FlexFAX Modem Bakeoff

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ABSTRACT

This paper reports on an experiment to evaluate the performance of a number of commonly used contemporary facsimile modems. Nine modems were used to send a 3-page facsimile to 37 different facsimile machines and modems located in North America and Europe. The results are discussed and a metric is presented for comparing the modems.

1. Introduction

This paper reports on an experiment to evaluate the reliability and performance of a number of commonly used facsimile modems. Nine different modems were used with the FlexFAX software package to send a 3-page high resolution facsimile to 37 different facsimile devices around the world. The ability of the modems to establish and hold a connection with the remote device was studied along with the time required to successfully transmit the facsimile data. Based on the data collected from this experiment a simple metric was developed for comparing the different facsimile modems.

This document is organized in six sections. In Section 2 the test environment and methodology is discussed. Section 3 provides a primer on the communication protocol used by Group 3 facsimile devices. Section 4 discusses the test results, while Section 5 presents the metric that was derived from this experiment. In Section 6 the conclusions that were drawn from the experiment are presented together with some advise to buyers of facsimile modems.

2. Test Environment and Methodology

The basic experiment involved using FlexFAX version 2.2.0 to send a 3-page facsimile to a variety of sites using nine different facsimile modems. FlexFAX is a freely available software package that supports a wide variety of modems—basically any modem that conforms to the Class 1 or Class 2 host-modem communication specifications.

Only sending was evaluated for several reasons. First, the Group 3 facsimile protocol is designed so that the sender is mainly responsible for the reliable transfer of facsimile data. Personal experience indicates that a modem that does well at sending facsimile also does well at receiving facsimile, while the reverse is not true. Second, most uses of facsimile modems are significantly more oriented toward sending than receiving facsimile. Consequently modem buyers are more concerned with a modem's ability to send than receive. (It should be noted however that because of just this reason, some modem vendors do *not* put as much effort into testing the receive capability of their modems as they should.) Finally, the logistics of running receive testing were too difficult to surmount in the time available to do the experiment.

The experiment was run on a Silicon Graphics Indigo machine under version 4.0.5H of the IRIX operating system[1]. The 3-page facsimile shown in Appendix B was used for testing. The document includes three different types of data, as shown in Table 1. While many facsimile are either mostly text or simple graphics (e.g. charts of tables), the selected matter represents a more difficult test of the Group 3 encoding algorithms and, consequently, of the performance of the sender and receiver. The pages were encoded and transmitted exclusively using the CCITT Group 3 1D encoding algorithm. FlexFAX also supports the 2D encoding algorithm but it was not used because some fax machines have been observed to falsely advertise support for 2D-encoded data. Thus, rather than complicate the tests it was decided to use only 1D-encoded data. As shown in Table 1, a 2D-encoded test document is 12% smaller than a 1D-encoded version of the same data. This is significant and should be taken into account when evaluating a modem's capabilities since not all facsimile modems support the transmission of 2D-encoded data.

Page	**Size (bytes)**		**Shrink**
	1D	2D	
1/mixed text and graphics	135846	115289	.85
2/mostly text, some graphics	67857	52752	.78
3/single shaded graphic	105486	95354	.90
Total	299057	263395	.88

Table 1. Size of encoded facsimile data.

The sending site was located in Berkeley, California USA (+141552687xx) and the phone line was a normal unconditioned 2-wire hookup[2]. The line is normally shared with a telephone, but for these tests it was isolated to avoid any possible interactions with the telephone set. All the tests were run at night or on the weekend in order to obtain lower utility rates.

2.1. Facsimile Modems Tested

The nine different Class 1 and Class 2 modems listed in Table 2 were used in the experiment. The modems were selected according to: availability, reputation, price, and correct functional operation with the FlexFAX software. Some modems were not tested because they fail to properly implement the draft Class 2 specification SP-2388-A of August 30, 1991[3].

It is critical to note the firmware revision that each modem was running during the testing. While some modem problems are due to hardware design limitations, many problems are caused by faulty firmware. Vendors routinely claim that problems that exist in one firmware revision are corrected in a subsequent version. This often is true, but when evaluating a modem one must always consider both the hardware platform and operating firmware together.

Class 2 modems differ from Class 1 modems in that more of the facsimile protocol is implemented in firmware in the modem. Class 1 modems provide four basic fax-specific operations: send/receive an HDLC protocol frame, and send/receive T.4-encoded message data. Class 2 modems do not expose these low-level calls, instead presenting higher-level interfaces that shield the host software from many of the timing

[1] The system was modified in one important way; it included a bug fix to the UART driver to correct a problem with the handling of DCD on devices that require RTS/CTS flow control. Without this bug fix the USR Sportster modem cannot be used with an SGI system.

[2] The phone numbers have been altered by replacing the last few digits with characters. The country and city/area codes have been retained.

[3] In particular, the PM14400FX models from Practical Peripherals Inc. and the FM144V model from GVC do not implement the +FDIS command properly. These modems ignore the command after a connection is established, so it is not possible to set session parameters based on the remote facsimile machine's capabilities.

Manufacturer	Model	Class	Firmware
AT&T Paradyne	DataPort 14.4/FAX	1	C01.45.00
Digicom Systems	Scout+	1	3507/3506
Everex Systems	EverFax 24/96D	2	911027
Multi Tech Systems	MT1432BA	2	0110
Supra	SupraFAXModem V.32bis	1, 2	V1.80-02 TR14-Jxxx-001
Telebit Systems	T3000	2	T3000SA - Version LA7.02
Twincom	144/DF	1, 2	V1.270 TR14-Jxxx-001
Zero One Networking	ZyXEL 1496E	2	V 6.01M
US Robotics	Sportster	1	Supervisor 4.1/DSP 10

Table 2. Facsimile modems tested.

critical aspects of the facsimile protocol. Class 1 modems place significant demands on the host computing resources while Class 2 modems are less sensitive to the performance of the host computer. Consequently Class 2 modems have been desirable for most UNIX systems. FlexFAX however supports both Class 1 and Class 2 modems and Class 1 modems function very well on some UNIX hosts. Modems that support both the Class 1 and Class 2 interfaces were used only in Class 2.

Table 3 shows the method by which the modems were connected to the host computer. All modems were run using RTS/CTS flow control whenever possible. Some modems were found to not correctly implement RTS/CTS flow control when sending facsimile or simply did not support hardware flow control for facsimile operation. Note that RTS/CTS flow control is not required by the Class 1 or Class 2 specifications. Using software flow control between a host and modem at rates above 9600 baud can be problematic.

Model	DTE-DCE Rate	Flow Control
AT&T DataPort 14.4/FAX	38400	RTS/CTS
Digicom Scout+	38400	RTS/CTS
Everex 24/96D	19200	XON/XOFF
Multi-Tech 1432BA	38400	RTS/CTS
SupraFAXModem V.32bis	19200	XON/XOFF
Telebit T3000	38400	RTS/CTS
Twincom 14.4/DF	19200	XON/XOFF
ZyXEL 1496E	38400	RTS/CTS
USR Sportster	38400	RTS/CTS

Table 3. Facsimile modem hardware configuration.

The Indigo serial port can operate up to 38.4 Kb/s without an external clock. All modems were run at the maximum possible rate. Many modems based on the Rockwell RC144DP lock the serial port rate to 19.2 Kb/s when sending or receiving facsimile; this is why the Supra and Twincom modems were run at 19.2 Kb/s. The Everex modem does not operate reliably at 38.4 Kb/s and so was run at 19.2 Kb/s.

2.2. Receiving Devices

Table 4 lists the devices that were used to receive facsimile during testing. Two different types of receivers are distinguished: a *machine* is a standalone facsimile machine that includes a scanner and printer, a *modem* is a standalone modem unit that interfaces to a computer and has no integral scanner or printer device.

There were 20 different facsimile machines and 17 modems, with 10 different modem models. The sites with modems were all running the FlexFAX software except for one site that was running Hayes SmartFax software on a 486 machine. The one non-FlexFAX site crashed early on in testing while receiving a facsimile and was unable to recover in time to participate in the majority of the testing. For this reason the tests include results for only 36 receivers: 20 machines and 16 modems.

