JHC

PROPOSED

SYSTEM STANDARD

FOR

CONTROL DATA

COMMUNICATION CONTROL PROCEDURE

(CDCCP)

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FORWARD

This document is the result of an effort initiated by the promulgation in July 1974 of a Corporate Strategic Directive on Link and Line Control Procedures. The purpose of this directive was to establish a standard link control procedure upon which future communication product development could be based.

Requirements of the new line control protocol, as set forth in the directive, included those features which are characteristics of the new bit oriented, code transparent independent numbering protocols being standardized by ANSI, ISO, IBM, NCR and others. The directive specifically requires compatibility with IBM's SDLC.

The communication control procedure defined in this document is intended to meet these objectives. The procedures are based on, and draw heavily from, studies of, and participation in, the work of various national, international, and vendor standards bodies. The format and terminology have been chosen to be compatible with other standards in order to promote understanding and avoid confusion.

Bit oriented procedures, such as defined in this document, are an outgrowth of attempts to overcome the deficiencies inherent in the older, character oriented procedures. These deficiences included:

a) Character-orientation meant that they were not naturally transparent to the structure or encoding of the text.

b) Transparency could be achieved only at the expense of incompatibility with non-transparent procedures.

c) Error detection was based on relatively weak and inefficient column and row parity.

d) Supervisory messages were protected only by column parity.

e) The mixture of message control, device control, and link control forced a significant amount of processing at a low functional level.

f) The procedures were basically two way alternate and thus could not take advantage of duplex facilities.

The objective of these procedures, then, is to overcome these deficiencies by defining a protocol which:

a) is independent of code structure.

b) is transparent to the information content, i.e., text.

c) separates the functions of link control from those of device and message control.

d) is unambiguous as to data link control functions.

e) provides a single format for all information and supervisory transmissions.

f) provides reliable error detection for all transmissions.

g) is equally applicable to all types of communication facilities.

The document is intended to ensure internal standardization as well as to promote compatibility when interfacing foreign, non-CDC systems. Its purpose is to serve as a design planning guide in writing developmental specifications. The definition of a function as mandatory does not mean that that function will exist in all stations in all applications. It is for this reason that a definitive interface specification, written within the framework of this document, must be written for each product type.

The procedures contained in this document, to the best knowledge of the authors, will assure compatibility with the various cited standards. It must be stressed, however, that bit oriented procedures are in a evolutionary stage and subject to some revision and change. Complete on-line compatibility with a particular device cannot be guaranteed without availability of complete specifications on that device.

The designation and acronym chosen for this procedure, i.e., Control Data Communication Control Procedure (CDCCP), was a deliberate one which is intended to divorce it completely from previous "Mode X" procedures. This in in keeping with its characteristics which are entirely new.

0 SCOPE

The Control Data Communication Control Procedure (CDCCP) is a bit oriented, code independent, modular data link control protocol. It is designed to be line and link compatible, to the greatest extent possible, with other national and international bit oriented procedures and with IBM's Synchronous Data Link Control (SDLC).

This document defines in detail the frame structure used in all CDCCP transmissions. It describes the structure, formatting, and significance of the various fields in the frame as well as the frame delimiting flags and frame check sequences.

The document includes a complete definition of the elements of procedure which comprise the building blocks of CDCCP. It describes the various modes of operation and includes description of communication facilities and links which form the CDCCP environment.

Various classes of procedures, which map the elements of procedure to general applications, are defined.

Appendices are provided which include additional information related to standards compatibility, bi-lateral agreements, error detection techniques, and examples of the protocol. A glossary is also included.

2.0 REFERENCES

2.1 Corporate Strategic Directive on Line and Link Control Procedures, 2 July 1974.

2.2 IBM Synchronous Data Link Control - General Information, IBM GA27-3093-0, March 1974.

2.3 Proposed American National Standard for Advanced Data Communication Control Procedures (ADCCP) - Independent Numbering, 3rd Draft, February 1975.

2.4 Proposed Draft International Standard on HDLC Elements of Procedure, ISO/TC97/SC6/1005, Revised May 1975.

2.5 Draft International Standard on HDLC Frame Structure, ISO DIS 3309.

3.0 COMMUNICATION FACILITIES AND LINKS

As a communications control procedure, CDCCP defines a protocol, or set of rules, governing the transfer of data between participating stations interconnected by communication links.

Before defining the protocol, it is necessary to clarify the sometimes confusing terminology applied to communication facilities. For example, communication interconnects are variously referred to as lines, channels, links, and facilities. They are described as being duplex, simplex, full duplex, half duplex, two-wire, and four-wire. Simultaneity of data transfer is sometimes equated to physical configuration, sometimes to logical configuration, and sometimes to information transfer. The advent of satellite facilities and the use of on-premise and off-premise loops further clouds the picture.

The purpose of this section, therefore, is to define and illustrate communication facilities and links in the context in which they are used in this document.

3.1 Communication Facilities

3.1.1 Definition

A communication facility is defined as the interconnecting communication resource normally provided by a common carrier. It may, however, be provided by a non-common carrier supplier or by a combination of the two. The interface or demarcation point of the facility is rigidly defined as the connector on the terminal equipment side of the data set, modem or other access equipment. See Figure 3-1a. Communication facilities may be characterized by modes of operation, types of channels, and interconnecting arrangements.

3.1.2 Modes of Operation

There are three modes of operation possible with commonly available communication facilities: simplex; half duplex; and duplex.

Simplex operation is the use of a channel to transfer data in one direction only. An example is a master station transmitting data to one or more remote stations with no signals required in the reverse direction.

Half-duplex operation is the use of a channel to transfer data in either direction on an alternate basis. For example, data is transmitted in one direction and the data sets are then turned around (transmit to receive) to permit data to be transmitted in the other direction.

Duplex operation is the use of a channel to transfer data in both directions simultaneously.

3.1.3 Types of Channels

Communication facilities are characterized as being 2-wire or 4-wire. These facilities are used to make up 2-wire or 4-wire channels. A 2-wire channel is the equivalent of one pair of wires which may carry both directions of transmission. A 4-wire channel is the equivalent of a separate pair of wires being used for each direction of transmission. It is possible to operate simplex, half-duplex, or duplex over either 2-wire or 4-wire channels.

The type of equipment comprising the communication facility is usually transparent to the user. He is unaware of whether his channel is carried on cable, carrier, microwave or satellite facilities. The only manifestation may be a change in propagation delay which is of concern to data link control.

3.1.4 Interconnecting Arrangements

Many interconnecting arrangements of communication facilities are possible. The most common are point-to-point and multipoint.

3.1.4.1 Point-to-Point Interconnect

A point-to-point facility is one which interconnects two and only two stations. See Figure 3-1a. Point-to-point facilities may be either non-switched, sometimes referred to as private line or dedicated, or they may be switched. The difference between switched and non-switched is one of facility acquisition. In the switched case the facility must be acquired prior to the transfer of data and released at the end of the transfer. Non-switched facilities are dedicated and usable on demand. Point-to-point facilities will be commonly used for CDCCP communications.

3.1.4.2 Multipoint Interconnects

Multipoint facilities are those used to communicate between more than two locations. There are three basic types of multipoint facilities: broadcast, conference, and broadcast polling.

The broadcast multipoint consists of a master transmitter and two or more remote receivers. There is not return path from the remotes to the master nor can the remotes communicate with each other. This arrangement uses 2-wire channels in a simplex mode. The broadcast multipoint is not suitable for CDCCP controlled data transmission because of the need for two way communication.

The conference multipoint is arranged such that transmissions from any station are received by all other stations. This arrangement is not suitable for CDCCP due to the contention problems involved.

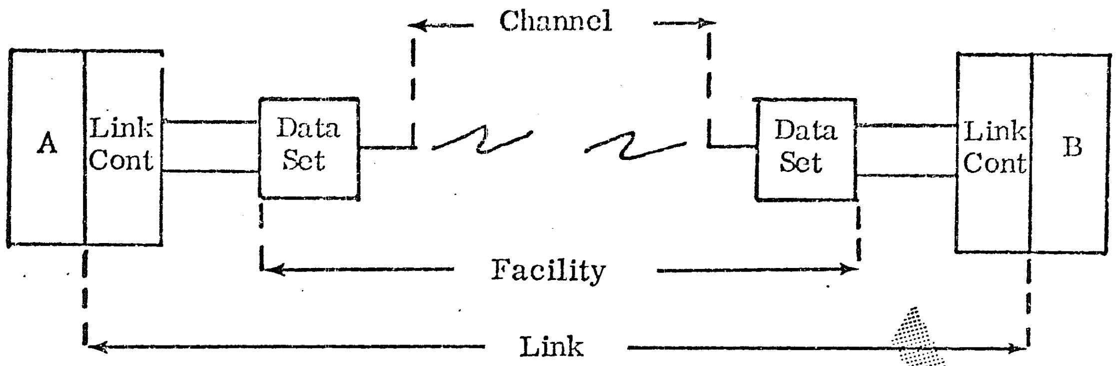
The third basic multipoint arrangement is the most commonly used for data transmission. This is the broadcast polling arrangement which consists of a single master and two or more remote stations as illustrated in Figure 3-1b. Transmissions from the master are received by all remotes. Transmissions from the remotes are logically received only by the master. This multipoint arrangement requires 4-wire channels. It is expected to be very common in CDCCP applications. ? ?

3.1.4.3 Loop Interconnects

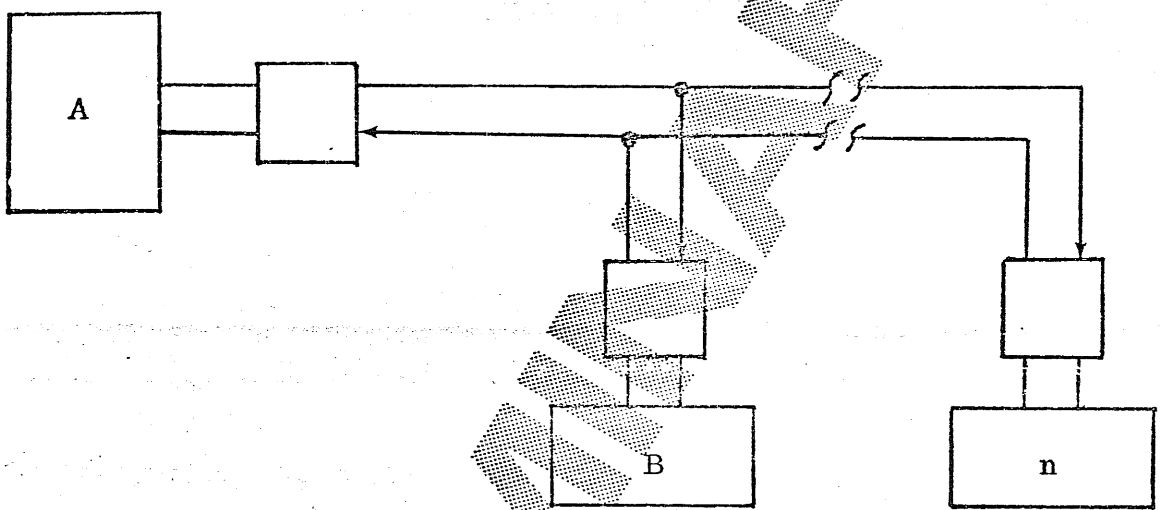
Many special and hybrid combinations of interconnect arrangements are possible. The most likely to be encountered in CDCCP applications is the loop arrangement.

