buffers to provide a "slip-free" data transfer. An Automatic Variable Buffer (AVB) feature is provided in order to smooth the potential differences in delays across the range of user port clock speeds.

7.5 Serial Management Interface

Connector:
Female 9 pin D type
Interface:
EIA-232, 9.6 Kbps & 19.2 Kbps, 8 bits/no parity/1 stop bit
Configuration:
Windows-based configuration software is provided with the VFX-250S which allows for the management of all the options within the unit. Alternatively, a "dumb" terminal can be used to access the menu driven configuration system directly. Available Settings:

- User defined Site Name

- 4 configuration entries, each of which contains TX and RX DLCI settings, User Clock Speed, Packet Length, and AVB
- LMI type control selection & parameter entry (ITU Annex A, ANSI Annex D, Frame Relay Forum, or Off)
- Master, Slave, or Auto-assign settings for Enhanced Buffer Management
- Local/Remote loopback facilities

Memory:
4 configuration entries are maintained within the memory of the VFX-250S. These can be updated from the much larger configuration library in the Windows-based configuration software. All configuration parameters are stored in non-volatile memory.

7.6 Mechanical/Environmental

Overall Size:
H: 4.6 cm (1.8")
W: 21.4 cm (8.4")
D: 20.9 cm (8.3")
Temperature:
Operating: 0° to +50°C
Non-operating:-20° to +70°C
Humidity:
10 to 90 % non-condensing
Altitude:
3,050 M (10,000 ft)

7.7 Power Supply

AC Input:
100 to 250 VAC (50 - 60 Hz), 15 W maximum
Type:
Universal Desktop with IEC 320 AC input connector (can be supplied with a variety of North American/International power cords)
Size:
H: 3.8 cm (1.5")
W: 6.6 cm (2.6")
D: 10.2 cm (4.0")

8. Approvals

FCC Class A Digital Devices and Peripherals

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

A note about system cables:

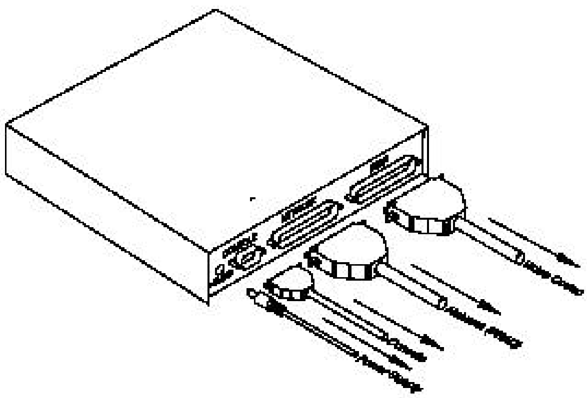
To maintain the EMC (ElectroMagnetic Compatibility) performance of the unit, user and network port cables must be high quality, fully shielded cables with EMI/RFI connector hoods.

9. Cable VFX-250S

In order to cable the VFX-250S into a frame relay network, you need to assemble the following cables according to your network requirements:

- Console Cable
- Network Cable
- User Cable

Refer to Appendix A, Cables and Pinouts, for pinouts and wiring diagrams. Plug the +5 VDC power supply into the VFX-250S and plug the supplied power cord into the power supply and a standard AC outlet. Only use the power supply provided by Science Dynamics (P/N LZUSD02001A0200). Connect the VFX-250S console port to a terminal or PC communications port to configure and maintain unit settings. For a video-conferencing application, install the VFX-250S in the frame relay network between the network (FRAD) equipment and the user (video codec) equipment. Please see User Manual for technical details.



Typical VFX-250S Cabling

10. Economics of Video over Frame Relay

The economics of video over frame relay are similar to those driving the use of voice over frame relay. Voice over frame relay is fairly well accepted as being economical when used in international applications. With international ISDN call prices frequently exceeding $1 per minute per line, the payback period for voice or video over frame relay, even with the higher international rates for frame relay, are dramatic.