Destination	BR	2D	MST	ECM	Type	Device
+121282556xx	9600	Yes	20/10	Yes	machine	Panasonic Panafax PD-4200
+121522136xx	14400	Yes	0		modem	SupraFAX v.32bis
+130597073xx	9600		0		modem	Hayes SmartFax
+140328387xx	9600		0		modem	Everex 24/96D
+140874538xx	9600	Yes	10/5	Yes	machine	Fujitsu DEX 170
+141596576xx	9600		10		machine	NEC BitFax
+141623971xx	9600	Yes	20/10		machine	OmniFax G66
+141636206xx	14400	Yes	10/5	Yes	machine	Xerox Telecopier 7033
+141696989xx	9600	Yes	10/5		machine	Pitney-Bowes 9300
+150866368xx	14400	Yes	0		modem	SupraFAX v.32bis
+151084934xx	14400	Yes	0		modem	ZyXEL 1496
+151292941xx	9600		20/10		machine	XEROX Telecopier 7010
+151974615xx	9600		0		modem	Telebit WorldBlazer
+151974637xx	9600	Yes	10/5	Yes	machine	Lanier Model 120
+160278928yy	9600	Yes	10	Yes	machine	Ricoh Fax65
+160278928xx	9600	Yes	10/5	Yes	machine	Lanier FaxWriter 4000
+160278929xx	9600		0		modem	Telebit WorldBlazer
+160496057xx	14400	Yes	0	Yes	machine	Canon FAX-L785
+161723336xx	9600		0		modem	Telebit WorldBlazer
+161945506xx	9600	Yes	10		machine	Ricoh 9200
+161954639xx	9600	Yes	20/10	Yes	machine	HP FAX-200
+170825003xx	14400		0		modem	PPI PM14400FX
+170836718xx	14400	Yes	0		modem	ZyXEL 1496
+170889876xx	14400	Yes	0		modem	USR Sportster
+171864874xx	9600		20/10		machine	Brother InstaFax 390
+181830557xx	4800		0		modem	Intel SatisFaxion 100
+191858837xx	9600	Yes	10	Yes	machine	Ricoh FAX 3000L
+41142227xx	14400		0		modem	Multi-Tech 1432
+446127560xx	9600	Yes	0	Yes	machine	Canon FAX-L770
+446127561xx	14400	Yes	0		modem	Zoom 14.4X
+4681025xx	9600	Yes	10/5	Yes	machine	OKIFAX OF-110N
+49428616xx	9600		20/10		machine	GUIS ETFax 7
+495115613xx	9600	Yes	10/5		machine	Canon 260E
+495117178xx	14400	Yes	0		modem	ZyXEL 1496
+4956180442xx	9600		20		machine	Olivetti OFX 430
+4991318587xx	9600		0		modem	Multi-Tech 1432

Table 4. Receiving devices and their capabilities.

Table 4 also lists some of the capabilities of the remote systems that can affect the results of the transmission tests. These capabilities are received by the sender in the initial facsimile protocol handshake. Several interesting trends can be observed from this data:

1. Only 2 of the 20 facsimile machines support V.17 communication at 14400 b/s.
2. Only 2 of the 20 facsimile machines support a minimum scanline time of 0 ms.
3. Most facsimile machines support 2D-encoded data (15 of 20), but only 22 of 37 total receivers advertised themselves as capable of receiving 2D-encoded data.
4. Only 10 of 37 receivers support the optional error correction mode (ECM); none of which are modem-based receivers.

Items 1 and 2 directly affect the transmission time of a facsimile in unavoidable ways. Obviously the higher the signaling rate the less time it takes to transfer the page data. Less obvious however is that using a V.17 modem can reduce other overhead in the protocol through the use of ‘‘short training’’; this is discussed in Section 3. The minimum scanline time is the minimum amount of time the receiver requires to process a row of pixels. Facsimile machines that immediately print received facsimile typically require a non-zero minimum scanline time so that they have time to mark and move the paper. 1D versus 2D encoding refers to the algorithm by which pixel data is encoded into a digital bit stream. 2D-encoding is more compact than 1D-encoding and is especially desirable for pages comprised of text and simple graphics. It is interesting that so many modems do not indicate a capability for the transfer of 2D-encoded data because doing so requires only trivial support in the modem firmware[4]. Item 4 is interesting from the perspective that using ECM can potentially reduce transmission time when poor line conditions are encountered. This issue was not explored in the experiment.

2.3. Test Methodology

Test data was collected by installing a modem on the sending machine, running the *faxaddmodem* script to configure the modem, and then submitting a facsimile job for each of the receivers. The FlexFAX software was then permitted to run normally until the queue was cleared. Each job was permitted five tries to reach the receiver before it was rejected. The FlexFAX software automatically rejects a job if three protocol errors occur in attempting to send the same page of a facsimile.

All communication was recorded using the standard FlexFAX session logging mechanism. Additional information logged via the system logging facility was also recorded as was the information recorded in the FlexFAX accounting file.

The participants were asked to collect the received facsimile and grade the quality of each page received based on a scale of 0-9, where 0 meant that a page was not received and 9 meant that a page was received completely and without any discernible errors. Some of the received facsimile were not available for this grading due to the usual circumstances associated with a communal facsimile device. For example, one person that was not involved with the experiment apparently decided there was no reason to keep duplicate pages and so discarded all but one good page for each of the pages that were received. Also some of the receivers were uncommunicative for various reasons (e.g. modems being turned off). This information was used only as a ‘‘sanity check’’ on the information collected at the sending site.

Note that the intent of the experiment was to simulate normal usage of FlexFAX. As such, manual intervention was minimized. The jobs were just entered into the system and permitted to run to completion.

3. Group 3 Facsimile Primer

In order to understand some of the test results it is important to have a basic understanding of the Group 3 facsimile protocol used for transmission. This section provides a simple primer on the subject. The reader is referred to [McConnell] and the [CCITT T.30] specification for more information. Other useful references are the [CCITT T.4] specification for a description of the data encoding algorithm, the EIA/TIA [Class1] specification for the Class 1 host-modem communication specification, and the draft Class 2 specification [SP-2388-A] for information on the Class 2 host-modem communication specification used by current Class 2 modems[5].

Facsimile are transmitted through a fax modem device that accepts digital information, encodes it according to CCITT Recommendation T.4, and then modulates it to form an analog signal that is transmitted on a telephone line. Facsimile machines include, in addition to the modem and associated digital logic, a scanner that converts document pages to a digital form, and a printer that converts digital data to a printed form. Facsimile modems by themselves are not useful; they must either be combined with a computer or integrated into a facsimile machine.

Data is communicated between facsimile modems according to a set of rules specified in CCITT Recommendation T.30. These rules comprise what we call the *Group 3 facsimile protocol*. The protocol deals with negotiating acceptable characteristics for the transmitted page data (page width, page length, data encoding, output resolution, etc.) and the correct communication of the negotiated page data. In particular, the standard protocol includes an acknowledgement by the receiver that each page has been correctly

[4] Unless the modem implements copy quality checking.

[5] A newly standardized version of this draft (‘‘Class 2.0’’) is slowly making its way into the marketplace. At this time however, there are no Class 2.0 modems.

received and is of acceptable quality.

The facsimile protocol actually operates using two different signaling schemes. A 300 b/s low speed carrier is used to carry handshaking information while a higher speed carrier is used to carry the T.4-encoded page data. The speed of the high speed carrier is determined during the handshaking procedure according to the capabilities of the sender and receiver and according to perceived quality of the telephone link between sender and receiver. All fax devices are required to support a V.27*ter* modem for sending page data at 4800 and 2400 b/s. Most devices also support a V.29 modem for transmitting page data at 7200 and 9600 b/s. Newer devices also support a V.17 modem which is a half-duplex trellis-coded modem that runs at 14400 b/s with fallback speeds of 12000, 9600, and 7200 b/s. Note that the techniques by which page data are transmitted by a facsimile modem are different from those of a normal data modem.