The loop configuration consists of two more point-to-point facilities arranged such that the loop starts and ends at the same location. See illustration in Figure 3-1c. The point-to-point facilities are normally 2-wire channels and operate in simplex mode: A transmits to B, B transmits to C, and so on around the loop. Transmission in the reverse direction is not possible. Each station on the loop operates as a repeater.

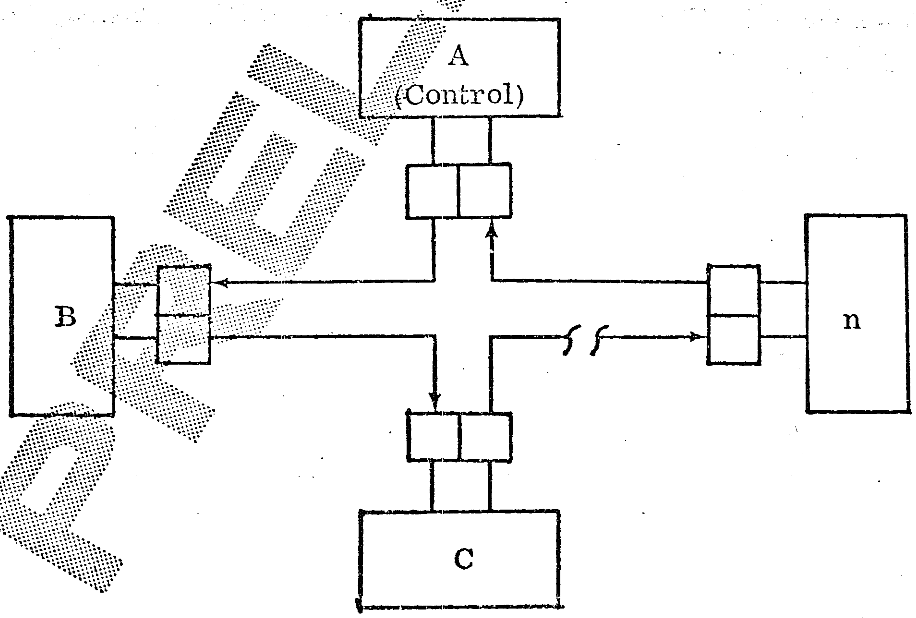
Loop facilities may be encountered which are completely user-owned, especially when located within the confines of a building. Others may use common carrier facilities when geographically dispersed.



a) POINT-TO-POINT



b) BROADCAST POLL MULTIPOINT



c) LOOP

3.1.5 Facility Control

Facility control is defined as that subset of data link control which is concerned with the manipulation and monitoring of the data set control signals available at the demarcation point. In the case of switched facilities, this function is also necessarily concerned with the acquisition and release of the switched facility.

The requirements of facility control are defined in a set of standards applicable to the interface between the data terminal equipment and the data communication equipment. These standards include EIA RS232-C, EIA RS-366, CCITT V.24, CCITT V.35, and others.

3.2 Communication Links

3.2.1 Definition

A communication link is defined as the communication facility plus the link control logic associated with the data terminal equipment. See Figure 3-1a. The link serves as a path for the transfer of information between stations. The control of this information transfer requires a set of rules for initializing, sequencing, verifying, and terminating the information transfer. This control is the function of data link control.

3.2.2 Data Link Control

A data link control procedure is the protocol which governs the use of a communications link to transfer information between participating stations.

Data link control procedures are commonly designed to control one or more of three classes of data transfer: One Way (OW); Two-Way Alternate (TWA); or Two-Way Simultaneous (TWS). These terms are used to avoid confusion with simplex, half duplex, and duplex operation of the facility. Two-way alternate data transfer, for example, can occur on a duplex facility but two-way simultaneous data transfer cannot occur on a half duplex facility. The term "data" when used here refers to information plus link control; i.e., two-way simultaneous operation does not necessarily mean that end user information is flowing in both directions simultaneously.

2.2.3 CDCCP Data Link

In CDCCP the normal cycle of communication between two stations consists of the transfer of frames containing information from the information source to the information sink, acknowledged by a frame in the opposite direction.

A CDCCP data link involves two or more participating stations. For control purposes, one station must assume responsibility for the organization of data flow and for link level error recovery. This control station is known as the Primary. The frames transmitted by a primary are always referred to as command frames. All other stations on the link are known as secondaries and the frames they transmit are referred to as responses. Each secondary is responsible for executing commands received from the primary and for responding when instructed to do so by the primary.

The link interconnecting the primary and secondaries may utilize facilities which are point-to-point, multipoint, simplex, half duplex, duplex, switched, or non-switched.

4.0 FRAME STRUCTURE

4.1 General

The vehicle for all command, response, and information transmissions under CDCCP is called a frame. A frame is a sequence of contiguous bits bounded by and including opening and closing flag sequences. A valid frame is a minimum of 48 bits in length and must conform to the following structure:

F, A, C, I, FCS, F

where

F =	Flag Sequence
A =	Address Field
C =	Control Field
I =	Information Field
FCS =	Flag Check Sequence

Frames containing only link control sequences form a special case where no I field is present.

The frame structure is illustrated in Figure 4-1. Each element of the frame is detailed in the following paragraphs.

4.2 Flag Sequence (F)

All frames open and close with the flag sequence. This sequence has the binary configuration 01111110, that is, a zero bit followed by six one bits, followed by a zero bit.

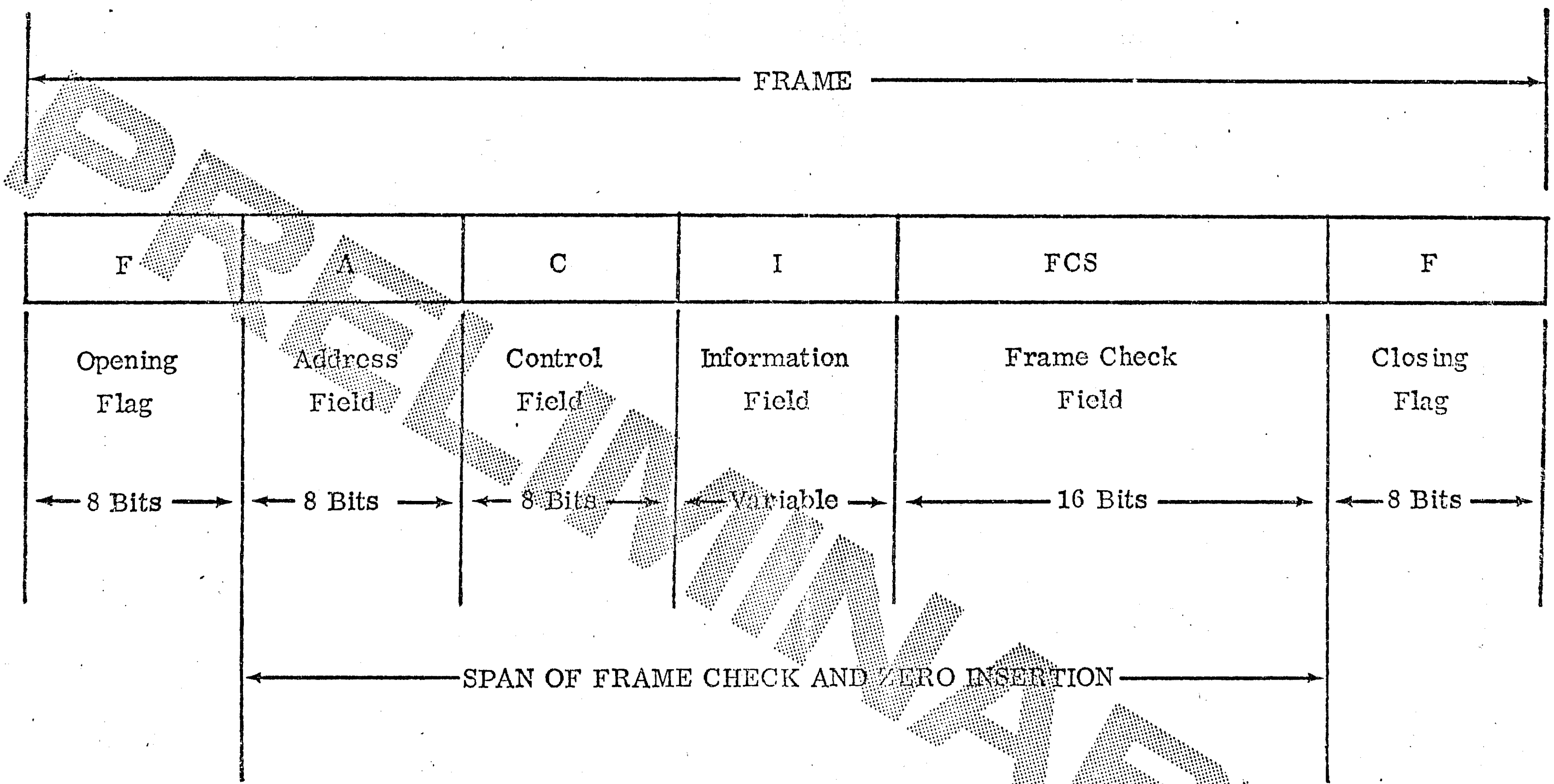


FIGURE 4-1. FRAME STRUCTURE

The opening flag serves as a position reference for the address, and control fields and initiates transmission error checking. The closing flag serves as a position reference for the flag check sequence.

Transmitters must send only complete eight-bit flags. All receivers attached to the data link must search continuously, on a bit-by-bit basis, for the flag sequence. Thus, the flag sequence provides frame synchronization.

An F may be followed by a frame, another F, or an idle line. An F which closes a frame may also be used as the opening F on a following frame. Any number of F's may be transmitted between frames.

Since the F sequence brackets and synchronizes the frame, it must be prevented from occurring in any field of the frame. This is accomplished by the zero insertion technique described below.

Each transmitter must insert a zero bit following five contiguous one bits anywhere between the opening and closing flag sequences. The insertion of the zero bit thus applies to the address, control, information, and FCS fields and effectively prevents the fortuitous transmission of the F sequence 01111110.

