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FAX Technology Tutorial and Testing Issues

White Paper

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Introduction

Facsimile technology, that is, the transmission of images over a telephone line, made its appearance in a commercial application about seventy years ago in the form known as "Wirephoto" which was used to transmit photographs for publication in newspapers. In the early 1960s, the development of modem technology coupled with the Carterfone Decision, made facsimile (fax) machines practical although the slow transmission time impeded widespread use. However, in the early 1970s, image data compression was introduced which drastically reduced transmission time and enabled the fax machine to become an integral part of the business environment. Since then, fax machines have become accepted as indispensable communications devices throughout the world and today there are over 100 million fax machines worldwide. Per year, fax traffic now exceeds 400 billion pages and the worldwide fax phone bill is more than 91 billion dollars. In fact, fax transmissions account for between 30% and 40% of the typical corporate phone bill today. With the explosive growth of the Internet and the development of techniques for incorporating voice and fax transmission into this new communications world, and for bridging the gap between fax and E-mail, the proliferation of fax can be expected to continue and even accelerate.

Because fax machines are so easy to use (put the paper in the hopper, dial the number, and push the "Send" button), many people assume that the whole process is very simple and that testing is not a big issue. The truth of the matter is that communications compatibility between fax devices is a major problem for several reasons:

- Fax technology continues to evolve with new features being added on a regular basis and new fax devices must be compatible not only with the latest models but also with the existing installed base of fax machines, some of which date back at least fifteen years.
- Many different companies with many different design approaches make fax products, and these products all have to communicate with each other.
- Communications technologies and network structures are changing at a rapid pace (for example, the Internet and cellular phone networks), and all of these must be able to handle fax traffic as well as voice.

Why FAX Testing is Necessary

New fax products must be designed to be compatible with the existing installed base of fax systems made by many different companies. They must be compatible with fax products from many suppliers having unique performance characteristics. They must adapt to changing fax technology over the years, and they must handle new enhanced services. Testing is a vital requirement for achieving and maintaining such compatibility. Since carriers and network operators have to be able to move huge and growing volumes of fax traffic over increasingly complex networks, transmission and compatibility problems must be quickly analyzed and corrected. Transmission efficiency (throughput) must be continuously improved by using the most effective data compression schemes in order to reduce the cost per call, and all factors working to impede efficient transmission such as unnecessary image padding must be identified and compensated for. Transmission quality must also be continually improved. Comprehensive testing on an ongoing basis is mandatory for achieving these goals.

With the advent of VoIP (Voice over IP) networks, fax traffic detection in VoIP gateways and fax transmission via IP networks is an important component for the success of real-time IP based services. The transport and quality expectations of fax in IP networks are very different from voice. To accommodate fax, special IP-fax protocols have been developed for the Store and Forward (T.37) and Real-Time (T.38) transmission of fax over IP networks. Systems using these new protocols not only require thorough testing during development and implementation, but will also require ongoing testing during operation to guarantee acceptable quality of service. Testing issues that must be addressed include:

- Interoperability problems between different vendor equipment on the IP side
- Compatibility problems between new IP-fax protocols and conventional telephony networks using older standard fax protocols.
- IP network impairments such as packet loss, jitter, and extensive delay that often must be compensated for by modification of the fax transmission in the telephone networks. These mostly timing-related problems are typically handled in network gateways via various spoofing techniques including stuffing of fax frames with "empty" information or sending dummy frames to keep the receiving fax on-line. Such techniques can have a severe impact on the length and completeness of the fax transmission.

Fax Operation Overview

Sending a fax is far more complex than just dialing a phone number and sending an image. The calling unit must first confirm that the call is being answered by an actual fax device rather than a data modem, answering machine, or human being. Once it is determined that two fax devices are talking to each other, these devices must then exchange information to find out what capabilities they both support (for example, data transmission rate, image resolution, data compression schemes, paper size). They then must agree on a mutually supported subset of these capabilities. Next, the phone connection must be evaluated to determine the maximum practical data rate available. Finally, the fax image is sent. However, it is possible that noise or distortion will corrupt the image during its transit of the connecting network. In order to check for this possibility, the receiving fax device must evaluate the image and send an "Acknowledge" message indicating whether the image was received correctly or whether it had an unacceptable number of errors.

The basic system structure of the typical fax device is shown in Figure 1.