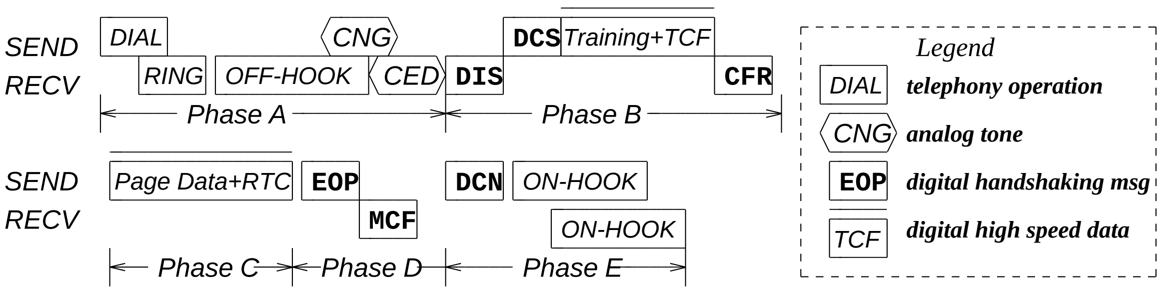

Figure 1. Group 3 transmit protocol (single page).

The basic flow of the Group 3 protocol is illustrated by the single page transfer shown in Figure 1. There are five *phases* of communication:

Phase A. Call establishment.

Phase B. Pre-message procedure.

Phase C. Message transmission.

Phase D. Post-message procedure.

Phase E. Call release.

In the following sections it is assumed that the sender and receiver interact using binary coded signaling rather than tonal procedures. The tonal mechanisms are required for backward compatibility with older facsimile equipment.

Phase A. Call establishment.

A facsimile call can be placed manually or automatically. We will not discuss manual call placement. With regard to automatic call establishment, the only thing to note is that the caller is required to transmit a CNG tone and the receiver is required to advertise its presence by transmitting a CED tone. The presence of a CNG tone is used by many combination facsimile and data modems to automatically determine if a caller is a facsimile modem, a data modem, or a voice caller. This automatic identification scheme is termed *adaptive-answer* in the Class 2 specification.

Phase B. Pre-message procedure.

In the pre-message stage of transmission the receiver identifies its capabilities by sending a Digital Identification Signal (DIS) at 300 b/s, after which the sender responds with a Digital Command Signal (DCS) specifying the set of capabilities to use for the message data that will follow in Phase C. The transmitter then sends a high speed training signal that is used to synchronize the two modems. A burst of data (1.5 seconds of zero data) is also transmitted in this procedure and the receiver is expected to analyze the received data and decide if the line quality is acceptable for transmission. If the receiver is satisfied with the signal quality it responds to the training with a Confirmation (CFR) message at 300 b/s and Phase C is entered. Otherwise, if the training failed, a Failure To Train (FTT) message is returned to the sender who has the option to continue or abort the call. The exact procedure to use when training fails is not part of the T.30 specification. Class 2 modems include this procedure as part of the firmware in the modem. Class 1 modems do not include this procedure; instead the host-based software is required to decide how to proceed. FlexFAX's Class 1 driver tries to do training twice at a given signaling rate before stepping down to a slower signaling rate. This corresponds to what many facsimile modems and machines do. Beware, however, that some Class 2 modems have firmware bugs that cause them to infinitely loop doing training under certain conditions.

Phase C. Message transmission.

The sender transmits a (usually short) training signal followed by a page of T.4-encoded image data. Data is sent on the high speed message carrier. The sender and receiver apply various timeouts to this process to insure that sender and receiver remain in step. For example, each scanline of data in a T.4-encoded image is punctuated by an End-Of-Line (EOL) code. Class 2 modems require that at least one EOL code be presented by the host every 5 seconds; otherwise the page transmission is aborted. The receiver places similar constraints on reception of page data.

There are two aspects to the image data transfer that are noteworthy. First, as part of the capabilities negotiation done in Phase B a *minimum scanline time* is selected. This value specifies the minimum amount of time that the receiver requires to process a row of image data. Receiving devices that immediately print a facsimile may need time to mark black on a page and advance the paper to the next row on the page. Senders must honor the requested minimum scanline time by zero-padding each scanline that so that it takes at least the requested time. Class 2 modems do this scanline padding automatically in the modem and only the raw scanline data must be transferred from the host. Class 1 modems typically do the zero-padding on the host and transfer the padded scanline data to the modem.

A second issue is the duration of the training signal sent prior to the page data. V.27 and V.29 modems use a longer training signal than V.17 modems. This also can affect the time spent in Phase C during a facsimile transmission.

Phase D. Post-message procedure.

The sender terminates a page of data transmitted on the high speed carrier with a Return To Control (RTC) code—six consecutive EOL codes. After RTC is transmitted the sender switches back to the low speed carrier and sends a Post-Page Message (PPM) to indicate whether this page is:

- followed by another page in the same document (MPS),
- followed by more pages in a new document (EOM), or
- the last page in the last document (EOP).

When the receiver receives RTC it listens on the low speed carrier for the post-page message and then responds with a message that acknowledges reception of the page or that indicates the page was received in error. In addition the Post-Page Response (PPR) returned by the receiver can request that the sender redo training if it believes that signal quality has degraded. Note that the sender is free to retrain at the same signaling rate or at a lower rate in response to a request to retrain.

The post-page handshake involves critical timing to insure the sender and receiver remain synchronized. If the sender does not receive a response to its post-page message within approximately 3 seconds it will retransmit the message. The sender will transmit the post-page message at most three times before aborting Phase D. Also, the delay between switching from the high speed message carrier to the low speed carrier is tricky. If this delay is made too short the receiver may miss the start of the post-page message and discard the data. If the delay is made too long the receiver may timeout waiting for a post-page message before the sender has had an opportunity to send its full complement of three messages. The timing characteristics of different facsimile devices varies widely in Phase D. Some machines are notorious for being slow to switch from the high speed message carrier to the low speed message carrier resulting in their only seeing the second or third transmit of the post-page message.

Phase E. Call release.

The caller sends a Disconnect (DCN) message and then both sides are free to hangup the line.

4. Test Results

In this section the test results are presented and analyzed from the perspective of the sender and the receiver. From the sender perspective, the modems are evaluated in terms of how well they communicate with the various receivers. Our examination of the receivers is done to look for trends in the performance of the receiving devices that may be used to understand anomalous results.

Results are summarized in a number of tables that have the following column headings: The *Tries* column gives the number of times that FlexFAX attempted to send a facsimile to the destination, while the *Calls* column indicates the number of times the modem reported that the receiver picked up the phone. These numbers are different when calls failed because the line was busy, because the receiver did not answer, or because the sending and receiving modems were unable to establish carrier. *ConnTime* is the total amount of time spent on the phone processing facsimile jobs—this number should be identical to the connect time charged by the phone company. Note that connect time does not include the time spent on the phone waiting for the phone to be answered[6]. The *Pages* column indicates the total number of pages that were successfully transmitted. There were initially 37 receivers but four were dropped from the experiment because of repeated failures. This left 33 receivers, so the total number of pages that a sender transmits successfully should be $3 \times 33 = 99$. (And each receiver should receive 3 pages from 10 different modems for $3 \times 10 = 30$ pages.) The final column marked *TypRate* is the most frequent signaling rate used to transmit page data.

4.1. Receiver Test Results

Tables 5a and 5b show the results of the transmission tests from the perspective of the receiving devices.

Destination	Tries	Calls	Pages	TypRate	ConnTime	Device
+121522136xx	26	15	24	14400	53:41	SupraFAX v.32bis
+130597073xx	34	2	6	9600	25:55	Hayes SmartFax
+140328387xx	10	10	30	9600	51:18	Everex 24/96D
+150866368xx	17	17	24	9600	53:09	SupraFAX v.32bis
+151084934xx	16	9	27	14400	40:11	ZyXEL 1496
+151974615xx	21	13	18	9600	1:00:16	Telebit WorldBlazer
+160278929xx	41	7	3	9600	31:28	Telebit WorldBlazer
+161723336xx	12	12	27	9600	56:13	Telebit WorldBlazer
+170825003xx	10	10	27	14400	38:51	PPI PM14400FX
+170836718xx	23	14	24	14400	47:07	ZyXEL 1496
+170889876xx	23	14	27	14400	47:30	USR Sportster
+181830557xx	17	15	30	4800	2:06:17	Intel SatisFaxion 100
+358045529xx	2	0	0	9600	0:45	Multi-Tech 1432
+41142227xx	26	21	9	9600	59:03	Multi-Tech 1432
+446127561xx	23	14	18	9600	49:12	Zoom 14.4X
+495117178xx	18	13	24	14400	49:26	ZyXEL 1496
+4991318587xx	18	13	24	9600	1:03:48	Multi-Tech 1432

Table 5a. Summary of transmission tests by receiver modem.