Each receiver after detecting the opening flag (start of frame) continuously monitors the received bit stream and removes any zero bit which follows a succession of five contiguous one bits. Note that zero insertion at the transmitter follows the computation of FCS and that zero deletion at the receiver precedes the FCS check process.

4.3 Address Field (A)

4.3.1 General

The address field (A) immediately follows the opening flag of a frame and precedes the control field. This field always contains the address of the secondary station. The primary station is never identified. The address field is N octets in length where $N \geq 1$. The contents of the field may be a single, group, or global address.

Two addressing modes are defined for the secondary station link address field. These are the basic and extended modes described below. All stations must be capable of operating in both modes. For a specific link the maximum number of octets must be explicitly defined.

4.3.2 Secondary Link Address Field - Basic Mode

In the basic mode, the secondary link address field contains one address, which may be a single, group, or global secondary address. In this mode, address extension is not permitted. All 256 combinations are available for addresses. This basic mode field consists of one eight bit octet with the format illustrated in Figure 4-2a.

4.3.3 Secondary Link Address Field - Extended Mode

In the extended mode, the secondary link address field is a sequence of octets which comprise a single secondary address. The least significant bit is used as an extension indicator. When this bit is zero, the following octet is an extension of the address field. The address field is terminated by an octet having a one in bit position one (least significant bit). Thus the address field is recursively extendable. The format of the extended address field is illustrated in Figure 4-2b.

4.3.4 Group and Global Addresses

Each secondary station on a data link must be capable of recognizing a group or global address which is contained in one unextended octet even when extended mode is normally used.

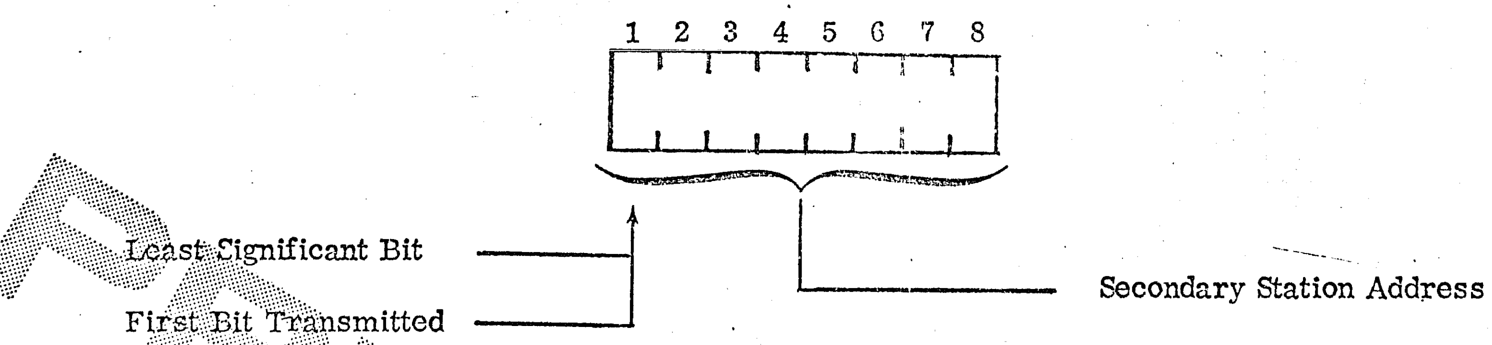
Two or more secondaries may be required to recognize the same group or global address. Each secondary, however, responds with its individual address.

4.4 Control Field (C)

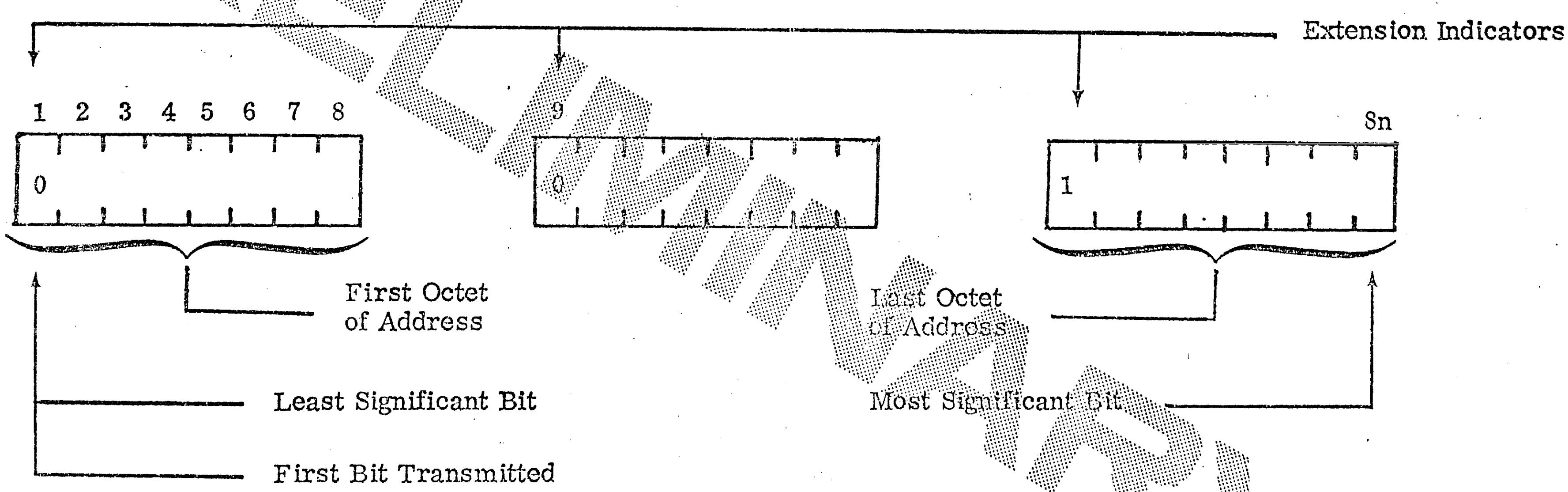
4.4.1 General

The control field (C) is located immediately following the address field and preceding the information field in the CDCCP frame structure. The control field is used to convey commands, responses, and sequence numbers necessary to control the data link.

There are two modes defined for the control field. These are the basic and extended modes described in the following paragraphs. Each station on a data link must be capable of operating in either mode. For a given link the mode must be specifically identified.



a) BASIC MODE ADDRESS FIELD



b) EXTENDED MODE ADDRESS FIELD

FIGURE 4-2. ADDRESS FIELD FORMAT

4.4.2 Control Field - Basic Mode

The basic control field consists of a single 8 bit octet. This field is structured into one of three formats. These are the information transfer format used by primary and secondary stations to transfer information, the supervisory format used to convey link supervisory data, and the non-sequenced format used to provide additional primary and secondary link control functions.

In addition, each format includes a format identifier and a poll/final bit. The poll/final bit serves as the send/receive control. A poll (P) bit is sent only by a primary and is used to authorize secondary transmission. The final (F) bit is used only by a secondary in response to a P bit. Only one P bit is outstanding, i.e., unanswered by an F bit, on a data link.

Section 6 provides additional information on the control field, details the command and response codes, and describes their use in conjunction with the poll/final bit.

Figure 4-3a illustrates the basic mode control field.

4.4.3 Control Field - Extended Mode

The basic mode control field provides for a modulus 8 sequence count (refer to paragraph   ). On long propagation delay links, e.g., satellite links, it may be necessary to extend the sequence number modulus. The extended mode control field provides this capability.

The control field is extended by the addition of a second contiguous octet immediately following the basic field. This extension increases the modulus count to 128. The three formats for an extended mode control field are illustrated in Figure 4-3b.

4.5 Information Field (I)

CDCCP exists as a vehicle for transporting the data contained in the information field (I). The data link control is completely transparent to the contents of the I field. The I field may, therefore, consist of any number of bits, in any code, related to character structure or not. The I field is unrestricted as to length but it should be recognized that typical length is contingent on system requirements and limitations beyond the link level. Factors limiting I field length may include channel error characteristics, station buffer sizes, and the logical properties of the data.

The occurrence of a flag or abort sequence within the I field is prevented by the zero insertion technique described in paragraph 4.2.

I fields are normally included in every frame having a C field with an information transfer format. These information transfer frames are the only ones which are sequence numbered. An information field with a length of zero is specifically permitted.

Provisions are also made for an I field in a non-sequenced C field format. Such frames are not protected by sequence checking.

Formats	1	2	3	4	5	6	7	8
Information Transfer	0	N (S)			PF	N (R)		
Supervisory	1	0	S	S	PF	N (R)		
Non-Sequenced	1	1	M	M	PF	M	M	M

Control Field Bits

First Bit Transmitted (bit 1)

where:

N (S) = Send Sequence Count (Paragraph)

N (R) = Receive Sequence Count (Paragraph)

S = Supervisory Function Bits (Paragraph)

M = Modifier Bits (Paragraph)

PF = Poll Final Bit

a) BASIC MODE CONTROL FIELD

	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Information Transfer	0	N (S)							PF	N (R)						
Supervisory	1	0	S	S	X	X	X	X	PF	N (R)						
Non-Sequenced	1	1	M	M	X	X	X	X	PF	M	M	M	X	X	X	X

First Bit Transmitted (bit 1)

where X bits are reserved and set to 0.

b) EXTENDED MODE CONTROL FIELD

FIGURE 4-3. CONTROL FIELD FORMAT

4.6 Frame Check Sequence (FCS)

Each CDCCP frame includes a 16 bit frame check sequence (FCS) immediately following the I field (or the C field if there is no I field) and preceding the closing flag. The FCS field serves to detect errors induced by the transmission link and validate transmission accuracy. The 16 bits result from a mathematical computation on the digital value of all binary bits (excluding inserted zeros) in the frame including the address, control and information fields.

The process is known as cyclic redundancy checking using a generator polynomial of $X^{16} + X^{12} + X^5 + 1$. The transmitter's 16 bit remainder value is initialized to all ones before a frame is transmitted. The binary value of the transmission is premultiplied by X^{16} and then divided by the generator polynomial. Integer quotient values are ignored and the transmitter sends the complement of the resulting remainder value, high order bit first, as the FCS field.

At the receiver the initial remainder is preset to all ones and the same process is applied to the serial incoming bits. In the absence of transmission errors the final remainder is 1111000010111000 (X^0 thru X^{15} respectively).

The receiver will discard a frame in error and will not advance the receive sequence count thus causing a retransmission of the errored block.

Appendix B provides more complete mathematical treatment of the FCS technique.

4.7 Transmission States

Once established, the data communication channel between DCE's on the link is assumed to be constant. Transmission over the channel is transitory. A definition of transmission states provides a convenient means of referring to the conditions which exist on the channel at any given point in time.

4.7.1 Transient State

A communication channel is defined to be in the transient state when a station is setting up to transmit, i.e., the station has issued a request-to-send to the DCE and is awaiting a clear-to-send signal from the DCE. During this transient state, any action necessary to establish the channel for transmission takes place.