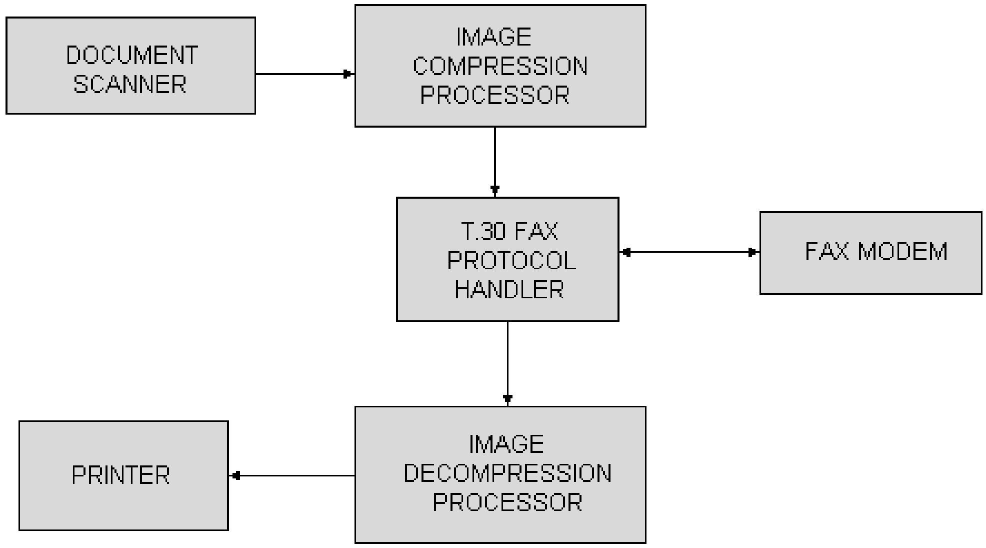


Figure 1: Basic Fax System Structure and Process.

The protocol for sending or receiving a fax image and exchanging associated messages is defined in the ITU (International Telecommunications Union) Recommendation T.30. The sequence proceeds as follows: An image to be transmitted is first scanned to create a bit map in which black and white dots are represented by "ones" and "zeros". This bit map is compressed to eliminate redundant data and then passed to a T.30 protocol handler, a set of software routines that manages the exchange of capability information and image transmission. The data is finally passed to a modem for transmission through the network.

In a similar manner, received images are extracted from the T.30 message sequences, decompressed and printed or stored. The sequence of events in a simple call with no errors is shown as:

- Calling unit dials phone number and waits for answer
- Answering unit detects RING and answers call
- Answering unit identifies itself as a fax device and lists its capabilities
- Calling unit responds with message specifying transmission parameters
    - Data rate
    - Image resolution
    - Data compression method to be used
    - Image size etc.
- Calling unit sends sample data pattern to test phone line connection
- Answering unit evaluates sample data pattern and either accepts proposed data rate or requests a lower data rate
- Calling unit sends image
- Answering unit acknowledges receipt of image
- Call ends

Fax Call Phases

As briefly outlined in the previous section, a fax call is made of different phases starting with dialing the number, proceeding through exchange of capabilities data, followed by transmission of the image, and finally ending with hanging up. These phases are:

- Call setup
- Pre-message handshake procedure
  - Calling and answering fax devices identify themselves and exchange capabilities data
  - Transmission parameters are selected
- Line testing procedure
  - The calling unit sends a test pattern to determine the maximum data rate
  - The answering unit either accepts data rate or requests lower rate
- Image transmission
  - The calling unit sends image using agreed upon compression methods
- Post image handshake procedure
  - End of message
  - Confirmation
  - Multi-document procedures
- Call release

The basic fax call phases are described in detail in the following sections.

Call Set Up Sequence

The Call Set Up sequence starts with detecting dial tone and dialing the number and ends with the detection of answer tone as follows:

- Detect dial tone
- Dial number
- Calling fax unit sends 1100 Hz Announce tone (for automatic operation)

Note: Not all fax machines generate this signal

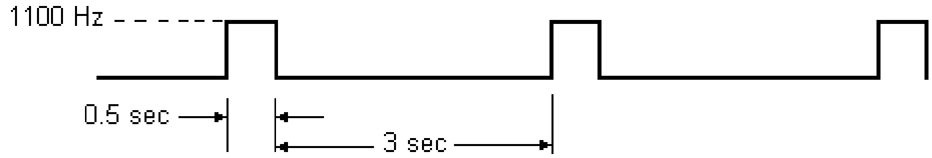
- Answering fax unit detects Ring signal
- Answering fax unit sends 2100 Hz answer tone

Note: Some fax machines send Group 2 tone (1850 Hz) instead of 2100 Hz and other fax machines omit answer tone altogether and just start with the first handshake message.

- Connection established - begin pre-message handshake

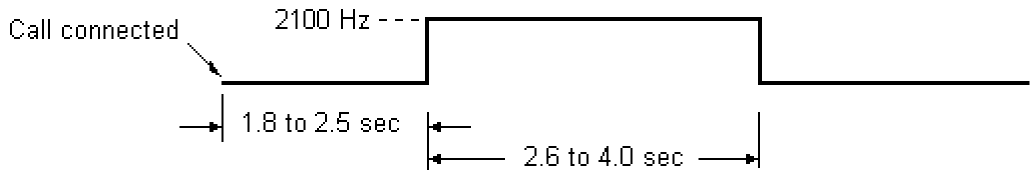
Call set up tones

Figures 2 and 3 show the Call Set Up tones used in Fax call setup.