The Ricoh Fax65 at +160278928yy and the Multi-Tech 1432 at +358045529xx were not called for all test runs for various reasons and their results have been discounted. The Telebit modem at +160278929xx also was dropped because it appeared to either be misconfigured or unavailable during most of the testing. As

[6] The software was configured to wait up to 60 seconds for carrier. Busy signals were recognized in significantly less than this time. Modems that reported ambiguous results for dialing were assumed to reach the receiver but be unsuccessful establishing carrier.

noted previously, the Hayes SmartFax system at +130597073xx crashed early on in the testing and did not respond to later calls. Otherwise, all devices were assumed to be functional and operating normally.

Destination	Tries	Calls	Pages	TypRate	ConnTime	Device
+121282556xx	11	11	30	9600	58:53	Panasonic Panafax PD-4200
+140874538xx	13	10	30	9600	57:20	Fujitsu DEX 170
+141596576xx	16	16	27	9600	1:08:47	NEC BitFax
+141623971xx	12	12	29	9600	1:06:17	OmniFax G66
+141636206xx	11	11	30	9600	51:43	Xerox Telecopier 7033
+141696989xx	18	17	21	9600	1:07:58	Pitney-Bowes 9300
+151292941xx	11	10	30	9600	1:06:29	XEROX Telecopier 7010
+151974637xx	11	11	30	9600	57:15	Lanier Model 120
+160278928yy	3	1	1	9600	7:18	Ricoh Fax65
+160278928xx	11	11	30	9600	57:41	Lanier FaxWriter 4000
+160496057xx	11	11	30	14400	46:33	Canon FAX-L785
+161945506xx	12	12	28	9600	1:02:51	Ricoh 9200
+161954639xx	13	13	29	9600	1:03:20	HP FAX-200
+171864874xx	13	12	27	9600	53:52	Brother InstaFax 390
+191858837xx	15	10	27	9600	52:35	Ricoh FAX 3000L
+446127560xx	21	13	20	9600	57:21	Canon FAX-L770
+4681025xx	12	11	30	9600	56:36	OKIFAX OF-110N
+49428616xx	16	15	30	9600	1:12:18	GUIS ETFax 7
+495115613xx	10	10	30	9600	58:43	Canon 260E
+4956180442xx	20	12	25	9600	1:02:50	Olivetti OFX 430

Table 5b. Summary of transmission tests by receiver machine.

Some observations can be made regarding the performance of the receiving devices:

1. The facsimile machines functioned significantly better than the standalone facsimile modems. Of course it is difficult to fully assess this as the quality of the modems is questionable (especially when the results of this experiment are taken into account) and their operation is open to confusion—i.e. a facsimile machine is significantly easier to operate correctly than a modem. Nonetheless one should recognize that since a facsimile machine is a self-contained system that can be fully tested for correct operation, it is possible to achieve a higher degree of reliability than a standalone modem unit that functions with a variety of hardware and software systems.
2. International phone calls were significantly more prone to failure. In 58% of the international calls, carrier was successfully established; compared to 71% of the continental calls (83% if we discount +130597073xx and +160278929xx).

Tables 5c and 5d show the average time spent in each phase of the Group 3 facsimile protocol, collated by receiver. Phases C and D are broken down by page: ‘‘C[2]’’ is the time spent in Phase C delivering page 2 of the test facsimile. The numbers were calculated from the timestamps recorded in the FlexFAX session log files. Only phases that were completed successfully were counted in the calculations. Phase E was not calculated because it is difficult to deduce the timing for Class 2 modems. Note that the per-phase timings are based on the time at which status messages were received by the host from the modem. If a modem, in particular a Class 2 modem, delays the delivery of a status message then these numbers will be skewed. Per-phase times are averaged over *all* the tests and given in ‘‘minutes:seconds’’ (beware that the calculation of the per-phase times effectively average transfer rates for V.29 and V.17 modems.) Appendix A shows the complete set of per-phase times for each modem and receiver.

4.2. Sender Test Results

Table 6 gives a synopsis of the transmission test results from the point of view of the sending modem. As described in section 4.1, only the data for 33 receivers was used.

Destination	A	B	C[1]	D[1]	C[2]	D[2]	C[3]	D[3]	Total
+121522136xx	20.8	4.2	1:23.7	7.4	42.1	7.2	1:06.5	6.7	3:58.6
+140328387xx	15.1	2.8	1:53.9	5.4	57.4	6.6	1:28.7	5.6	4:55.5
+150866368xx	21.7	5.1	1:30.3	6.0	46.5	6.2	1:11.9	6.2	4:13.9
+151084934xx	17.7	3.5	1:28.7	5.1	44.6	5.2	1:09.0	5.2	3:59.0
+151974615xx	14.4	3.3	1:53.8	5.9	57.6	6.2	1:29.0	6.2	4:56.4
+161723336xx	13.7	2.8	1:54.0	5.4	57.5	5.6	1:28.8	5.6	4:53.4
+170825003xx	17.6	2.9	1:30.4	5.6	45.4	5.7	1:10.2	5.8	4:03.6
+170836718xx	16.7	3.9	1:27.4	5.4	45.2	5.5	1:10.1	6.2	4:00.4
+170889876xx	13.5	3.0	1:30.2	5.1	45.2	5.3	1:10.0	5.3	3:57.6
+181830557xx	23.4	4.2	4:07.0	7.6	2:04.6	7.1	3:10.1	7.1	10:11.1
+41142227xx	25.0	8.6	1:22.1	12.9	49.6	9.5	1:17.5	9.9	4:35.1
+446127561xx	31.3	3.9	1:28.3	6.6	47.2	6.8	1:13.3	6.9	4:24.3
+495117178xx	29.7	4.1	1:27.6	5.4	45.2	5.6	1:10.1	5.6	4:13.3
+4991318587xx	23.0	5.6	1:54.0	5.0	1:12.4	5.0	1:20.3	5.5	5:10.8

Table 5c. Summary of protocol times by receiver modems.

Destination	A	B	C[1]	D[1]	C[2]	D[2]	C[3]	D[3]	Total
+121282556xx	14.1	3.6	1:55.9	10.4	1:03.2	10.9	1:37.8	10.7	5:26.6
+140874538xx	19.0	3.0	1:56.1	6.0	1:03.5	5.8	1:35.9	5.9	5:15.2
+141596576xx	17.5	3.9	1:55.4	7.2	1:03.5	7.4	1:38.6	8.5	5:22.0
+141623971xx	20.2	4.0	2:12.7	7.0	1:11.3	7.6	1:48.9	6.5	5:58.2
+141636206xx	18.2	4.6	1:37.1	5.6	56.0	6.2	1:23.0	6.3	4:37.0
+141696989xx	20.5	5.5	1:55.0	9.4	1:04.0	7.4	1:37.0	7.6	5:26.4
+151292941xx	19.6	4.1	1:55.8	5.7	1:03.2	6.3	1:51.8	6.1	5:32.6
+151974637xx	14.7	3.2	1:56.2	10.7	1:04.4	10.5	1:35.9	6.1	5:21.7
+160278928xx	21.6	3.2	1:56.2	5.4	1:03.6	5.9	1:35.9	6.0	5:17.8
+160496057xx	25.0	3.5	1:27.8	5.0	44.6	5.2	1:09.0	5.2	4:05.3
+161945506xx	16.5	3.8	1:56.0	6.4	1:06.0	9.7	1:38.9	6.2	5:23.5
+161954639xx	18.4	3.6	1:56.0	11.0	1:03.8	8.7	1:38.3	11.1	5:30.9
+171864874xx	31.6	2.9	1:56.4	6.5	1:03.5	6.4	1:37.3	6.7	5:31.3
+191858837xx	12.8	3.1	1:54.4	3.2	1:04.0	4.1	1:40.2	3.5	5:05.3
+446127560xx	26.5	3.9	1:53.8	5.8	57.5	6.0	1:28.8	6.5	5:08.8
+4681025xx	19.1	4.0	1:56.2	5.6	1:03.5	6.0	1:35.9	6.2	5:16.5

Table 5d. Summary of protocol times by receiver machines.