Let us assume an international company with offices in New Jersey-USA, San Francisco-USA and London-UK. This company conducts a total of three hours of videoconferencing a week between these offices, at 384kbps. On ISDN, the non-discounted cost per month is $6,040. ($1,170 USA + $4,870 International)

In this instance, assuming the "worst case" for frame relay, the user purchases bandwidth for the exclusive use of video, the non-discounted cost (excluding access lines) is approximately $4,300 per month (based upon a 256Kbps CIR), a saving of $20,880 per annum.

Unfortunately, the above ‘video only’ example totally disregards the usual economies found in combining video with existing voice, data and fax applications on frame relay. In fact, a more realistic example would be a user who already has a 128 kbps frame relay link (with a CIR of 64kbps) for voice / data requirements.

This could then be upgraded to 512kbps (with a CIR of 384kbps). The incremental upgrade cost would then be approximately $2,000, thus the true monthly savings would be approximately $4,000 ($48,000 p.a).

A return on the investment will be realised in a matter of months.

11. Appendix A: Cables and Pinouts

11.1 Standard Console Cable

The console port on the VFX-250S conforms to EIA-232/V.24 electrical specifications.

	VFX-250S Console Port DB9 Male		PC COM Port DB9 Female	Terminal DB25
DESCRIPTION				
Transmit Data	2	------------->	2	3
Receive Data	3	<--------------	3	2
Ground	5	----------------	5	7

11.2 Standard EIA-449/RS449 Cables

11.2.1 Network Cable

DESCRIPTION	VFX-250S (RS449) Network Port DB37 Female PIN		Network (RS449) DCE Port PIN	RS449 Mnemonic
Shield	1	--------------	1	
Send Data A	4	------------->	4	SD (A)
Send Timing A	5	<-------------	5	ST (A)
Receive Data A	6	<-------------	6	RD (A)
Request To Send A	7	------------->	7	RS (A)
Receive Timing A	8	------------->	8	RT (A)
Clear To Send A	9	<-------------	9	CS (A)
Local Loopback	10	------------->	10	LL
Data Set Ready A	11	<-------------	11	DM (A)
Data Terminal Ready A	12	------------->	12	TR (A)
Data Carrier Detect A	13	<-------------	13	RR (A)
Remote Loopback	14	------------->	14	RL
Ring Indicator	15	<-------------	15	RI
Terminal Timing A	17	------------->	17	TT (A)
Test Mode	18	<-------------	18	TM
Signal Ground	19	--------------	19	SG
Send Data B	22	------------->	22	SD (B)
Send Timing B	23	<-------------	23	ST (B)
Receive Data B	24	<-------------	24	RD (B)
Request To Send B	25	------------->	25	RS (B)
Receive Timing B	26	<-------------	26	RT (B)
Clear To Send B	27	<-------------	27	CS (B)
Data Set Ready B	29	<-------------	29	DM (B)
Data Terminal Ready B	30	------------->	30	TR (B)
Data Carrier Detect B	31	<-------------	31	RR (B)
Terminal Timing B	35	------------->	35	TT (B)

11.2.2 User Cable

A note about RTS signalling:
Some manufacturers state that their network interface is RS449 (which uses RS422 signalling levels) but actually use RS423 signals for the control leads. If this is the case, then check the position of the RTS straps on page 11.