Frequency tolerance - 1100 Hz + 38 Hz
Timing tolerance - + 15%

Figure 2: Calling unit Announce tone (CNG).



Frequency tolerance - 2100 Hz + 15 Hz

Figure 3: Responding unit Answer tone (CED).

Pre-Image Handshake Sequence

After sending a 2100 Hz Answer tone for approximately 3 seconds, the Answering fax unit sends a handshake message to identify itself and list its capabilities.

• Digital Identification Signal (DIS) handshake message
  - Modulation - V.21 Frequency Shift Keying (FSK) - 300 BPS
  - Lists capabilities
    * Data rates supported
    * Image resolution supported
    * Data compression mode supported
    * Image size supported, etc.
  - Optionally includes International Phone number and manufacturer specific proprietary features

The Calling fax unit responds with configuration data specifying the parameters to be used in transmitting the image.

- Digital Command Signal (DCS) handshake message
    - Modulation - V.21 Frequency Shift Keying (FSK) - 300 BPS
    - Lists proposed call parameters
        * Data rate selected
        * Image resolution selected
        * Data compression mode selected
        * Image size selected, etc.
    - Optionally includes International Phone number and manufacturer specific proprietary features
- Capability data exchanged - continue with line testing phase

Handshake Message Modulation and Data Format

Handshake messages are strings of data bytes used to negotiate image data rate, resolution, compression, and so on. The modulation used is defined in ITU Recommendation V.21

- Data signaling rate - 300 BPS half duplex, synchronous
- Bit encoding method (shown in Figure 4) - Frequency Shift Keying (FSK)
- Zeros are represented by 1850 Hz
- Ones are represented by 1650 Hz

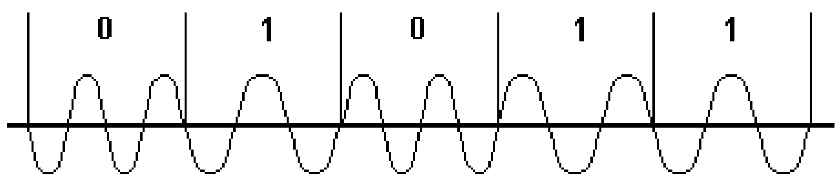


Figure 4: Frequency Shift Keying.

Handshake messages start with a preamble of flag characters (01111110 in binary or 7E in hex) repeated for 1 second + 15% and followed by one or more frames of five or more bytes each (see Figure 5). Each frame is preceded and followed by at least one flag character.

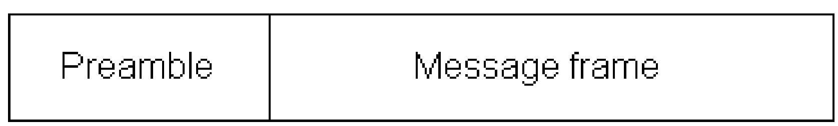


Figure 5: Handshake message format.

Each frame ends with a 2 byte "Frame Check" sequence, which is calculated over all the data in the frame and is used as a validation check. Data within frames (including the Frame Check sequence) is processed according to the HDLC standard (shown in Figure 6) in which temporary "zeros" are inserted in the frame data after every five consecutive "ones" before transmission to prevent false flags from being detected. These temporary "zeros" are removed when the frame is received.

Flag	Address	Control	Information	Frame check	Flag
01111110	8 bits	8 bits	1 or more bytes	sequence - 2 bytes	01111110

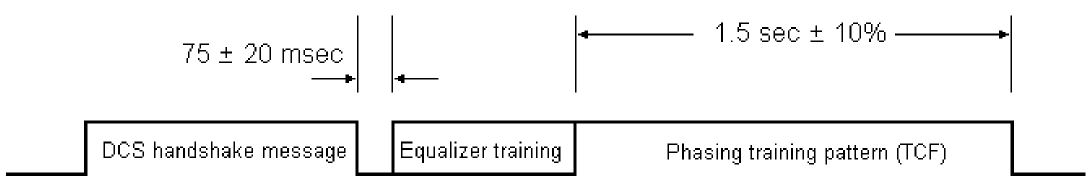
Figure 6: HDLC frame structure

Note: In multi-frame handshake messages, such as those used to exchange capabilities data at the beginning of a call, the T.30 Standard specifies the order in which the frames should be transmitted. However there are many fax machines in use today which do not follow the standard in this regard. Testing is required to make sure that any new fax system is compatible with these older fax machines which violate the Standard.