Modem	Tries	Calls	ConnTime	Pages	TypRate
AT&T DataPort 14.4/FAX	36	35	3:10:50	99	9600
Multi-Tech 1432BA	36	34	2:48:55	96	9600
Everex 24/96D	51	36	3:38:33	93	9600
Digicom Scout+/V.17	54	45	3:13:29	90	9600
Zyxel 1496E	53	45	3:14:48	89	9600
SupraFAXModem V.32bis	52	49	3:23:29	87	9600
Twincom 14.4/DF	63	57	4:01:09	83	9600
Telebit T3000	50	39	2:48:02	81	9600
USR Sportster	50	45	3:07:44	81	9600
Digicom Scout+/V.29	72	32	2:48:25	67	9600

Table 6. Summary of transmission tests by sending modem.

There are two entries in Table 6 for the Digicom Scout+ modem. These entries correspond to the modem operating with two different versions of firmware: one that supports V.27, V.29, and V.17; and one that supports only V.27 and V.29. Section 4.3.2 explains the reason for the additional tests.

4.3. Sending Modem In-depth Results

The following sections present the individual results for each modem and explore some of the problems that were encountered. Each section contains a table similar to Table 6 that indicates *only* the receivers that required some unusual effort to complete the transmission. All receivers that are not listed in these tables received their test facsimile at the maximum signaling rate the sender and receiver were capable of, and without anomalous events.

4.3.1. AT&T DataPort 14.4/FAX

Table 7 shows the anomalous jobs for the AT&T DataPort. The first call to the Supra modem at +121522136xx failed to establish carrier; a subsequent call succeeded without a problem. The Telebit modem at +151974615xx failed on the first call to respond to the PPM sent after the first page; a subsequent call succeeded without a problem. Both Ricoh facsimile machines required page retransmissions at a lower signaling rate. The GUIS ETFax machine at +49428616xx required a second call to transfer the third page; the first call failed when the receiver did not acknowledge the EOP post-page message. The Multi-Tech modem at +4991318587xx took excessive time to transfer the 3-page document because each of the first two pages required retransmission (though at the same signaling rate).

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+121522136xx	2	2	6:13	3	9600	SupraFAX v.32bis
+151974615xx	2	2	7:27	3	9600	Telebit WorldBlazer
+161945506xx	1	1	9:07	3	7200	Ricoh 9200
+191858837xx	1	1	8:16	3	7200	Ricoh FAX 3000L
+49428616xx	2	2	8:02	3	9600	GUIS ETFax 7
+4991318587xx	1	1	8:08	3	9600	Multi-Tech 1432

Table 7. Transmission anomalies for DataPort 14.4/FAX.

4.3.2. Digicom Systems Scout+

Table 8 shows the anomalous jobs for the Digicom Scout+. The Scout+ had a decided problem establishing carrier with both modems and machines. Frequently the modem would return a +FCERROR status when calling, indicating that an incorrect carrier was encountered. For example,

```
Oct 04 03:45:05.62: [ 1504]: DIAL 130597073xx
Oct 04 03:45:05.62: [ 1504]: <-- [21:ATS24=2DT130597073xx@]
Oct 04 03:45:40.53: [ 1504]: --> [8:+FCERROR]
Oct 04 03:45:55.55: [ 1504]: --> [10:NO CARRIER]
Oct 04 03:45:55.55: [ 1504]: SEND FAILED: No carrier detected
```

This is the reason for many of the unsuccessful calls to the: Fujitsu DEX 170 at +140874538xx, Pitney-Bowes 9300 at +141696989xx, and XEROX Telecopier 7010 at +151292941xx.

The calls to the Pitney-Bowes 9300 at +141696989xx and the Multi-Tech 1432 at +41142227xx failed because no response was received to the PPM sent after the first page. After three successive attempts to send a page FlexFAX will abort the job and return the untransmitted contents to the sender. The call to the Zoom 14.4X at +446127561xx failed because the two modems were unable to succeed in training.

The first call to the Supra modem at +150866368xx, the ZyXEL modem at 170836718xx, and the Sportster at +170889876xx, failed because of training; with the subsequent call going perfectly. Other calls failed either because of failure to train the modems or because of failure to receive a response to the post-page message for the first page. The call to the Olivetti OFX 430 at +4956180442xx took a long time because of retraining and having to make an extra call to retransmit the last page.

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+140874538xx	4	1	8:02	3	9600	Fujitsu DEX 170
+141696989xx	4	3	9:08	0	2400	Pitney-Bowes 9300
+150866368xx	2	2	6:14	3	14400	SupraFAX v.32bis
+151292941xx	2	1	6:12	3	9600	XEROX Telecopier 7010
+170836718xx	2	2	4:39	3	14400	ZyXEL 1496
+170889876xx	5	2	6:46	3	14400	USR Sportster
+181830557xx	3	2	13:16	3	4800	Intel SatisFaxion 100
+41142227xx	3	3	5:29	0	14400	Multi-Tech 1432
+446127561xx	3	3	6:49	0	2400	Zoom 14.4X
+4956180442xx	2	2	12:42	3	4800	Olivetti OFX 430
+4991318587xx	2	2	7:25	3	9600	Multi-Tech 1432

Table 8. Transmission anomalies for Scout+ with V.17 support.

In general it appeared that the Scout+ performed poorly in the face of line noise and/or low signal quality. Discussions with informed parties confirmed this observation: *firmware revision 3507/3506 has problems with line noise and poor signal quality*. For this reason the tests were rerun with a previous version of the firmware that did not include V.17 support but which was thought to perform well otherwise. The results for firmware revision 2A19/2931 are shown in Table 8a. Problems with misrecognized carrier (+FCERROR) were encountered for many of the same receivers. Otherwise the older firmware did a better job of communicating with facsimile machines (as opposed to modems); but performed worse than the newer firmware that includes support for V.17.

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+121522136xx	5	0	3:29	0	0	SupraFAX v.32bis
+151084934xx	5	0	1:30	0	0	ZyXEL 1496
+151974615xx	5	1	7:06	0	9600	Telebit WorldBlazer
+170836718xx	5	0	2:51	0	0	ZyXEL 1496
+170889876xx	3	2	8:11	3	9600	USR Sportster
+41142227xx	5	0	3:36	0	0	Multi-Tech 1432
+446127560xx	3	3	8:31	0	9600	Canon FAX-L770
+446127561xx	5	1	3:55	0	9600	Zoom 14.4X
+495117178xx	5	1	4:48	0	2400	ZyXEL 1496
+4956180442xx	5	3	8:08	1	9600	Olivetti OFX 430
+4991318587xx	5	0	2:56	0	0	Multi-Tech 1432

Table 8a. Transmission anomalies for Scout+ without V.17 support.

4.3.3. Everex Systems EverFax 24/96D

The Everex modem is the oldest modem that was tested; in fact it is no longer sold. The older hardware design was seen in the lower transmission performance. Table 9 shows the anomalous jobs for the EverFax 24/96D.

Typically when the modem was able to establish a connection communication was very reliable. Calls to the GUIS ETFax 7 at +49428616xx, the Pitney-Bowes 9300 at +141696989xx, and the Intel SatisFaxion 100 at +181830557xx required an additional call because the receiver failed to respond to a post-page message.