4.7.2 Active State

A communication channel is in the active state when a station is transmitting or receiving frames or interframe time fill (paragraph).

4.7.3 Idle State

A communications channel is in the idle state when it is neither in the active or transient states. A station identifies the idel state by the receipt of 15 or more contiguous one bits in the following channel configurations:

a) Full duplex - point-to-point - primary or secondary
b) Full duplex - multipoint - primary
c) Loop - primary

A station identifies the idle state by the absence of signal in the following channel configurations:

a) Half duplex - primary or secondary.

b) Full duplex - multipoint - secondary.

Note that a full duplex channel may be active in one direction and idle in the other.

4.8 Interframe Time Fill

Interframe time fill may be transmitted by a primary or full duplex secondary to maintain the link in an active state and to retain bit synchronism. Time fill may also be used to avoid time outs and to hold the authority to transmit.

When used, interframe time fill must be a series of contiguous flags which are contiguous to the closing flag of one frame and the opening flag of the next frame.

4.9 Abort

Abort is the process by which a station, in the act of transmitting a frame, decides before the end of that frame to terminate in an unusual manner which will cause the receiver to discard the frame.

Aborting a frame is accomplished by transmitting at least seven but less than 15 consecutive one bits with no zero insertion. Receipt of seven contiguous one bits is interpreted as an abort.

A secondary station which transmits an abort may not start another frame until it receives a command from the primary.

4.10 Invalid Frame

An invalid frame is defined as one not properly bounded by an opening and closing flag or one which is too short, i.e., less than 32 bits between flags. A station will ignore an invalid frame.

4.11 Order of Bit Transmission

Addresses, commands, responses, and sequence numbers are to be transmitted low order bit first, e.g., the first bit of the transmitted sequence number carries a weight of 2^0.

The order of bit transmission for data contained within the information field is application dependent and is not specified in this procedure.

The order of bit transmission for the FCS is most significant bit first.

4.12 Loop Operation

Operation in a loop configuration as defined in paragraph 3.1.4.3 requires that stations be capable of operation as repeater stations. The loop configuration also places some unique requirements on frame handling and requires the definition of an initializing sequence called a "Go-Ahead" sequence.

4.12.1 Go-Ahead Sequence

The GA is the 8 contiguous bit sequence 0 1 1 1 1 1 1 1. In loop operation, a secondary station must receive a GA pattern before it begins transmission of a response. The primary station interprets the receipt of the GA as the end of a series of responses.

A GA pattern following a frame is illustrated below.

```
F, A, C, FCS, F,|0 1 1 1 1 1 1 1|1 1 1 1 1 1 1
                |<----- GA ---->|
```

Loop procedures require that the primary station always initiates the GA sequence subsequent to the transmission of a frame which invites the secondary (secondaries) to initiate a transmission. Secondaries, in turn, are required to relay the GA following their response transmission. The GA sequence thus provides a means whereby linked secondaries can sequence responses to a group-addressed command (command addressed to more than one secondary) without creating mutual interference.

The GA sequence follows any command frame which requires a response It is not restricted to group-addressed command frames.

The secondary station which has a frame or frames to submit recognizes a legitimate GA sequence (the first 0 1 1 1 1 1 1 1 sequence following a poll frame) and substitutes an 0 bit for the seventh 1 bit of the GA, thus generating an opening flag. It then transmits the frame(s) (A, C, I, FCS) and the closing flag.

A secondary station implements either of two means of terminating a transmission after sending the closing flag:

a) It generates a GA sequence, then resumes the repeater function. This assures that the GA sequence will be relayed even if the primary is sending to an uploop secondary when the secondary in question ends its last frame.

b) It immediately resumes the repeater function and depends upon steady ones from the primary to create a GA pattern. With this method of operation, the primary has the capability of interrupting transmission from a group of secondaries.

In either a or b, the GA sequence will be relayed downloop and will elicit transmissions from the next downloop station with the authority and need to transmit. Eventually, after all secondary stations have completed their transmissions, the GA sequence will be returned to the loop controller station (primary).

All secondary stations on a particular loop implement either method a) or b).

4.12.2 Primary Station Generation of GA

The primary station generates the GA sequence according to the following rules:

a) The primary station generated GA sequence always contains a leading 0-bit. This 0-bit is not a part of the preceding flag, whether this preceding flag is the closing flag of a frame, or if it is a time-fill flag.

Closing Flag	GA
0 1 1 1 1 1 1 0	0 1 1 1 1 1 1 1

b) The primary station may insert any number of complete flags following the closing flag of the frame granting response permission to the secondary station before generating the GA sequence.

Closing Flag	n Flags of Time-Fill	GA
0 1 1 1 1 1 1 0		0 1 1 1 1 1 1 1

4.12.3 Secondary Recognition of GA

The secondary station activates recognition of the GA sequence upon receipt of a command frame which legitimately instructs or invites it to transmit a frame. If the secondary station response to the command frame is optional, and if the station chooses not to transmit a frame when the first GA sequence is detected, it shall deactivate the GA recognition capability and forego its right to transmit a frame until again instructed or invited as above.

The secondary station thus recognizes the following sequence before transmitting a response frame.

Poll Frame	Any Bit Stream (Not GA)	GA Sequence

where:

a) The Poll Frame is a command frame which requires or invites the station to transmit a frame.

b) "Any Bit Stream" may be generated by up-loop secondary stations; that is, stations situated on the loop such that they receive (and generate) bit sequences before these sequences are received by the station in question.

c) The GA sequence is created by secondary stations when they resume their repeater function after sending their last frame.

4.12.4 Loop Secondary Frame Formats

Secondary stations on a loop format frames when they are transmitting as follows:

Received:	0 1 1 1 1 1 1 1 (GA Sequence)
Transmitted:	0 1 1 1 1 1 1 0 (Opening Flag)

The secondary is in a repeating mode before and until it receives a complete GA sequence. In this mode, all received sequences from the up-loop side are relayed to the down-loop transmitter. While repeating, some amount of logical transit delay is necessary because of the requirement that the secondary inspect and withhold the GA sequence when it wants to send a frame. This transit delay is equivalent to a propagation delay through each repeating secondary.

It is desirable that the logical transit delay be only one bit time in order to achieve highest efficiency. In no case will this delay exceed 8 bit times.

The secondary station always transmits a closing flag following the last frame it transmits and prior to relaying the GA sequence.

Secondaries are permitted to generate interframe time-fill after changing the GA sequence to a flag and between consecutive frames sent by a given station.

Once a secondary station recognizes a GA sequence and begins transmitting, it does not depend upon receiving steady one bits on its up-loop side as a condition for continuing transmission.

5.0 ELEMENTS OF PROCEDURE

This section defines the elements of procedure which represent the building blocks of CDCCP. The elements of procedure emply the basic frame structure delineated in Section 4.

Using these common elements, various classes of control procedures which meet requirements of various application situations can be constructed. Classes of control procedures are discussed in Section 6.

5.1 Operational Modes

CDCCP defines two primary operational modes. These are the Normal Response Mode (NRM) and the Asynchronous Response Mode (ARM).

5.1.1 Normal Response Mode (NRM)

NRM is an operational mode in which a Secondary station may initiate transmission only as the result of receiving explicit permission to do so from the Primary station. Explicit permission is defined as transmission by the Primary of a command frame with the Poll bit set to 1. After receiving permission, the Secondary shall initiate a response transmission. The response transmission may consist of one or more contiguous frames. The last frame of the transmission will be explicitly indicated by the Secondary by means of a Final bit set to 1. Following transmission of the last frame, the Secondary will stop transmitting until explicit permission is again received from the Primary.

5.1.2 Asynchronous Response Mode (ARM)

ARM is an operational mode in which a Secondary may initiate transmission without receiving explicit permission from the Primary. Such an asynchronous transmission may contain single or multiple frames and is used for information field transfer and/or status changes in the Secondary. Examples of status changes are the number of the next expected frame, change from a ready to a busy condition or vice versa, or establishment of an exception condition.

In ARM, a Secondary will transmit a frame with a Final bit set to 1 only in response to a received command frame with the Poll bit set to 1. Additional response frames may be transmitted following the frame which has the Final bit set to 1.

Should a Secondary on a FDX link be in the process of transmitting when a command with the Poll bit set to 1 is received, the Final bit will be set to 1 in the earliest possible subsequent frame to be transmitted.

5.1.3 Secondary Response Queuing

Secondary stations do not queue sequential responses for command frames received. In the operational defined above the Secondary response to received command frames is predicated on station status at that time, any exception condition previously established, or the previous receipt of a command which requires a specific response format. In the event a Secondary has no information field to send, the response shall be a single supervisory or unnumbered response frame.

5.2 Transmission Formats

The three control field formats introduced in Paragraph 4.4.2 and illustrated in Figure 4-3 are used to perform information transfer, basic supervisory control functions, and special or infrequent control functions.

5.2.1 Information Transfer Format (I)

The I format is used to perform an information transfer. It is the only format which may contain an information field. The functions of sequence counts and poll/final bit are independent, that is, each frame has a transmit send sequence count, the receive sequence count may or may not acknowledge additional frames at the receiving station, and the P/F bit may or may not be set to 1.

5.2.2 Supervisory Format (S)

The S format is used to perform link supervisory control functions such as to acknowledge information frames, to request retransmission of information frames, or to indicate temporary interruption of receive capability.

5.2.3 Unnumbered Format (U)

The U format is used to provide additional Primary and Secondary link control functions. This format contains no sequence numbers. As a result, 5 modifier bit positions are available which allow definition of up to 32 additional supervisory functions.

5.3 Transmission Parameters

The parameters associated with the three transmission formats are described in the following paragraphs.

5.3.1 Sequence Number Modulus

Each information frame is sequentially numbered and may have the value 0 through modulus minus 1 (where modulus is the modulus of the sequence numbers). Modulus equals 8 for the unextended control field, and the sequence numbers cycle through the entire range. See Paragraph 4.4.3 for a description of the extended control field modulus.

The maximum number of sequentially numbered information format frames that the Primary or Secondary may have outstanding (i.e., unacknowledged) at any given time may never exceed one less than the MODULUS of the sequence numbers. This restriction is to prevent any ambiguity in the association of transmission frames with sequence numbers during normal operation and/or error recovery action. In most cases, the number of outstanding frames is further restricted by the station storage capability; e.g., the number of information response frames that can be stored for transmission and/or retransmission in the event of a transmission error.

5.3.2 Frame Variables and Sequence Numbers

In CDCCP operation, each station maintains a separate (independent) Send Sequence Number N (S) and a Receive Sequence Number N (R) on the information frames it sends and receives. Each Secondary station then maintains an N (S) count on the information format frames it transmits to the Primary, and an N (R) count on the information format frames it has correctly received from the Primary. In the same manner, the Primary maintains separate N (S) and N (R) counts for information format frames sent to and received from each Secondary on the link.