Line Testing Sequence

After the initial handshake messages exchanged to determine mutually supported capabilities (including the proposed modulation scheme and data rate), the calling unit sends a test pattern to test the phone line.

- Training Check Function (TCF) test pattern (shown in Figure 7)
    - Modulation - V.17, V.29, V.27 ter as specified in DCS message
    - Data rate as specified in DCS message
        * Tests phone line to determine maximum acceptable data rate. Continuous zeros transmitted for 1.5 seconds + 10%



Test pattern consists of 1.5 seconds of continuous zero bits.

Figure 7: TCF test pattern.

The Answering fax unit responds with a handshake message indicating acceptance or rejection of the test pattern - either:

• Confirmation To Receive (CFR) handshake message
• Modulation - V.21 Frequency Shift Keying (FSK) - 300 BPS
• Accepts TCF test pattern data rate

Or:

• Failure To Train (FTT) alternative handshake message
• Modulation - V.21 Frequency Shift Keying (FSK) - 300 BPS
• Rejects TCF test pattern data rate

The basic "Line Testing" sequence starts with DCS (Digital Command Signal) sent by the Calling unit to specify proposed data rate and image parameters. The DCS is followed with a TCF (Training Check Function) training pattern at the specified data rate. The Answering unit responds to the TCF with CFR if the TCF pattern was received correctly, or FTT if the TCF test pattern was judged to be bad. If the Calling unit receives an FTT, it then sends a new DCS specifying a new data rate followed by a TCF test pattern at the new rate. This process is continued until a TCF test pattern is received OK or until all data rates have been attempted.

Note: No guidance is provided in the T.30 Standard for evaluating a TCF test pattern. The algorithm used to decide whether the phone line is adequate for the proposed data rate is at the discretion of each manufacturer. It should also be noted that if an FTT message is received, the Standard provides no guidance as to what action to take next, e.g., whether to drop down to a lower data rate, try the same data rate again, or discontinue the call.

Image Transmission Sequence

After testing the phone line and agreeing on a data rate, the Calling fax unit sends one or more image sequences consisting of an image followed by a post image handshake message and an acknowledging handshake message from the receiving unit:

• Image data
  - Modulation - V.17, V.29, V.27 ter as specified in DCS message
  - Data rate as specified in DCS message
  - Data compression, resolution, paper size, etc. as specified in DCS
• Post image handshake - End Of Procedure (EOP), Multi-Page Signal (MPS), or End Of Message (EOM)
  - Modulation - V.21 Frequency Shift Keying (FSK) - 300 BPS
  - EOP indicates final image - disconnect to follow after acknowledgment
  - MPS indicates more images to follow after acknowledgment
  - EOM indicates polling request or possible parameter change after acknowledgment

The Answering fax unit analyzes the received image and responds with acceptance or rejection:

• Message ConFirmation (MCF), ReTrain Positive (RTP), or ReTrain Negative (RTN) handshake message
  - Modulation - V.21 Frequency Shift Keying (FSK) - 300 BPS
  - MCF accepts image
  - RTP accepts image but requests retest of line before receiving additional images
  - RTN rejects image
  - Image acknowledged - send additional images or send DCN and disconnect

The basic image transmission sequence starts with the Calling unit sending an image using the agreed upon data rate and image parameters. Immediately following the image, the Calling unit sends an EOP, MPS, or EOM handshake message to indicate final image, more images to come, or a request for polling or to change parameters (for example, different resolution, paper size, etc.). The Answering unit responds to the EOP, MPS, or EOM message with MCF if the image was received OK, RTP if image was received OK but with some errors and the phone line must be retested before receiving additional images, or RTN if the image was unacceptable. If the Calling unit receives an MCF message, then it sends additional images, if any, or sends DCN and disconnects if done. If the Calling unit receives an RTP or RTN message, then it sends a new DCS/ TCF sequence to retest the phone line before sending any more images.

Note: No guidance is provided in the T.30 Standard for evaluating an image. The algorithm used to decide whether an image is acceptable or whether the phone line should be retested is at the discretion of each manufacturer.

Image Modulation and Data Format

Images are transmitted at data rates from 2400 BPS to 14.4K BPS using V.27 ter, V.29 or V.17 modulation as determined during the pre-image handshake exchange and "Line testing" sequence. Images are compressed prior to transmission using compression schemes specified in the T.4 or T.6 Standards.