4.3.4. Multi Tech Systems MT1432BA

Table 10 shows the anomalous jobs for the MT1432BA. Calls to the Telebit modem at +151974615xx failed because no response was received to the post-page message; subsequent calls were not answered and the jobs were prematurely removed from the queue. The call to the Ricoh 9200 at +161945506xx required excessive time because the third page had to be retransmitted. The GUIS ETFax at +49428616xx required

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+121522136xx	4	3	8:49	3	9600	SupraFAX v.32bis
+141696989xx	2	2	9:57	3	9600	Pitney-Bowes 9300
+170836718xx	3	1	5:51	3	9600	ZyXEL 1496
+181830557xx	2	2	14:42	3	4800	Intel SatisFaxion 100
+191858837xx	5	0	0:00	0	0	Ricoh FAX 3000L
+49428616xx	2	2	11:17	3	9600	GUIS ETFax 7
+4956180442xx	5	0	0:00	0	0	Olivetti OFX 430

Table 9. Transmission anomalies for EverFax 24/96D.

a second call to retransmit the third page; the first try failed when no acknowledgement was received to the post-page message. The Multi-Tech modem at +4991318587xx took extra time because the first page had to be retransmitted.

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+151974615xx	2	1	3:22	0	9600	Telebit WorldBlazer
+161945506xx	1	1	7:05	3	9600	Ricoh 9200
+49428616xx	2	2	8:11	3	9600	GUIS ETFax 7
+4991318587xx	1	1	6:32	3	9600	Multi-Tech 1432

Table 10. Transmission anomalies for MT1432BA.

4.3.5. Supra SupraFAXModem V.32bis

Table 11 shows the anomalous jobs for the Supra modem. There are some interesting results here. The OmniFax G66 at +141623971xx required extra time because the modem retrained down to 7200 baud from the requested 9600 baud. The XEROX Telecopier 7010 at +151292941xx took extra time because the third page had to be retransmitted. The Canon 260E at +495115613xx also required extra time because of retraining; though this time no page retransmission was requested. The remaining problems were reported as +FHNG: 51 or +FHNG: 52; the latter indicates ‘‘No response to MPS repeated 3 times’’ (i.e. no response to the MPS post-page message), while the former means ‘‘RSPREC error/got DCN’’, or disconnect was received when waiting for the post-page response. These sort of failures are indicative of a modem that does not do a good job handling line noise and poor signal quality. The Supra modem is based on the Rockwell RC144DP, a part that is considered to be susceptible to poor line conditions.

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+141596576xx	2	2	8:17	3	9600	NEC BitFax
+141623971xx	1	1	7:07	3	7200	OmniFax G66
+141636206xx	2	2	6:41	3	14400	Xerox Telecopier 7033
+150866368xx	2	2	4:48	3	14400	SupraFAX v.32bis
+151292941xx	1	1	7:26	3	9600	XEROX Telecopier 7010
+160278928xx	2	2	8:41	3	9600	Lanier FaxWriter 4000
+160496057xx	2	2	6:11	3	14400	Canon FAX-L785
+170836718xx	3	3	5:28	0	14400	ZyXEL 1496
+170889876xx	5	3	2:39	0	14400	USR Sportster
+181830557xx	2	2	14:31	3	4800	Intel SatisFaxion 100
+191858837xx	2	2	7:59	3	9600	Ricoh FAX 3000L
+41142227xx	3	3	6:37	0	14400	Multi-Tech 1432
+446127561xx	2	2	6:26	3	14400	Zoom 14.4X
+495115613xx	1	1	7:05	3	9600	Canon 260E
+495117178xx	4	3	7:46	0	14400	ZyXEL 1496

Table 11. Transmission anomalies for SupraFAXModem V.32bis.

4.3.6. Telebit Systems T3000

Table 12 shows the anomalous jobs for the Telebit T3000. Several jobs were prematurely terminated which accounts for their having only three or four tries instead of the expected five. Calls to two different ZyXEL modems failed the first time to establish carrier but were successful on the second try—this may be related to the ZyXEL's adaptive-answer scheme (it is not known if all the ZyXEL modems involved were configured to use adaptive-answer). The Pitney-Bowes 9300 at +141696989xx failed because of a failure to receive a response to the MPS post-page message.

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+121522136xx	4	0	3:36	0	9600	SupraFAX v.32bis
+141696989xx	3	3	8:28	0	9600	Pitney-Bowes 9300
+171864874xx	4	3	2:28	0	9600	Brother InstaFax 390
+41142227xx	3	3	2:48	0	9600	Multi-Tech 1432
+446127560xx	4	0	2:36	0	9600	Canon FAX-L770
+4991318587xx	3	3	2:43	0	9600	Multi-Tech 1432

Table 12. Transmission anomalies for Telebit T3000.

The Pitney-Bowes 9300 at +141696989xx, the Multi-Tech 1432 at +41142227xx, and the Canon FAX-L770 at +446127560xx failed with what looks to be an oversight in the modem firmware. The modem sent a ''NO CARRIER'' result string without first sending a Class 2 ''+FHNG:'' result:

```
Oct 03 21:16:33.34: [19850]: <-- [6:AT+FDT]
Oct 03 21:16:34.50: [19850]: --> [74:+FHT:FF C0 C2 04 04 04 04 ...
Oct 03 21:16:34.50: [19850]: --> [26:+FHT:FF C8 C1 00 62 1F 00 ]
Oct 03 21:16:39.93: [19850]: --> [74:+FHR:FF C0 02 0C CC EC 4C ...
Oct 03 21:16:40.29: [19850]: --> [26:+FHR:FF C8 01 00 76 5F 00 ]
Oct 03 21:16:41.31: [19850]: --> [74:+FHT:FF C0 C2 04 04 04 04 ...
Oct 03 21:16:41.31: [19850]: --> [26:+FHT:FF C8 C1 00 62 1F 00 ]
Oct 03 21:16:45.47: [19850]: --> [10:NO CARRIER]
```

The Class 2 specification is not clear on whether or not this is permissible; about all that can be said is that the Telebit modem is unique in its operation in this respect.

The calls to the Brother InstaFax 390 at +171864874xx failed with another problem that is definitely a firmware bug:

```
Oct 03 23:32:40.14: [25845]: DIAL 171864874xx
Oct 03 23:32:40.15: [25845]: <-- [15:ATDT171864874xx]
Oct 03 23:33:11.98: [25845]: --> [74:+FHR:FF C0 02 9C 2C 2C EC ...
Oct 03 23:33:12.27: [25845]: --> [26:+FHR:FF C8 01 00 72 1D 00 ]
Oct 03 23:33:12.27: [25845]: --> [28:+FCSI:"        718 648 74XX"]
```

The modem did not send the host the expected +FCON message that indicates a facsimile connection was established.

4.3.7. Twincom 14.4/DF

The Twincom modem was running old firmware. The vendor was contacted several weeks before these tests were run, but newer firmware was not available for testing. Table 13 shows the anomalous jobs for the Twincom modem. Like the Supra modem the Twincom is based on the Rockwell RC144DP; a component that is considered to be susceptible to poor line conditions.

A significant test was to the Multi-Tech 1432 at +41142227xx. Two different calls to this receiver left the modem in a state where it held carrier but did not respond to DTR. Manual intervention was required to hangup the line. This is a serious problem that alone makes the modem unacceptable for unmonitored operation.

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+121522136xx	5	5	11:21	3	14400	SupraFAX v.32bis
+141596576xx	2	2	8:55	3	9600	NEC BitFax
+141623971xx	1	1	9:53	3	9600	OmniFax G66
+141696989xx	3	3	8:24	0	9600	Pitney-Bowes 9300
+150866368xx	3	3	4:09	0	14400	SupraFAX v.32bis
+151292941xx	1	1	14:10	3	9600	XEROX Telecopier 7010
+151974615xx	3	3	10:27	0	9600	Telebit WorldBlazer
+151974637xx	2	2	7:44	3	9600	Lanier Model 120
+161723336xx	3	3	10:22	0	9600	Telebit WorldBlazer
+170825003xx	2	2	4:37	3	14400	PPI PM14400FX
+170836718xx	3	3	5:34	3	14400	ZyXEL 1496
+170889876xx	3	1	3:37	3	14400	USR Sportster
+181830557xx	1	1	18:11	3	7200	Intel SatisFaxion 100
+41142227xx	3	3	12:12	0	14400	Multi-Tech 1432
+446127560xx	5	1	5:29	2	9600	Canon FAX-L770
+4681025xx	2	2	7:48	3	9600	OKIFAX OF-110N
+49428616xx	3	3	10:31	3	9600	GUIS ETFax 7
+495117178xx	2	2	4:57	3	14400	ZyXEL 1496
+4991318587xx	2	2	11:23	3	9600	Multi-Tech 1432

Table 13. Transmission anomalies for Twincom 14.4/DF.