5.3.3 Send State Variable - S

A Primary station and all Secondary stations capable of receiving information format frames have a state variable, S, which denotes the sequence number of the next in sequence information frame to be transmitted. S can take on the value 0 through MODULUS -1 (where MODULUS is the modulus of the sequence numbering scheme and the numbers cycle through the entire range). The value of S is incremented by one with each successive information format frame transmission, but cannot exceed N (R) of the last received frame by more than MODULUS -1.

5.3.4 Send Sequence Number N (S)

Only information frames contain N (S), the send sequence number of transmitted frames. Prior to transmission of an in-sequence information format frame, the value of N (S) is updated to equal the value of the Send State Variable S. The N (S) field comprises bits 2 thru 4 of the basic mode and bits 2 thru 8 of the first octet of the extended mode control field of all information transfer frames.

5.3.5 Receive State Variable - R

A Primary station and all Secondary stations capable of receiving information format frames have a state variable, R, which denotes the sequence number of the next in sequence information frame to be received. R can take on the values 0 through MODULUS -1 (where MODULUS is the modulus of the sequence numbering scheme and the numbers cycle through the entire range). The value of R is incremented by the receipt of an error free in-sequence information frame whose send sequence number N (S), equals R.

5.3.6 Receive Sequence Number N (R)

All information frames, supervisory command and supervisory response frames contain N (R), the expected sequence number of the next received frame. Prior to transmission or retransmission of a frame of the above three types, the value of N (R) is updated to equal the current value of the Receive State Variable R. N (R) indicates that the station transmitting the N (R) has correctly received all information format frames numbered up to N (R) -1. The N (R) field comprises bits 6 thru 8 of the basic mode and bits 2 thru 8 of the second octet of the extended mode control field of all information transfer and supervisory format frames.

5.4 Poll/Final (P/F) Bit

The Poll/Final (P/F) bit serves a function in both command and receive frames. In command frames, it is referred to as the P bit. In response frames, it is referred to as the F bit. In both cases, the bit is set to 1.

The P/F bit is located in bit 5 of the basic mode control field and in bit 1 of the second octet of the extended mode control field. It is used in all three transmission formats.

5.4.1 Poll Bit Functions

The P bit is used by a Primary to solicit a response or sequence of responses from Secondaries.

In NRM, the P bit is set to 1 when the Primary desires to solicit information frames from a Secondary or solicit supervisory or unnumbered responses from a Secondary. In NRM, the Secondary cannot transmit until a command frame with a P bit is received.

The Primary can solicit information frames by sending an information frame with a P bit or by sending certain supervisory frames with a P bit. The Primary can also restrict the Secondary from transmitting information frames by sending a "receive not ready" supervisory frame with a P bit.

In ARM, the P bit is not used to solicit information frames since these can be transmitted by the Secondary on an asynchronous basis. The P bit may, however, be used to solicit supervisory or unnumbered responses. For example, if the Primary wants to get positive acknowledgment that a particular command was received, it may set the P bit in the command. This will force a response from the Secondary as described in Paragraph 5.4.2.

5.4.2 Final Bit Functions

The F bit is used only by a Secondary and only to respond to a P bit received from a Primary.

In NRM, the Secondary is required to set the F bit to 1 in the last frame of its response which may consist of one or more frames. Following the transmission of a frame with the F bit set to 1, the Secondary must halt transmission until a command frame with a P bit set to 1 is received.

In ARM the Secondary is required to transmit a response frame with the F bit set to 1 in response to a P bit but is not required to halt transmission. The F bit shall be sent at the earliest opportunity as a function of link configuration, i.e., TWA or TWS. Since additional frames may be transmitted by a Secondary in ARM following an F bit response, the F bit is not to be interpreted by the Primary as the end of transmission. It simply serves to finalize the response to the Primary command frame with the P bit set.

5.4.3 Checkpointing

Since P and F bits are exchanged on a one for one basis and only one P bit can be outstanding at a time, the N (R) count of a frame containing a P or F bit set to 1 can be used to detect I frame sequence errors. This capability is referred to as checkpointing and can be used not only to detect frame sequence errors but to indicate the frame sequence number to begin retransmission.

In NRM the N (R) count of a received frame which has the P or F bit set to 1 shall initiate retransmission if the N (R) does not acknowledge at least all I frames transmitted previous to and/or concurrent with the last frame which was transmitted with the P or F bit set to 1. In all cases the N (R) count of a correctly received I or S format frame shall confirm previously transmitted I frames through N (R) -1.

In ARM the N (R) count of a received frame which has the P or F bit set to 1 shall cause the receiver to initiate retransmission if the N (R) does not acknowledge at least all I frames transmitted previous to and/or concurrent with the last frame which was transmitted with the P or F bit set to 1.

5.4.4 Poll/Final Bit Summary

The figure below summarizes the applicability of P/F functions in the two operational modes NRM and ARM and on two-way alternate (TWA) and two-way simultaneous (TWS) links.

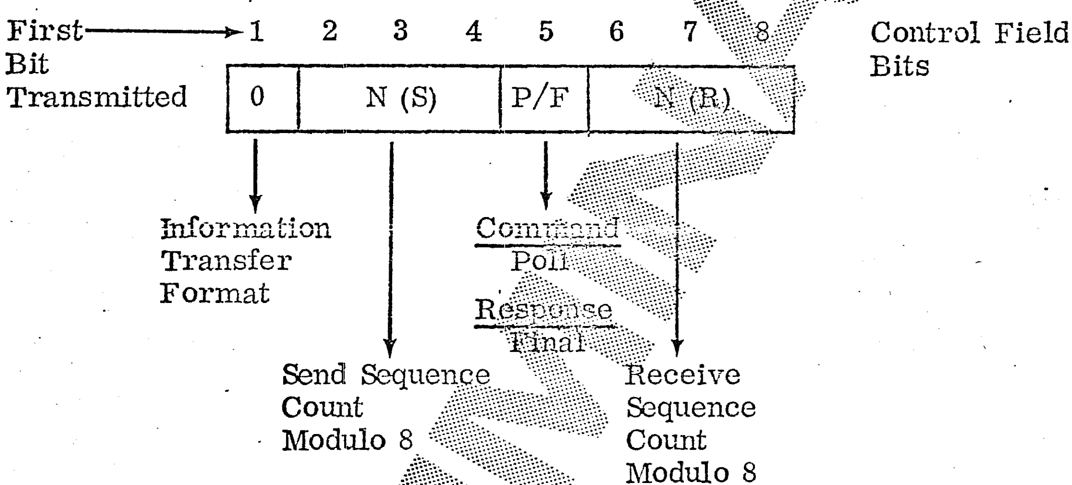
OPERATIONAL MODE	NRM				ARM			
LINK CONFIGURATION	TWA		TWS		TWA		TWS	
P/R BIT IN COMMAND/RESPONSE	P	F	P	F	P	F	P	F
Solicit Information	X		X					
Last Frame Indication	X	X		X				
Solicit Supervisor or Unnumbered Responses	X		X		X		X	
Checkpointing	X	X	X	X	X	X	X	X

5.5 Commands and Responses

The following paragraphs define in detail each of the set of commands and responses used in each of the three transmission formats. Table 5-1 summarizes these commands and responses.

5.5.1 Information Transfer (I) Format Command and Response

The function of the Information Transfer command and response is to transfer sequentially numbered frames containing an information field across a data link. The I command and response control field is encoded as follows:



Bit 1 of the I control field is always zero and identifies this frame as an I frame.

The Information format control field contains two sequence numbers. Bits 2, 3, and 4 comprise N (S), the send sequence count which indicates the sequence number associated with this information frame. Bits 6, 7, and 8 comprise N (R), the receive sequence count which indicates the sequence number of the next expected information format frame to be received. The N (R) implicitly acknowledges correct receipt of information frames numbered up to N (R) -1.

FORMAT	COMMANDS	RESPONSES
Information	I - Information	I - Information
Supervisory	RR - Receive Ready	RR - Receive Ready
	RNR - Receive Not Ready	RNR - Receive Not Ready
	REJ - Reject	REJ - Reject
	SREJ - Selective Reject	SREJ - Selective Reject
Unnumbered	SNRM - Set Normal Response Mode	
	SARM - Set Asynchronous Response Mode	
	DISC - Disconnect	
	RSPR - Response Reject	
	SNRME - Set Normal Response Mode Extended	
	SARME - Set Asynchronous Response Mode Extended	
	NSI -	NSI -
	SIM -	
	ORP -	
		UA - Unnumbered Acknowledge
		CMDR - Command Reject
		RQI -
		ROL -

TABLE 5-1. COMMAND/RESPONSE SUMMARY

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	RNR - Receive Not Ready	RNR - Receive Not Ready
	REJ - Reject	REJ - Reject
	SREJ - Selective Reject	SREJ - Selective Reject
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	SARM - Set Asynchronous Response Mode	
	DISC - Disconnect	
	RSPR - Response Reject	
	SNRME - Set Normal Response Mode Extended	
	SARME - Set Asynchronous Response Mode Extended	
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	ORP -	
		UA - Unnumbered Acknowledge
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	RNR - Receive Not Ready	RNR - Receive Not Ready
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	SREJ - Selective Reject	SREJ - Selective Reject
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	SARM - Set Asynchronous Response Mode	
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	RSPR - Response Reject	
	SNRME - Set Normal Response Mode Extended	
	SARME - Set Asynchronous Response Mode Extended	
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	SREJ - Selective Reject	SREJ - Selective Reject
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	DISC - Disconnect	
	RSPR - Response Reject	
	SNRME - Set Normal Response Mode Extended	
	SARME - Set Asynchronous Response Mode Extended	
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	SREJ – Selective Reject	SREJ – Selective Reject
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	SARM – Set Asynchronous Response Mode	
	DISC – Disconnect	
	RSPR – Response Reject	
	SNRME – Set Normal Response Mode Extended	
	SARME – Set Asynchronous Response Mode Extended	
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	SNRME - Set Normal Response Mode Extended	
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	REJ - Reject	REJ - Reject
	SREJ - Selective Reject	SREJ - Selective Reject
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	SARM - Set Asynchronous Response Mode	
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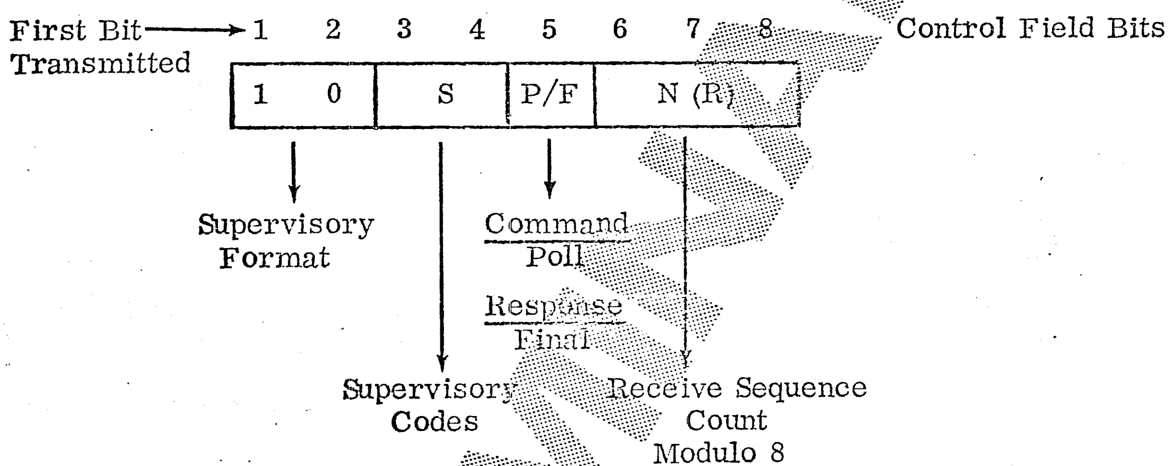
	RSPR - Response Reject	
	SNRME - Set Normal Response Mode Extended	
	SARME - Set Asynchronous Response Mode Extended	
	NSI -	NSI -
	SIM -	
	ORP -	
		UA - Unnumbered Acknowledge
		CMDR - Command Reject
		RQI -
		ROL -