• V.27 ter, V.29, V.17 - Used for transmitting images
  - Data signaling rate - 2,400 to 14,400 BPS half duplex, synchronous
  - Bit encoding method - Combination of phase and amplitude modulation (shown in Figure 8)

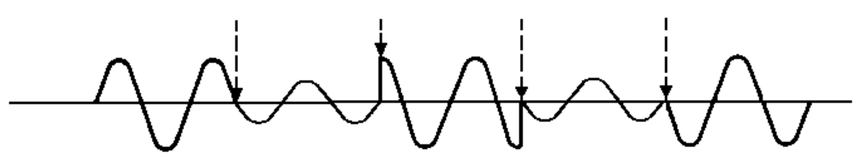


Figure 8: Phase and frequency modulation.

T.4 one dimensional (1D) compression

- Run length codes (shown in Figure 9) are used to represent strings of all white or all black pixels
- Run lengths of up to 63 consecutive all white or all black pixels are coded with terminating codes - run lengths of 64 or more pixels are coded with makeup codes plus terminating codes

Terminating codes				Make-up codes			
00110101	0 white pixels	0000110111	0 black pixels	11011	64 white pixels	0000001111	64 black pixels
000111	1 white pixel	010	1 black pixel	10010	128 ...	000011001000	128 ...
0111	2 ...	11	2 ...	010111	192 ...	000011001001	192 ...
1000	3 ...	10	3 ...	0110111	256 ...	000001011011	256 ...
...		...		...		...	
...		...		...		...	
00110011	62 ...	000001100110	62 ...	011000	1664 ...	0000001100100	1664 ...
00110100	63 white pixels	000001100111	63 black pixels	010011011	1728 white pixels	0000001100101	1728 black pixels

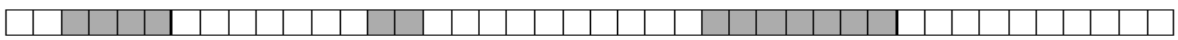


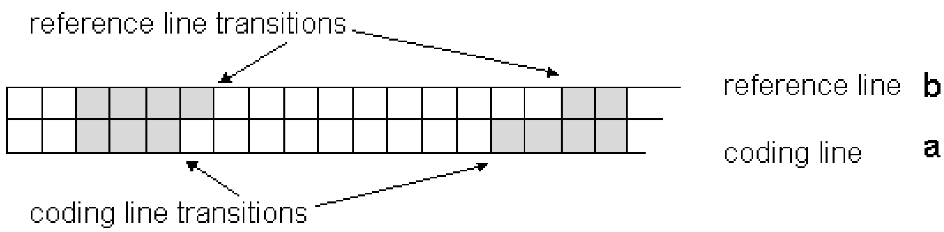
Figure 9: Run length codes.

- 1st data line preceded by EOL (000000000001)
- Each line starts with white run length code - if line starts with black then a zero run length white code is used (00110101)
- Coding for sample line in Figure 9:

2 Wht	4 Blk	7 Wht	2 Blk	10 Wht	7 Blk	10 Wht
0111	011	1111	11	00111	00011	00111

T.4 two dimensional (2D) compression

- Each scan line is compared with the immediately preceding line (reference line) and the differences are encoded. Three different types of coding are used:
- Vertical mode - used when a color transition in the coding line is within 3 pixels of a reference line transition - Code words represent transition separations from 0 to 3 pixels.



relative position	code word
a = b	1
a = b + 1	011
a = b + 2	000011
a = b + 3	0000011
a = b - 1	010
a = b - 2	000010
a = b - 3	0000010

Figure 10: Two dimensional compression.

• Pass mode (shown in Figure 11) - used when complete block of pixels in the reference line is absent from the following line - Each missing block is encoded as: 0001

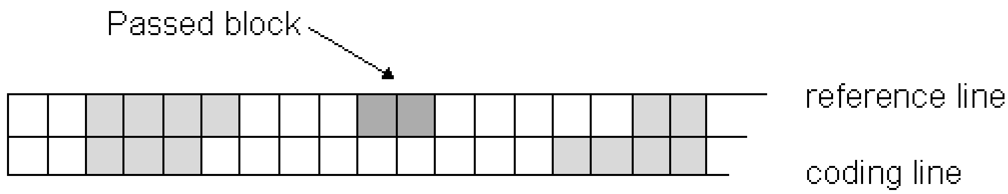


Figure 11: Passed block encoding.

• Horizontal mode (shown in Figure 12) - used when other modes are less efficient or when color transitions are displaced by 4 or more pixels - 001 code word followed by 1 D coding words for the next 2 run lengths

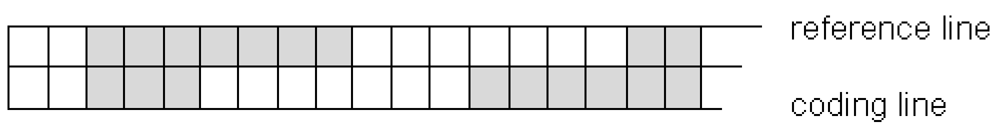


Figure 12: Horizontal mode encoding.