DESCRIPTION	VFX-250S (RS449) User Port DB37 Male PIN		User (RS449) User Port PIN	RS449 Mnemonic
Shield	1	--------------	1	
Send Data A	4	<-------------	4	SD (A)
Send Timing A	5	------------->	5	ST (A)
Receive Data A	6	------------->	6	RD (A)
Request To Send A	7	<-------------	7	RS (A)
Receive Timing A	8	<-------------	8	RT (A)
Clear To Send A	9	------------->	9	CS (A)
Local Loopback	10	<-------------	10	LL
Data Set Ready A	11	------------->	11	DM (A)
Data Terminal Ready A	12	<-------------	12	TR (A)
Data Carrier Detect A	13	------------->	13	RR (A)
Remote Loopback	14	<-------------	14	RL
Ring Indicator	15	------------->	15	RI
Terminal Timing A	17	<-------------	17	TT (A)
Test Mode	18	------------->	18	TM
Signal Ground	19	--------------	19	SG
Send Data B	22	<-------------	22	SD (B)
Send Timing B	23	------------->	23	ST (B)
Receive Data B	24	------------->	24	RD (B)
Request To Send B	25	<-------------	25	RS (B)
Receive Timing B	26	------------->	26	RT (B)
Clear To Send B	27	------------->	27	CS (B)
Data Set Ready B	29	------------->	29	DM (B)
Data Terminal Ready B	30	<-------------	30	TR (B)
Data Carrier Detect B	31	------------->	31	RR (B)
Terminal Timing B	35	<-------------	35	TT (B)

11.3 Standard EIA-530/RS530 Cables

11.3.1 Network Cable

	VFX-250S (RS449)		Network (RS530)	RS530 Mnemonic
	Network Port		DCE Port	
	DB37 Female			
DESCRIPTION	**PIN**		**PIN**	
Shield	1	----------	1	
Send Data **A**	4	--------->	2	BA (A)
Send Timing **A**	5	<---------	15	DB (A)
Receive Data **A**	6	<---------	3	BB (A)
Request To Send **A**	7	--------->	4	CA (A)
Receive Timing **A**	8	--------->	17	DD (A)
Clear To Send **A**	9	<---------	5	CB (A)
Local Loopback	10	--------->	18	LL
Data Set Ready **A**	11	<---------	6	CC (A)
Data Terminal Ready **A**	12	--------->	20	CD (A)
Data Carrier Detect **A**	13	<---------	8	CF (A)
Remote Loopback	14	--------->	21	RL
Terminal Timing **A**	17	--------->	24	DA (A)
Test Mode	18	<---------	25	TM
Signal Ground	19	----------	7	AB
Send Data **B**	22	--------->	14	BA (B)
Send Timing **B**	23	<---------	12	DB (B)
Receive Data **B**	24	<---------	16	BB (B)
Request To Send **B**	25	--------->	19	CA (B)
Receive Timing **B**	26	<---------	9	DD (B)
Clear To Send **B**	27	<---------	13	CB (B)
Data Set Ready **B**	29	<---------	22	CC (B)
Data Terminal Ready **B**	30	--------->	23	CD (B)
Data Carrier Detect **B**	31	<---------	10	CF (B)
Terminal Timing **B**	35	--------->	11	DA (B)

11.3.2 User Cable

	VFX-250S (RS449)		User (RS530)	RS530 Mnemonic
	User Port		User Port	
	DB37 Male			
DESCRIPTION	**PIN**		**PIN**	
Shield	1	----------	1	
Send Data **A**	4	<---------	2	BA (A)
Send Timing **A**	5	--------->	15	DB (A)
Receive Data **A**	6	--------->	3	BB (A)
Request To Send **A**	7	<---------	4	CA (A)
Receive Timing **A**	8	<---------	17	DD (A)
Clear To Send **A**	9	--------->	5	CB (A)
Local Loopback	10	<---------	18	LL
Data Set Ready **A**	11	--------->	6	CC (A)
Data Terminal Ready **A**	12	<---------	20	CD (A)
Data Carrier Detect **A**	13	--------->	8	CF (A)
Remote Loopback	14	<---------	21	RL
Terminal Timing **A**	17	<---------	24	DA (A)
Test Mode	18	--------->	25	TM
Signal Ground	19	----------	7	AB
Send Data **B**	22	<---------	14	BA (B)
Send Timing **B**	23	--------->	12	DB (B)
Receive Data **B**	24	--------->	16	BB (B)
Request To Send **B**	25	<---------	19	CA (B)
Receive Timing **B**	26	--------->	9	DD (B)
Clear To Send **B**	27	--------->	13	CB (B)
Data Set Ready **B**	29	--------->	22	CC (B)
Data Terminal Ready **B**	30	<---------	23	CD (B)
Data Carrier Detect **B**	31	--------->	10	CF (B)
Terminal Timing **B**	35	<---------	11	DA (B)