The Pitney-Bowes 9300 at +141696989xx and the Supra at +150866368xx failed because there was no response to the post-page message. The Telebit modems at +151974615xx and +161723336xx, and the Multi-Tech 1432 at +41142227xx failed because the modem locked up during Phase B/C; for example:

```
Oct 03 18:58:09.40: [17733]: <-- [23:AT+FDIS=1,3,0,2,0,0,0,0]
Oct 03 18:58:09.68: [17733]: --> [2:OK]
Oct 03 18:58:09.68: [17733]: <-- [6:AT+FDT]
Oct 03 19:01:09.68: [17733]: TIMEOUT: reading line from modem
```

FlexFAX times out the AT+FDT command after three minutes to insure the sender does not leave the phone off hook due to a modem problem. This timeout is configurable and scaled according to the signaling rate used for the high speed message carrier. In practice three minutes is significantly longer than could possibly be needed to carry out the Phase B handshaking.

4.3.8. Zero One Networking ZyXEL 1496E

Table 14 shows the anomalous jobs for the ZyXEL 1496E. The ZyXEL firmware has a bad problem of not reporting useful hangup codes when problems occur. Virtually any problem is reported to the host as ‘‘+FHNG: 50’’ which means ‘‘Unspecified Transmit Phase D error, including +FPHCTO timeout between data and +FET command.’’ Consequently it is difficult to interpret many of the results.

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+121282556xx	2	2	8:00	3	9600	Pan. Panafax PD-4200
+141596576xx	3	3	10:29	3	9600	NEC BitFax
+141623971xx	3	3	10:24	2	9600	OmniFax G66
+150866368xx	2	2	5:12	3	14400	SupraFAX v.32bis
+161945506xx	3	3	8:14	1	9600	Ricoh 9200
+161954639xx	4	4	12:20	2	9600	HP FAX-200
+41142227xx	3	3	6:56	0	14400	Multi-Tech 1432
+446127561xx	5	0	0:00	0	0	Zoom 14.4X

Table 14. Transmission anomalies for ZyXEL 1496E.

The Panasonic Panafax PD-4200 at +121282556xx required an extra call because the response to the EOP was apparently not received. Unfortunately the modem does not indicate this directly but instead reports:

```
Oct 02 10:18:49.33: [  579]: <-- [8:AT+FET=2]
Oct 02 10:18:55.38: [  579]: --> [10:NO CARRIER]
```

without a hangup code. This is a firmware bug since the modem should present a +FHNG: status message.

Three tries were required to transmit the third page to the NEC BitFax at +141596576xx. The first try failed with the above problem, while the second try returned:

```
Oct 02 12:43:42.00: [  579]: <-- [8:AT+FET=2]
Oct 02 12:43:58.24: [  579]: --> [8:+FHNG:50]
```

The OmniFax G66 at +141623971xx failed with problems similar to the above two jobs. The first two pages went through without a problem, but the third page was unsuccessful with either no hangup code or with hangup code 50.

The Supra modem at +150866368xx required two calls because the first failed with a ‘‘Unspecified Transmit Phase B error’’ (hangup code 20). Once again a better hangup code would help to understand what actually took place.

The Ricoh 9200 at +161945506xx failed after three attempts to send the second page. As above, a generic error code (50) was returned to the host.

The results are indicative of a modem that has problems with line noise. This is surprising since the modem is reputed to do well as data modem.

4.3.9. US Robotics Sportster

Table 15 shows the anomalous jobs for the Sportster modem. A significant test was to the Zoom modem at +446127561xx. On one occasion the modem entered a state where it held carrier but did not respond to DTR. Manual intervention was required to hangup the line (after over an hour of connect time!) This is a serious problem that alone makes the modem unacceptable for unmonitored operation.

Destination	Tries	Calls	ConnTime	Pages	TypRate	Device
+121522136xx	2	1	4:54	3	14400	SupraFAX v.32bis
+141596576xx	3	3	7:49	0	9600	NEC BitFax
+150866368xx	3	3	7:37	0	0	SupraFAX v.32bis
+151974615xx	4	1	5:59	0	9600	Telebit WorldBlazer
+181830557xx	4	3	17:52	3	4800	Intel SatisFaxion 100
+41142227xx	3	3	6:12	0	14400	Multi-Tech 1432
+446127560xx	3	3	8:22	0	9600	Canon FAX-L770
+446127561xx	3	3	7:41	0	14400	Zoom 14.4X
+4991318587xx	1	1	6:06	3	9600	Multi-Tech 1432

Table 15. Transmission anomalies for USR Sportster.

The Supra modem at +121522136xx took a little extra time because of some handshaking messages had to be retransmitted. The NEC BitFax at +141596576xx failed when three consecutive attempts to send the first page were unsuccessful because no response was received to the post-page message. Communication with the Supra modem at +150866368xx failed because the modems were unable to establish training—specifically the sender never received a CFR/FTT response to training. The Telebit modem at +151974615xx failed when no response was received to the first post-page message; subsequent calls failed when no carrier was established. The Intel modem at +181830557xx required three tries to successfully transfer the first page, after which the remainder of the document went through without a problem. The Multi-Tech modem at +4991318587xx required extra time because the second page had to be retransmitted.

5. A Simple Metric

The data presented in Section 4 and Appendix A is too difficult for most people to understand and use in comparing facsimile modems. For better or worse, people want a single number that they can use to guide them in comparing the modems. Creating a single number is however problematic. The results of Section 4 indicate there are at least two distinct characteristics that are important in rating a modem: reliability and performance. Reliability refers to whether or not a modem accomplishes a requested task—in this case delivering the test facsimile document to a receiving device. Performance is a measure of how well the modem carries out the set of tasks it has been assigned. Some modems support V.27, V.29, V.17, but do not handle poor line conditions well or have difficulties establishing carrier under certain conditions. These modems may perform well in limited use but not be as reliable as other modems. Other modems may excel under poor line conditions but not support the higher signaling rate of V.17. These modems should score high for reliability but may not rate as the highest performing modems available. Our measure for comparing modems rates reliability and performance separately, combining them afterwards for the purpose of defining a single *quality rating*.

The *reliability* of a modem, R_m, is given by Equation 5.1:

$$R_m = \frac{\textit{\# pages delivered}}{\textit{total \# pages}} \tag{5.1}$$

Remember that a page is not considered delivered unless an acknowledgement is received from the receiving device. Note also that the reliability of a Class 1 modem is heavily dependent on the host software that implements the Group 3 facsimile protocol. This is much less true for Class 2 modems. In our tests the same software was used for all tests. We assume that it functions correctly and efficiently. The results tend to support this premise. When all pages are delivered, R_m reduces to:

$$R_m = 1$$

The *performance* of a modem, P_m, is given Equation 5.2:

$$P_m = \sum_{r \in \textit{Receivers}} \sum_{p = \textit{Phase A}}^{\textit{Phase D}} T(r,p) \tag{5.2}$$

where $T(r,p)$ is the average time spent in phase p of the Group 3 protocol communicating with receiver r. If a modem does not successfully complete a phase then the average time for a modem of its capabilities is substituted. That is, if a modem that supports only V.27 and V.29 is unable to successfully transmit page 3 to a particular receiver, then the average time for similar modems for each unexecuted phase of the transfer is used when calculating P_m.

The above equations measure how well a modem does under error-free conditions. When a modem does not transmit a facsimile on the first call it should be penalized. Also, when a modem sends multiple copies of a page it should be penalized. Thus we define an *error metric* for a modem as E_m:

$$E_m = -W_{ep}\left(\frac{\textit{\# extra pages transmitted}}{\textit{maximum \# extra pages}}\right) - W_{ec}\left(\frac{\textit{\# extra calls}}{(.67 \cdot \textit{maximum \# extra calls})}\right) \tag{5.3}$$

where W_{ep} and W_{ec} are weights that reflect the relative importance of each term in E_m. The .67 term in Equation 5.3 is present to balance the two terms because the maximum number of extra pages is $2 \cdot 3 \cdot 33 = 198$ and the maximum number of extra calls is $4 \cdot 33 = 132$.