Message Repetitions and Time-Outs

Fax communications takes place through complex networks that are subject to impairments of various kinds. These impairments (for example, noise, delay, lost data packets, etc.), can result in corrupted or lost messages. In order to compensate for the effects of possible impairments, the fax protocol specifies that handshake messages expecting to receive a response will be repeated automatically if no response is received within three seconds.

The handshake messages used in simple fax calls are:

• Pre-fax transmission messages
DIS (Digital Identification Signal) - sent by Answering unit - specifies unit capabilities
DTC (Digital Transmit Command) - sent by Calling unit - polling request to ask for document from answering unit
DCS (Digital Command Signal) - specifies transmit parameters

- Training response messages
  CFR -ConFirmation to Receive: valid TCF test pattern received acknowledgment
  FTT -Failure To Train: TCF test pattern unacceptable, request for retraining
- Post-fax transmission messages
  EOM - End Of Message: end of fax transmission, request turnaround or new parameters
  MPS -Multi-Page Signal: end of fax page, more pages to follow
  EOP -End Of Procedure: end of fax message, disconnect after confirmation
- Post-fax transmission response messages
  MCF -Message ConFirmation: valid image received, ready for more pages
  RTP -ReTrain Positive: valid image received but retraining required before next page
  RTN -ReTrain Negative: bad image received, retrain and re-send image
- Disconnect message
  DCN - DisConNect: line disconnect to follow - no response required

These message types can be classified as command messages and response messages as shown below:

- Command message types
  DIS - capabilities message - expects DCS or DTC as response
  DTC - polling request - expects DCS as response
  DCS/TCF - configuration message - expects CFR or FTT as response
  EOP, MPS, EOM - image completion message - expects MCF, RTP, or RTN as response
- Response message types
  DCS/TCF - configuration message - response to DIS or DTC
  DTC - polling request - response to DIS
  CFR, FTT - test pattern acknowledgment response to DCS/TCF sequence
  MCF, RTP, RTN - image reception response to EOP, MPS, or EOM etc.

Unacknowledged command messages are automatically repeated after listening for a response for 3 seconds. Commands are sent up to 3 times or until acknowledged, whichever comes first. Unacknowledged DIS messages are repeated every 3 seconds until the end of the T1 time-out - 35 seconds. These timing and automatic message retransmission constraints can result in a wide variety of error conditions and error recovery sequences, all of which must be tested.

Fax System Testing Issues

Fax systems must be tested in order to insure compliance with industry standards and to verify compatibility with the existing installed base of fax devices many of which deviate from the standards in a variety of ways.

Fax operating procedures are defined by standards published by the International Telecommunications Union. Committees made up of representatives from fax machine manufacturers, telecommunications companies, and government agencies develop these standards, some of which are listed below:

- Modulation Standards - bit encoding methods for transmission of images and control data
  - V.21 - defines modulation used for transmission of control messages at 300 BPS in conventional FAX
  - V.17, V.29, V.27 ter - define modulation used for transmission of image data at rates up to 14.4K BPS
  - V.34 fax - defines modulation and procedures used for transmission of images at rates up to 33.6K BPS
  - V.8 - defines modulation and procedures for initial data interchange to set up V.34 fax
- Protocol Standards - procedures and message sequences
  - T.30 - defines procedures and message sequences used for fax communications
- Data Compression Standards - procedures used to compress images for fax transmission
  - T.4 - defines algorithms used for one dimensional and two dimensional data compression
  - T.6 - defines algorithms used for image compression for Error Correction Mode

The intent of these standards is to insure that all fax devices follow a common procedure in order that devices manufactured by different companies can communicate reliably with one another. Unfortunately standards compliance varies from manufacturer to manufacturer. ITU standards are recommendations not laws and are subject to interpretation (or misinterpretation) and sometimes manufacturers for various technical reasons deliberately compromise the standards. Extensive testing is required to insure Standards compliance and smooth handling of common deviations.

Network Testing Issues

It is not just the manufacturers of fax systems who need to test their products. Network equipment manufacturers and network operators also require fax testing capabilities for the following reasons:

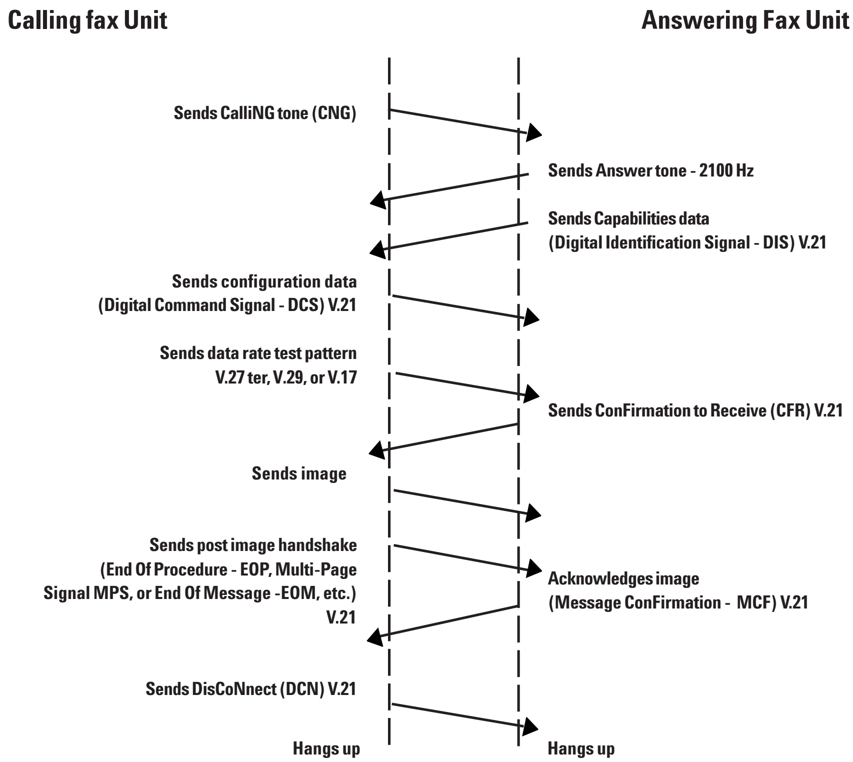
- Network delays can conflict with T.30 timing constraints
  - Testing is required to pinpoint network timing conflicts and assist users in implementing solutions
- Network induced errors and distortion can degrade quality
  - Ongoing testing shows how errors can be reduced and quality improved
- Inefficient compression schemes and unnecessary padding can reduce network throughput
  - Testing is required to compare network performance with optimum performance and identify causes of reduced throughput
- Gateways and servers can be overloaded resulting in lost calls
  - Bulk call generation can show the effects of heavy fax traffic and measure performance limitations

Testing is required to measure network performance and enable users to fix problems and fine tune operations.

Common Deviations from ITU Standards

The ITU Standards for fax specify the sequence of operations in a fax call including the handshake messages to be exchanged, the format of such messages, procedures for testing the validity of handshake messages, error recovery procedures, timing, and so on. Most fax systems deviate from the ITU Standards in one way or another. In order to be compatible with the worldwide installed base of fax devices, systems and networks should be tolerant of the many anomalies and standards violations which will be encountered. Some the most common anomalies and standards deviations are described in the following sections.

For convenience, a single fax LAN is shown again as:



Common Timing Deviations

In addition to the format of the messages, the T.30 Standard also specifies various timing requirements. For example, after dialing a number, the calling fax unit is supposed to listen for a response for 35 seconds before giving up. These time-out periods are:

- T1 - 35 ± 5 seconds — the length of time two fax units attempt to identify each other
- T2 - 6 ± 1 seconds — a time-out used to start the sequence for changing transmit parameters
- T3 -10 ± 5 seconds — a time-out used in handling operator interrupts
- T5 -60 ± 5 seconds — a time-out used in Error Correction mode

These time-outs are sometimes misinterpreted. In addition, they are routinely ignored, and in many cases they should be. For example, after placing a call, the calling fax unit is supposed to wait for 35 seconds before giving up. If the Answering unit doesn't answer on the first ring or if a voice Answering machine is connected to the line, or if there are many delays through the network etc., then the delay before answer can be much longer than 35 seconds.

Fax units which support the Error Correction Mode can respond to a post image handshake message with an RNR (Receiver Not Ready) message. The calling unit then queries the receiving fax unit with an RR (Receiver Ready?) message. If the Answering unit is still busy (printing for example) it will repeat the RNR message. According to the T.30 Standard, this sequence (RR/RNR RR/RNR etc.) can be repeated for up to the end of T5 (60 + 5 seconds) but many fax systems ignore the time-out and will continue the sequence indefinitely unless the user manually overrides.

All of the time-outs are subject to alteration and, in some cases, misuse. Extensive testing is required to verify that commonly encountered deviations are handled smoothly.

Inter-carrier Gap Problems

The T.30 Standard specifies that there must be a silent period of 75 ± 20 msec between signals using different modulation modes, e.g., between the end of a DCS handshake message and the start of a TCF test pattern or between the end of an image and the start of a post-image handshake transmission. This requirement is frequently violated, particularly the duration of the silent period between DCS and TCF. Many fax systems routinely extend the duration of this silent period to well over 100 msec. Unfortunately, if this period is too long, it can interfere with the handshake message error recovery procedure when the DCS message is corrupted by lost packets or noise on the line. All systems should be tested to make sure that they stay within the prescribed T.30 limits and that if they exceed these limits, their ability to recover from error conditions is not impaired.