TABLE 5-1. COMMAND/RESPONSE SUMMARY

Bit 5 is the Poll/Final bit which functions as described in Paragraph 5.4.

5.4.2 Supervisory (S) Commands and Responses

Supervisory format commands and responses are used to perform basic link supervisory control functions such as acknowledgment, polling, and error recovery. Frames with the supervisory format shall not contain an information field and therefore do not increment the sequence counts at either the transmitter or the receiver. The Supervisory command and response control fields are encoded as follows:



Bits 1 and 2 of the S control field identify the frame as an S Frame.

Bit 5 is the Poll/Final bit which functions as described in Paragraph 5.4.

Bits 6, 7, and 8 comprise the N (R), receive sequence count, which indicates the sequence number of the next expected information format frame to be received. It also implicitly acknowledges correct receipt of information frames numbered up to and including N (R) -1.

Bits 3 and 4 of the S control field define the supervisory function and are encoded as follows for both command and response frames:

Bit	3	4	Command/Response
	0	0	RR - Receive Ready
	0	1	REJ - Reject
	1	0	RNR - Receive Not Ready
	1	1	SREJ - Selective Reject

The following paragraphs delineate each of these commands and responses.

5.5.2.1 Receive Ready (RR) - Command and Response

The Receive Ready (RR) supervisory frame is used by the Primary or Secondary to indicate that it is ready to receive an information frame and to acknowledge previously received information frames numbered up to and including N (R) -1.

A Primary may use the RR command with the Poll bit set to 1 to solicit responses from, i.e., "poll", Secondary stations.

5.5.2.2 Reject (REJ) Command and Response

The Reject (REJ) supervisory frame is used by the Primary or Secondary to request retransmission of information format frames starting with the frame numbered N (R). Information format frames numbered N (R) -1 and below are acknowledged. Additional I frames pending initial transmission may be transmitted following the retransmitted I frame(s).

Only one REJ exception condition, from a given station to another station, may be established at any given time; another REJ or SREJ may not be actioned until the first REJ exception condition has been cleared.

The REJ exception condition is cleared (reset) upon the receipt of an I frame with an N (S) count equal to the N (R) of the REJ command/response.

See Section 7 for sequence error recovery protocols.

5.5.2.3 Receive Not Ready (RNR) Command and Response

The Receive Not Ready (RNR) Supervisory frame is used by the Primary or Secondary to indicate temporary inability to accept additional incoming information format frames. Information format frames numbered up to and including N (R) -1 are acknowledged; information frame N (R) and any subsequent information format frames received, if any, are not acknowledged.

A station receiving an RNR frame when in the process of transmitting (i.e., a FDX station) is to stop transmitting at the earliest possible time by completing or aborting the frame in process.

The Primary station may use the RNR command with the Poll bit set to "1" to obtain the receive status of a Secondary station. The Secondary response will be either RR or RNR with the Final bit set to "1".

5.5.2.4 Selective Reject (SREJ) Command and Response

The Selective Reject, SREJ, Supervisory frame is used by the Primary or Secondary to request retransmission of the single information numbered N (R).

Information format frames numbered through N (R) -1 and below are acknowledged. Once a SREJ has been transmitted the only I frames accepted are those which are numbered contiguously and in sequence following the I frame requested and the specific retransmitted I frame indicated by the N (R) in the SREJ command/response.

The SREJ exception condition is cleared (reset) upon receipt of an I frame with an N (S) count equal to the N (R) of the SREJ command/response.

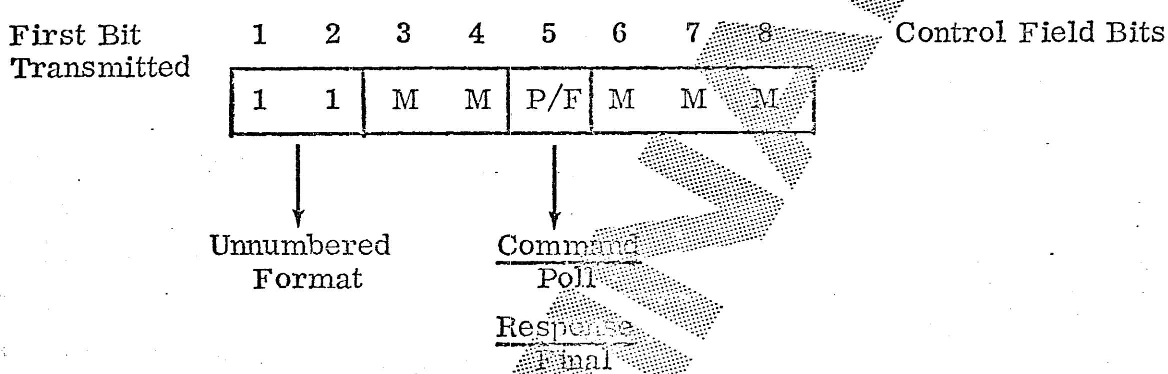
After a station transmits a SREJ it may not transmit SREJ or REJ for an additional sequence error until the first SREJ error condition has been cleared. (To do so would acknowledge as correctly received all frames up to N (R) -1, where N (R) is the sequence number in the second SREJ or REJ).

I frames that may have been transmitted following the I frame indicated by the SREJ command/response are not retransmitted as the result of receiving a SREJ. Additional I frames pending initial transmission may be transmitted following the retransmission of the specified I frame requested by the SREJ.

See Section 7 for sequence error recovery protocols.

5.5.3 Unnumbered (U) Commands and Responses

The Unnumbered (U) format commands and responses are used by the Primary and Secondary to extend the number of link supervisory functions. Frames transmitted with the unnumbered format do not increment the Send Sequence counts N (S) at either the transmitting or receiving station. Five modifier bits are defined which allow up to 32 additional supervisory functions. Of these 10 are defined. The remaining combinations are reserved for future assignment. The Unnumbered command and response control field is encoded as follows:



Bits 1 and 2 of the U format control field identify the frame as a U frame.

Bit 5 is the Poll/Final bit which functions as described in Paragraph 5.4.

Bits 3, 4, 6, 7, and 8 are the modifier bits and are encoded as shown in Table 5-2.

Each of these commands and responses is detailed in the following paragraphs.

BITS					DEFINITION	USED AS	
3	4	6	7	8		Command	Response
0	0	0	0	0	NSI - Non Sequenced Information Frame	X	X
0	0	0	0	1	SNRM - Set Normal Response Mode	X	
0	0	0	1	0	DISC - Disconnect	X	
0	0	1	0	0	ORP - Optional Response Poll	X	
0	0	1	1	0	UA - Unnumbered Acknowledge		X
1	0	0	0	0	SIM - Set Initialization Mode	X	
					RQI - Request for Initialization		X
1	0	0	0	1	RSPR - Response Reject	X	
					CMDR - Command Reject		X
1	1	0	0	0	SARM - Set Asynchronous Response Mode	X	
					ROL - Request Online		X
1	1	0	1	0	SARME - Set ARM Extended	X	
1	1	0	1	1	SNRME - Set NRM Extended	X	
All Others					Reserved For Future Assignment		

TABLE 5-2. UNNUMBERED FORMAT - MODIFIER BIT ENCODING

5.5.3.1 Non Sequenced Information (NSI) - Command and Response

The Non Sequenced Information frame is used to convey non sequenced information to the Secondary (Command) or from the Secondary to the Primary (Response). An NSI frame is not acknowledged.

5.5.3.2 Set Normal Response Mode (SNRM) Command

The SNRM command is used to place the addressed Secondary station in the Normal Response Mode (NRM) where all control fields are one octet in length. No information is permitted with the SNRM command.

The Secondary station confirms acceptance of SNRM by transmission of an Unnumbered Acknowledge (UA). Upon acceptance of this command the Secondary station send and receive counts are set to zero.

Previously transmitted frames that are unacknowledged when this command is actioned remain unacknowledged.

5.5.3.3 Disconnect (DISC) Command

The DISC command is used in switched networks to perform a physical disconnect; i.e., cause the addressed station to go "on-hook". It is also used in non-switched networks to perform a logical disconnect; i.e., inform stations that the Primary is suspending operation with that Secondary station. No information field is permitted with the DISC command. Prior to actioning the command the Secondary confirms acceptance of DISC by the transmission of a Non- Sequenced, NSA. Upon actioning this command the Secondary station is placed in the unextended (i.e., single octet) control field mode.

Previously transmitted frames that are unacknowledged when this command is actioned remain unacknowledged.

5.5.3.4 Optional Response Poll (ORP) Command

An Optional Response Poll command is used to solicit transmission from the addressed Secondary station. An I field is not permitted in an ORP frame.

5.5.3.5 Unnumbered Acknowledge (UA) Response

The Unnumbered Acknowledge response is used by a Secondary to acknowledge receipt and acceptance of an unnumbered command. The UA response is transmitted in the normal or extended control field format as directed by the received unnumbered command. No information (I) field is permitted with the UA response.

5.5.3.6 Set Initialization Mode (SIM) Command

The SIM command is used to initiate system specified link level initialization procedures at the Secondary station. The expected response is UA. Both Primary and Secondary N (R) and N (S) counts are reset to zero.

5.5.3.7 Request for Initialization (RQI) Response

An RQI is transmitted by a Secondary to notify the Primary of the need for a SIM command. The receipt of command except a SIM will cause the Secondary to repeat the RQI.