11.4 Standard V.35 Cables

11.4.1 Network Cable

DESCRIPTION	VFX-250S (RS449) Network Port DB37 Female PIN		Network (V.35) DCE Port PIN
Shield	1	---------------	A
Send Data A	4	-------------->	P
Send Timing A	5	<--------------	Y
Receive Data A	6	<--------------	R
Request To Send	7	-------------->	C
Receive Timing A	8	<--------------	V
Clear To Send	9	<--------------	D
Data Set Ready	11	<--------------	E
Data Terminal Ready	12	-------------->	H
Data Carrier Detect	13	<--------------	F
Ring Indicator	15	<--------------	J
Terminal Timing A	17	-------------->	U
Signal Ground	19	---------------	B
Send Data B	22	-------------->	S
Send Timing B	23	<--------------	AA
Receive Data B	24	<--------------	T
Receive Timing B	26	<--------------	X
Terminal Timing B	35	-------------->	W

11.4.2 User Cable

Description	VFX-250S (RS449) User Port DB37 Male Pin		User (V.35) User Port Pin
Shield	1	---------------	A
Send Data A	4	<--------------	P
Send Timing A	5	-------------->	Y
Receive Data A	6	-------------->	R
Request To Send	7	<--------------	C
Receive Timing A	8	-------------->	V
Clear To Send	9	-------------->	D
Data Set Ready	11	-------------->	E
Data Terminal Ready	12	<--------------	H
Data Carrier Detect	13	-------------->	F
Ring Indicator	15	-------------->	J
Terminal Timing A	17	<--------------	U
Signal Ground	19	---------------	B
Send Data B	22	<--------------	S
Send Timing B	23	-------------->	AA
Receive Data B	24	-------------->	T
Receive Timing B	26	-------------->	X
Terminal Timing B	35	<--------------	W

12. Appendix C: Glossary and abbreviations

AVB

- Automatic Variable Buffer.

Buffering

- This is a term used to describe a method where data is held in a queue to allow equalisation of speeds on either side.

CIR

- Committed Information Rate

Codec

- A device, which takes an analogue or digital video signal and converts it into a serial data bit-stream compatible with a standard data-communications infrastructure. Codecs used in the Videoconferencing market, also employ a complex and powerful real-time compression system.

DE

- Discard Eligible

DLCI

- (Data Link Circuit Identifier). A high-level description of a section of the frame relay structure which defines addressing information.

DTE

- Data Terminal Equipment.

FRAD

- (Frame Relay Access Device). A device, which is designed to take a myriad of different types of information; e.g. LAN, data, compressed voice and multiplex them onto a single frame relay data-stream. These devices can often include switching functionality.

H.320

- An international standard, which defines various functions of encoding and compression for Videoconferencing applications.

HDLC

- A standard, low-level, synchronous data bit-stream format, used either in its raw format, or by higher-level data-communications protocols, such as X.25 and frame relay.

ISDN

- Integrated Services Digital Network.

LAN

- Local Area Network.

Pixelation

- This is a Videoconferencing term, which is used to identify picture break-up. Digital video pictures are made up of 1000’s of pixels, each representing a colour on the image. In videoconferencing, pixels are grouped into blocks (the number of which is determined by the speed of the link). Pixelation is a term often used to describe an image, which has errors in the colours of these blocks, creating obvious squares of wrong colour on the screen.

QoS
- Quality of Service.

SLA
- Service Level Agreement.

TDM
- Time Division Multiplexing

WAN
- Wide Area Network.

13. Appendix D: Information about the manufacturer

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