Other Timing Variations

Testing is also required to determine the ability of a fax system to handle variations in the duration of pauses between unacknowledged handshake message repetitions and also in the pauses between the receipt of a handshake command and the start of a response to that command. Many fax systems, in order to reduce the total transmission time, start sending a response message before the end of the command has been received.

Answer Tone Anomalies

The T.30 Standard directs that the Answering fax device send an answer tone of 2100 Hz for approximately 3 seconds before sending the first handshake message. Some fax machines send an 1850 Hz tone, some send an 1100 Hz tone, and some omit the answer tone altogether and just begin with the first handshake message. Testing is required to verify that a Calling fax unit can complete the call even in the absence of answer tone.

Other Deviations from ITU Standards

There are many other commonly encountered anomalies and deviations which must be tested for including:

- Frame sequence deviations
- Preamble and flag sequence variations
- Improper EOM usage
- Unusual data rate fallback sequences
- Common training pattern detection algorithms
- Image transmission deviations
- Echo Protect Tone usage
- Image padding & short lines
- RTP/RTN handshake message usage
- Long duration lines
- Non-standard disconnect sequences
- DCN usage

Fax Testing Customer Types

Many types of enterprises have a requirement for fax testing. Manufacturers of fax machines, fax modems, fax related products and software companies, network equipment manufacturers, and network operators all have requirements for fax testing. These requirements include not only diagnostic testing for product development but also production and QA testing, customer support testing, and, for network operators in particular, quality of service measurements on a continuing basis. Typical customer types include:

- Fax machine manufacturers
- PC fax card manufacturers
- Modem manufacturers
- fax software companies
- Cellular fax companies
- Fax server companies
- Gateway suppliers
- Network equipment suppliers
- Network operators

Fax Testing Application Areas

Fax testing is a necessity not only in engineering labs where fax products are created but also in many other areas. Fax testing application areas include:

- Fax Product Developers
  - Real time testing to view operations in detail
  - Test bed to send and receive faxes
- Quality Assurance
  - Worst case testing
  - Regression testing using comparison with standard reference calls
  - Generation of customized reports to document results
- Production Test
  - Testing T.30 compliance & interoperability
  - Comparison with standard reference calls to spot performance deviations
  - Generation of reports tailored to production needs
- Customer Support
  - Requirement to send and receive faxes from customer's systems
  - Real time testing and analysis of customer's problems
- Cellular fax operations
  - Simulation of unique cellular problems - carrier drop outs etc.
- Fax Server Testing
  - Generation of large volumes of simultaneous calls for load testing
- Network Testing
  - End to end testing to record and analyze delay effects
  - Real-Time monitoring to show effects of network noise and distortion
- Gateway Testing
  - T.30 compliance and interoperability testing
  - Generation of simultaneous calls for load testing

Conclusion

The continued proliferation of fax-based products and services, particularly those products and services that will (along with voice-based services) use IP networks and the Internet, creates a growing need for fax testing. Fax systems and fax networks must be tested for the following reasons:

- Standards Compliance - call setup, handshake and capability exchanges, and timing issues must all adhere to agreed upon standards to ensure the most reliable and efficient performance. In addition, methods used to handle deviations from standards and industry practices must be verified.

- Network Performance - as more and more fax traffic ends up on net works designed for data, it will become increasingly important to fine-tune the data network's performance. More important, however, the performance of the fax systems themselves will have to be monitored and improved to ensure a consistent quality of service.

- Troubleshooting - because businesses depend so heavily on fax services, isolating and eliminating problems is a key objective of service providers and network administrators. This becomes even more important when fax services begin to run on IP and other data networks. The need for fax system and network testing is well established for equipment manufactures and software developers. But fax service companies, network operators, and carriers need test applications and methodologies as well. From product development and quality assurance, to production testing and customer support, fax testing and verification will continue to be necessary as long as fax plays such an important role in the business communication and consumer environments.

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About the Author

Mr. Gray, has held the position of Fax Product Marketing Manager for Hewlett-Packard's Network Systems Test Division, and is the founder of Gray Associates and Telegra Corporation (recently acquired by Agilent Technologies), he has more than twenty years experience in the design and development of high technology digital products with specialization in the areas of telecommunications and man/machine interfaces. He is an expert in data communications, voice, and facsimile technology and has provided consulting services to many clients in this field. Mr. Gray guided the development efforts of the first commercial fax protocol analyzer and Telegra's Windows based FaxTrace Pro Series of fax stress testing systems.

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