5.5.3.8 Response Reject (RSPR) Command

The RSPR command is used by the Primary station to report that one of the following conditions resulted from the receipt of an error free frame from the Secondary station.

- The receipt of a response that is invalid or not implemented.

- The receipt of a response having an I frame with an Information field which exceeded the size of the buffer available.

- The receipt of a response frame having an invalid N (R) count. (See 5.5.3.9 for definition of an invalid N (R) count).

A Status field is returned with this command to provide the reason for the Response Reject, RSPR. Refer to Section 5.5.3.9 for the size and content of the Status field and Extended Status field except substitute "response reject" for "command reject" and "Primary station" for "Secondary station".

5.5.3.9 Command Reject (CMDR) Response

The CMDR is used by a Secondary to report that one of the following conditions resulted from the receipt of an error free frame from the Primary.

- The receipt of a command that is invalid or not implemented.

- The receipt of an I frame with an I field which exceeded the size of the buffer available.

- The receipt of an invalid N (R) count from the Primary. An invalid N (R) is defined as a count which points to an I frame which has previously been transmitted and acknowledged or to an I frame which has not been transmitted and is not the next sequential I frame pending transmission.

A status field is returned with a CMDR to provide the reason for issuance of the CMDR. The status field contains the following fields and information.

First Bit Transmitted	1 2 3 4 5 6 7 8	9	10 11 12	13	14 15 16	17	18	19	20	Status Field Bits
	Rejected Control Field	0	N (S)	0	N (R)	w	x	y	z	

where:

Rejected Command Control Field is the control field of the received frame which caused the Command Reject.

N (S) is the current Send Sequence Variable value at the Secondary.

N (R) is the current Receive Sequence Variable value at the Secondary.

w set to "1" indicates the control field received and returned in bits 1 through 8 was invalid or not implemented.

x set to "1" indicates the control field received and returned in bits 1 through 8 was considered invalid because the frame contained an information field which is not permitted with this command. Bit w must be set to "1" in conjunction with this bit.

y set to "1" indicates the information field received exceeded the buffering available at the Secondary. This bit is mutually exclusive with bit w above.

z set to "1" indicates the control field received and returned in bits 1 through 8 contained an invalid N (R) count. This bit is mutually exclusive with bit w above.

An all zero information field (including w, x, y, and z all equal to zero) indicates an unspecified rejection of the command.

If required the information field contained with the CMDR may be padded with zero bits to provide a modulo of the character width being used.

The format for the status field returned with the CMDR response is as follows when Control Field Extension (see Section 4.4.3) is used:

← STATUS FIELD BITS →

1 16	17	18 [illegible]	25	26 32	33			36
Rejected Extended Command Control Field	0	N (S)	0	N (R)	w	x	y	z

5.5.3.10 Set Asynchronous Response Mode (SARM) Command

The SARM command is used to place the addressed Secondary station in an Asynchronous Response Mode (ARM) where all control fields are one octet in length. No information field is permitted with the SARM command.

The Secondary confirms acceptance of SARM by the transmission of an Unnumbered Acknowledge (UA). Upon acceptance of this command the Secondary station send and receive sequence counts are set to zero.

Previously transmitted frames that are unacknowledged when this command is actioned remain unacknowledged.

5.5.3.11 Request Online (ROL) Response

ROL is transmitted by a Secondary to indicate that it is disconnected.

5.5.3.12 Set NRM Extended (SNRME) Command

The SNRME command is used to place the addressed Secondary station in the Normal Response Mode Extended (NRME) where all control fields will be two octets in length as defined in Section 4.4.3. The Secondary station confirms acceptance of SNRME by transmission of a Non-Sequenced Acknowledge, NSA response. Upon acceptance of this command the Secondary send and receive counts are set to zero.

Previously transmitted frames that are unacknowledged when this command is actioned remain unacknowledged.

5.5.3.13 Set ARM Extended (SARME) Command

The SARME command is used to place the addressed Secondary station in the Asynchronous Response Mode Extended (ARME).

5.6 Timers and Retry Counts

5.6.1 Primary NRM Response Timeout

In order for the primary to detect a no response or lost response condition, each primary must provide a response timeout function.

In NRM, this timer is started whenever a command frame with the P bit set to "1" is transmitted. The timer is restarted upon receipt of an error free frame with the F bit set to "0" and is stopped upon receipt of an error free frame with the F bit set to "1". No more than one P bit may be outstanding at one time. Should the timer expire, appropriate higher level action shall be initiated.

The duration of the timer is a function of frame length and link characteristics. It is therefore system dependent and subject to bi-lateral agreement.

5.6.2 Primary ARM - Response Timeout

This timer is the ARM equivalent of the Primary NRM timer. The difference is that in TWS, the timer is not restarted. In TWA the timer is restarted upon transmission of each frame until the link is relinquished by the primary going to idle state.

5.6.3 Secondary ARM - Command Timeout

In ARM each secondary must provide a command timeout in order to detect a no command or lost command condition.

This timer is started with the transmission of an I frame. It is restarted in TWA with the transmission of each frame until the link is relinquished by the secondary going to idle state. In TWS, the timer is never restarted. The timer is stopped by the receipt of an error free frame containing the expected N (R). Expiration of the timer shall initiate appropriate higher level recovery action.

The duration of the timer is system dependent and subject to bi-lateral agreement.

5.6.4 Idle Timer

The detection of an idle link condition may require the use of a timer to detect receipt of a "continuous ones" condition for 15 bit times if the facility does not provide clock signals in an idle condition.

5.6.5 Retry Counts

Each station should include a retry counter to control the number of retransmissions resulting from timeouts. The types of action which should be retried are attempts to initialize a station, resume communication with a busy station, and obtain acknowledgment of a command. The number of retries is system dependent and subject to bi-lateral agreement. The counter would normally be set to a value "n". If n plus one is reached the condition is reported to higher level as unrecoverable at link level.

6.0 EXCEPTION CONDITION REPORTING AND RECOVERY

This section describes the recovery procedures which are available to effect recovery following the detection/occurrence of an exception condition at the link level. Exception conditions described are those situations that may occur as the result of transmission errors, station malfunction or operational situations.

For each exception condition, a description of the cause, the procedure to be followed upon detection, and recovery from the condition are described.

6.1 Busy Condition

A busy condition occurs when a station temporarily cannot receive or continue to receive Information frames due to internal constraints, e.g., receive buffering limitations. A station in a busy condition will discard incoming sequenced or non-sequenced information frames.

The "busy" condition is reported by transmission of an RNR frame with the N (R) number of the first information frame that is expected. Traffic pending transmission may be transmitted prior to or following the RNR. The continued existence of a busy condition must be reported by retransmission of RNR at each P/F frame exchange.

A Secondary transmitting in NRM will upon receipt of an RNR cease transmission at the earliest possible time. The frame in process may be completed or aborted, however transmission must be terminated in the usual manner; i.e., either ended with a frame with the F bit set to "1" (see example, Appendix D) or going to the Idle Link State. The Secondary may resume transmission of I frames at the next poll command (an RR, REJ, SREJ, or I command frame with the P bit set to "1").

A Secondary transmitting in ARM will, upon receipt of an RNR, cease transmitting at the earliest possible time by completing or aborting the frame in process and going to the Idle Link State. If the RNR command frame had the P bit set to "1" the Secondary must transmit a frame with the F bit set to "1" before going to the Idle Link State. See examples in Appendix D. The Secondary must perform a Response/Command Timeout before resuming asynchronous transmission.

The busy condition is cleared at the station which transmitted the RNR when the internal constraint ceases.

Clearance of the busy condition is reported to the remote station by transmission of an RR, REJ, or SREJ frame (with or without the P/F bit set to "1"), or by transmitting an I frame with the P/F bit set to "1".

6.2 N (S) Sequence Error

An N (S) sequence exception is established in the receiving station when an Information frame received error free (no FCS error) contains an N (S) sequence number that does not agree with the stations N (R) sequence number. The receiving station does not acknowledge (increment its N (R) number) the frame causing the sequence error or any I frames which may follow until an Information frame with the correct N (S) number is received.

A station which receives one or more valid frames having sequence errors but otherwise error free will accept the control information contained in the N (R) number and the P/F bit to perform link control functions; e.g., to receive acknowledgment of previously transmitted information frames (via the N (R) number), to cause a Secondary station to respond (P bit set to "1"), and in NRM to detect that the Secondary will terminate transmission (F bit set to "1").

Following the detection of a sequence error, one of three recovery procedures is implemented to achieve recovery. These are:

a) REJ Recovery
b) Poll/Final Recovery
c) SREJ/REJ Recovery

Which of the recovery procedures is used is a function of whether SREJ is implemented by a given secondary; and, in the case of REJ vs Poll/Final recovery, largely a matter of system choice and efficiency. The REJ recovery procedure is more efficient especially on TWS links. The Poll/Final Recovery is always a poll-back recovery scheme should the REJ be errored in transmission.

.2.1 REJ Recovery

The REJ command/response is primarily used to initiate more timely exception recovery (retransmission) following the detection of a sequence error than is possible by Poll/Final recovery; e.g., in FDX information transfer if REJ is immediately transmitted upon detection of a sequence error there is not requirement to wait for a Poll/Final frame exchange. See examples in Appendix D.

Only one REJ exception condition is established at any given time and the REJ command/response may be transmitted only one time.

A station receiving REJ initiates retransmission of I frames starting with the I frame indicated by the N (R) number contained in the REJ frame.

The REJ exception condition is cleared (reset) upon the receipt of an I frame with a N (S) number equal to the N (R) number of the REJ command/response.

6.2.2 Poll/Final Recovery

If, following a sequence error, the REJ command/response is not received (i.e., either not transmitted or due to transmission errors) recovery is initiated by P/F bit exchange. Following the exchange of Poll/Final frames, sequential transmission of Information frames (if available) is initiated starting with any previously transmitted but unacknowledged I frames or, if none, starting with additional I frames not previously transmitted. See examples in Appendix D. A station which has received and actioned a REJ prior to or concurrent with the receipt of a Poll/Final frame will not additionally initiate Poll/Final recovery.

6.2.3 SREJ/REJ Recovery

The SREJ command/response is primarily used to initiate more efficient error recovery by requesting the retransmission of a single information frame following the detection of a sequence error rather than the retransmission of the frame requested plus all additional frames which may have been subsequently transmitted. To improve transmission efficiency, it is recommended that the SREJ command/response be transmitted as the result of the detection of a sequence error where only a single I frame is missing (as determined by receipt of the out-of-sequence N (S) number).

6.2.3.1 SREJ Recovery

When a frame sequence error is detected the SREJ is transmitted at the earliest possible time. Although multiple SREJ (or multiple SREJ and one REJ) exception conditions may exist within a station, only one exception recovery is actioned at any given time; i.e., after a station starts the SREJ recovery procedure it may not begin a second SREJ or a REJ recovery procedure until the first error condition has been cleared. For a given error condition the SREJ command/response is transmitted only one time in each Poll/Final frame exchange.