Given the above definitions, we define a quality rating Q_m by:

$$Q_m = W_r \cdot R_m + W_p \cdot \left(\frac{T_{base}}{P_m}\right) + E_m \tag{5.4}$$

where W_r and W_p are weights that are used to reflect the relative importance of the R_m and P_m terms and T_{base} is a *baseline time* that is combined with W_p to normalize the performance numbers to a range that is more consistent with the other terms.

For a modem that transmits all the test data without extraneous phone calls or page retransmissions the metric reduces to:

$$Q_m = W_r \cdot 1 + W_p \cdot \left(\frac{T_{base}}{P_m}\right) - 0$$

$$= W_r + W_p \cdot \left(\frac{T_{base}}{P_m}\right)$$

So long as a modem is able to transmit all the test pages its rating is controlled by its performance metric P_m and any error costs. A failed call incurs cost through an extra phone call and possibly an extra page transmission. This cost appears in the error term E_m. Modems are usually double-penalized for pages that are never successfully transmitted because the failed page appears both in R_m and indirectly in E_m as extra calls and (probably) extraneous transmitted pages.

Table 16 shows the parameters for Q_m derived from the test data. The performance metric P_m was calculated as described above. Because there were relatively few modems that supported V.29 but not V.17, the results for the Everex 24/96D were not used in calculating ''fill in'' entries for failed phases (since the Everex times were significantly skewed from the norm).

Modem	**Pages**	**ExtraPages**	**ExtraCalls**	**P$_m$**
AT&T DataPort 14.4	99	4	3	2:48:55
Digicom Scout+/V.17	90	2	20	2:39:19
Everex 24/96D	93	3	6	3:27:41
Multi-Tech 1432BA	96	4	3	2:35:55
SupraFAXModem V.32bis	87	12	17	2:44:40
Telebit T3000	81	2	17	2:49:41
Twincom 14.4/DF	83	20	24	2:51:04
USR Sportster	81	11	17	2:33:59
ZyXEL 1496E	89	13	18	2:43:43

Table 16. Modem quality rating parameters.

To complete the calculations for the Q_m we need to select a baseline time and values for the different weights. Choosing weights requires selecting ranges for the different factors that reflect desired characteristics of a ''good modem''. Our criteria weights reliability significantly higher than performance, with extra calls more important than extraneous pages. In addition we want quality metrics for a good modem to be around 100. A possible set of weights that meets our criteria are: W_r of 80, T_{base} of 2:23:11[7], W_p of 16, W_{ep} of 8, and W_{ec} of 20. Using these weights we define a *FaxStone* to be:

$$FaxStone[m] = Q_m[W_r = 80,\ W_p = 16,\ T_{base} = 2{:}23{:}11,\ W_{ep} = 8,\ W_{ec} = 20] \tag{5.5}$$

$$= 80 \cdot R_m + 16\left(\frac{2{:}23{:}11}{P_m}\right) + \left[-8\left(\frac{extra\ pages}{132}\right) - 20\left(\frac{extra\ calls}{132}\right)\right]$$

This set of parameters has many good intuitive properties. The reliability term is in the range [0,80] while the performance term is in the approximate range [0,16]. This weights reliability over performance by a factor of five–as desired. The error metric is in the range [-28,0] with the majority of the error metrics in the range [-5,0]. The overall range for the quality rating is large enough to distinguish between modems but not so wide as to make comparisons difficult. Differences in modem reliability are distinguishable and it is possible to identify raw performance by looking solely at the P_m term. Clearly other weights may be selected in order to emphasize other performance characteristics of the modems.

Table 17 shows the FaxStones calculated from our test data. The columns marked R, P, and E are the weighted reliability, performance, and error terms, respectively.

6. Conclusions

Two modems were clearly the best performers: the AT&T DataPort 14.4/FAX and the Multi-Tech MT1432BA. The modems were extremely reliable. The DataPort lagged noticeably behind the Multi-Tech modem in performance because it did not support V.17, however this was not especially significant in

[7] The value of T_{base} is based on an analysis of the T.4-encoded data, the average phase times, and the receiver capabilities. It represents the best expected time that a sender can do.

Modem	Class	2D	BR	Price	R	P	E	FaxStones
AT&T DataPort 14.4	1	Yes	V.29	200	80.0	13.6	-0.84	92.7
Multi-Tech 1432BA	2	No	V.17	450	77.6	14.7	-0.84	91.4
Everex 24/96D	2	Yes	V.29	N/A	75.2	11.0	-1.48	84.7
Digicom Scout+/V.17	1	Yes	V.17	185	72.7	14.4	-4.60	82.5
ZyXEL 1496E	2	Yes	V.17	325	71.9	14.0	-4.60	81.3
SupraFAXModem V.32bis	1,2	Yes	V.17	225	70.3	13.9	-4.33	79.9
USR Sportster	1	Yes	V.17	185	65.5	14.9	-4.29	76.0
Telebit T3000	2	No	V.29	600	65.5	13.5	-3.03	75.0
Twincom 14.4/DF	1,2	Yes	V.17	225	67.1	13.4	-6.24	74.2

Table 17. Quality metric results for test modems.

the results because the majority of the receiving devices also did not support V.17.

The Everex 24/96D proved to be very reliable also, though it was unable to connect to several of the more difficult receivers. Its performance lagged significantly behind all the other modems. This is due to it being based on old hardware technology.

The remaining modems all rated fairly close together: Digicom Scout+, ZyXEL 1496E, USR Sportster, SupraFAXModem v.32bis, Telebit T3000, and Twincom 14.4/DF. The Scout+ had a significant problem establishing carrier with a variety of receivers. The ZyXEL 1496E was particularly disappointing because of the relatively low cost of the modem and its excellent reputation as a data modem. The test results however indicate that the firmware has problems and the modem may be susceptible to line noise during facsimile operation. The USR Sportster modem had the highest performance rating of any modem but rated very unreliable in testing. Also, as reported earlier, the Sportster had a serious firmware problem that makes unattended use uncertain. The Telebit modem had at least one firmware problem that when corrected will significantly raise the modem's FaxStone rating. This modem also appears to be one of the quickest modems and also appears to handle poor line conditions well. The Twincom 14.4/DF rated last in the tests; it also exhibited serious firmware problems.

Table 17 includes price estimates in US dollars for the modems that were tested. Given these prices, the best buy is the AT&T DataPort 14.4/FAX. The one complaint that can be made about the modem is that it does not support V.17. Since Telebit offers fax upgrades to existing T3000 and WorldBlazer modems for less than US$200 this may also be an excellent route to take for people that already own a Telebit modem, once the Telebit firmware problems are resolved. The Multi-Tech modem looks to be an excellent modem for people that require a Class 2 modem. The only complaint one can make about the MT1432BA is that it does not support 2D-encoded data (though this should be trivial to add to the firmware).

Future Work

This experiment used a very pragmatic approach to evaluating each modem's performance. Another valid approach is to test each modem using equipment that can simulate varying line conditions and protocol errors. This would be useful in understanding exactly how well the modems do under poor line conditions rather than guessing at such behaviour based on the way the modem operates.

Another worthwhile area of work is to get a better understanding of the value of the optional T.30 Error Correction Mode (ECM). ECM could only be used to communicate with the facsimile machines in this experiment, but it is potentially a worthwhile mechanism for improving the reliability of facsimile communication when poor line conditions are encountered.

Finally, the set of receivers used in this experiment were all located in highly industrialized areas of the world. It is important to recognize that other parts of the world may not have such high quality phone systems. In such areas devices such as echo-suppressors may have more of an effect on communication. The test results reported here are likely not to reflect how well the modems work under such conditions.

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Availability of Materials

FlexFAX version 2.2.1 is available by public ftp from the host sgi.com in the directory **˜ftp/sgi/fax**. The PostScript™ source files for the test document are available also by public ftp from sgi.com in the directory **˜ftp/sgi/fax/bakeoff**. A PostScript version of Appendix A is also available in this directory. The session logs are available to modem vendors by request.

References

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Appendix A – Detailed Group 3 Protocol Transfer Times

(*This table is available separately; it was deleted to save space.)*

Appendix B – Test Facsimile

(*This material is available separately; it was deleted to save space.)*