The SREJ exception condition being actioned is cleared (reset) upon the receipt of an I frame with an N (S) number equal to the N (R) of the SREJ command/response, i.e., the missing I frame.

See examples in Appendix D.

6.2.3.2 REJ Recovery

In the event the sequence error is caused by two or more sequential frames not being received, as determined by the received N (S) numbers, it is recommended that the REJ command/response be transmitted.

Only one REJ exception condition is established at any given time. (Note that there may be one or more SREJ exception conditions pending when the REJ exception condition occurs). A station receiving REJ initiates retransmission of I frames starting with I frame indicated by the N (R) number contained in the REJ frame.

The REJ exception condition is cleared (reset) upon the receipt of an I frame with an N (S) number equal to the N (R) of the REJ command/response.

6.2.3.3 Retransmission of SREJ or REJ

In the event the SREJ or REJ command/response is transmitted but not received by the remote station (i.e., due to a transmission error) it must be retransmitted following detection that it was not received. This detection will occur either at the exchange of P/F bit frames (as described below) or by a Response/Command Timeout. In either case the SREJ or REJ command/response is retransmitted so that the proper recovery action may be executed.

For example, in the case where a SREJ (or REJ) is transmitted by a Secondary but is not received correctly by the Primary, the Secondary senses the SREJ (or REJ) must be retransmitted when, following transmission of a response frame with Final bit set to "1" concurrent with or after the SREJ (or REJ), the requested frame(s) is not received by the Secondary prior to or concurrent with the receipt of a command frame with the Poll bit set to "1". In other words, since the Secondary transmitted the SREJ (or REJ) concurrent with or before sending the response frame with the Final bit set to "1", then the I frame(s) requested by SREJ (or REJ) should be received prior to or concurrently with the next command frame with Poll bit set to "1".

In like manner if a Primary which has transmitted a SREJ (or REJ) does not receive the requested I frame(s) prior to or concurrent with receiving the response frame with the Final bit set to "1" which is itself in reply to the first command frame with the Poll bit set to "1" concurrent with or following the SREJ, it will retransmit the SREJ (or REJ).

In the event the remote station, due to a transmission error, does not receive (or receives and discards) a single I frame or the last I frame(s) in a sequence of I frames it will not detect an out-of-sequence exception condition and therefore will not transmit SREJ/REJ. The station which transmitted the unacknowledged I frame(s) will, following the completion of a system specified timeout period take appropriate recovery action to determine the point where retransmission must begin.

In the event an SREJ is transmitted but not received (or is received in error and discarded) the station that transmitted the SREJ may convert the SREJ to REJ when again reporting the exception condition (e.g., if additional transmission errors have occurred since the SREJ was first transmitted).

6.3 FCS Error

Any frame received with an FCS error is not accepted by the receiver. The frame is discarded and no action is taken as a result of that frame. Should the frame with an FCS error have been a response frame from the Secondary with the F bit set to "1 , a resulting timeout will occur at the primary prior to initiating recovery action.

6.4 CMDR/RSPR Condition

A CMDR or RSPR exception condition is established upon the receipt of an error-free frame which cannot be actioned by the receiver for any of several reasons including:

a) the frame contains an invalid command or response in the control field.

b) the frame format is invalid.

c) the frame contains an invalid N (R) number.

d) the frame contains an information field which exceeds the stations buffer capability.

At a primary station, receipt of a Command Reject (CMDR) is subject to resolution and recovery at a higher level than link control.

At a secondary station, receipt of a Response Reject (RSPR) is subject to resolution and recovery at a higher level than link control.

The detection of a command reject condition at a secondary station is reported by transmitting a CMDR response to the primary station for action. When a secondary has established a CMDR exception condition, any additional commands received, other than those which clear the CMDR exception condition, are monitored only to detect a respond opportunity to retransmit CMDR. No additional commands are accepted or actioned until the condition is cleared by receipt of a SNRM, SNRME, SARM, SARME, SIM, or DISC command.

6.5 Modulo Count Overflow Condition

A station establishes the modulo count overflow condition when the number of outstanding (unacknowledged) sequenced I frames equals modulo-1.

When this condition occurs the transmission of sequenced I frames is halted. The last I frame transmitted should have the P/F bit set to "1" or should be followed by an RR command or response with the P/F bit set to "1". If the primary experiences the condition the P = 1 will solicit the secondary to send an N (R) acknowledgment which may or may not update the acknowledged frame count. If the secondary encountered the overflow the F = 1 will indicate to the primary that no further I response frames will be forthcoming.

7.0 CLASSES OF PROCEDURE

Procedural differences among applications, based on overall system considerations such as network configuration, recovery procedures, terminal sophistication, etc., are accommodated in CDCCP by defining various classes of procedure. These classes combine the modes of operation (ARM and NRM) and commands and responses of Section 5 with the exception recovery procedures of Section 6. Each class forms an implementation subset of CDCCP procedures. A class is thus characterized as the ability at the primary to receive and action all responses in the prescribed subset and the ability at the secondary to receive and action all commands in the prescribed subset.

All classes of procedure use the frame structure of Section 4. All procedures assume that the links include primary and secondary link controllers. The primary link controller is responsible for control of the link by determining, within the constraints of this standard, which commands to send. Primary link controllers transmit only commands, in frames (with or without data). Secondary link controllers receive the command frames and transmit responses in frames (with or without data).

Illustrative examples of the data link control dialog using different facilities and with various exception conditions are provided in Appendix D.

Table 7-1 summarizes the command and response usage by class for comparison purposes.

COMMANDS AND RESPONSES		CLASSES					
		NB	NS	NAB	NAS	PPB	PPS
COMMANDS	I	X	X	X	X	X	X
	RR	X	X	X	X	X	X
	RNR	X	X	X	X	X	X
	REJ	X	X	X	X	X	X
	SREJ		X		X		X
	SNRM	X	X	X	X		
	SNRM E	*	*	*	*		
	SARM			X	X	X	X
	SARM E			*	*	*	*
	SIM	X	X	X	X		X
	DISC	X	X	X	X	X	X
	UI	X	X	X	X	X	X
	UP	X	X	X	X		X
	XID	X	X	X	X	X	X
	RSPR	X	X	X	X	X	X
RESPONSES	I	X	X	X	X	X	X
	RR	X	X	X	X	X	X
	RNR	X	X	X	X	X	X
	REJ	X	X	X	X	X	X
	SREJ		X		X		X
	DM	X	X	X	X		
	RIM	X	X	X	X		
	UI	X	X	X	X	X	X
	UA	X	X	X	X	X	X
	XID	X	X	X	X	X	X
	CMDR	X	X	X	X	X	X

* Optional

TABLE 7-1

SUMMARY OF COMMAND/RESPONSE IMPLEMENTATION BY CLASS

7.1 Normal Mode - Classes of Procedure

In these classes the secondary station may transmit a frame or frames only as a result of the receipt of an appropriate command frame as described in Section 5.1.1.

7.1.1 Normal Mode - Basic Exception Recovery (Class NB)

Stations operating in this class may use the REJ command/response to solicit retransmission of any frame detected in error. The subsequent retransmission will consist of the frame in error plus any subsequent transmitted frames in accordance with Section 6.0.

The P/F bit recovery procedure is used as a fallback recovery procedure in conjunction with the REJ instruction.

The following commands and responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SNRM (E)	UA
SIM	CMDR
DISC	XID
RSPR	RIM
UP	DM
XID	UI
UI	

7.1.2 Normal Mode - Selective Reject Exception Recovery (Class NS)

Stations operating in the Normal Mode with Selective Reject capability can request retransmission of a single specified information frame without requiring retransmission of previously transmitted following frames as defined in Section 6.0.

The P/F bit recovery procedure is prohibited in this class.

The following commands and responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SREJ	SREJ
SNRM(E)	UA
SIM	CMDR
DISC	XID
RSPR	RIM
UP	DM
XID	UI
UI	

7.2 Normal and Asynchronous Mode - Classes of Procedure

In these classes, in addition to operation in NRM, the primary station can condition secondary stations to transmit frames at any time independent of further action by the primary. This is the ARM mode described in Paragraph 5.1.2.

7.2.1 Normal and Asynchronous Mode - Basic Exception Recovery (Class NAB)

Stations operating in this class may use the REJ command/response to solicit retransmission of any frame detected in error. The resulting retransmission will consist of the frame in error and subsequent transmitted frames.

The following commands and responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SNRM (E)	UA
SARM (E)	CMDR
SIM	XID
DISC	RIM
RSPR	DM
UP	UI
XID	
UI	

7.2.2 Normal and Asynchronous Mode - Selective Reject Exception Recovery (Class NAS)

Stations operating in the Normal Mode with Asynchronous capability and with Selective Reject Operation can request request retransmission of a single, specified information frame as described in Section 6.0.

The P/R bit recovery procedure is prohibited in this class.

The following commands and responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SREJ	SREJ
SNRM (E)	UA
SARM (E)	CMDR
SIM	XID
DISC	RIM
RSPR	DM
UP	UI
XID	
UI	

7.3 Primary to Primary Classes of Procedure

These primary to primary classes of procedures are restricted to point-to-point, full-duplex, switched or non-switched transmission facility. Each station is responsible for control of traffic on its transmit path in the link. Each station is responsible for correction of errors associated with the traffic it originates. Each station can transmit frames at any time independent of action by the other station. Stations operating according to these classes of procedures use Asynchronous Response Mode operation. Each station maintains only one sequence number for all transmitted I frames and only one sequence number for all received I frames.

7.3.1 Primary to Primary Mode - Basic Exception Recovery (Class PPB)

Stations operating in this class use the REJ command/response to solicit retransmission of any frame(s) detected in error. The subsequent retransmission will consist of the frame in error plus any previously transmitted following frames in accordance with Section 6.0.

The P/F bit recovery procedure is used as a fallback recovery procedure in conjunction with the REJ instruction.

The following commands and responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SARM	UA
DISC	CMDR
RSPR	XID
XID	UI
UI	

In this class, SARM and SARME commands reset only the N (S) of the transmitting station and the N (R) of the receiving station.

7.3.2 Primary to Primary Mode - Selective Reject Exception Recovery (Class PPS)

Stations operating in the Primary to Primary Mode with Selective Reject operation can request retransmission of a single, specified information frame without requiring retransmission of previously transmitted following frames, in accordance with Section 6.0.

The P/F bit recovery procedure is prohibited in this class.

The following commands and responses must be implemented in this class:

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SREJ	SREJ
SARM	UA
SIM	CMDR
DISC	XID
RSPR	UI
UP	
XID	
UI	

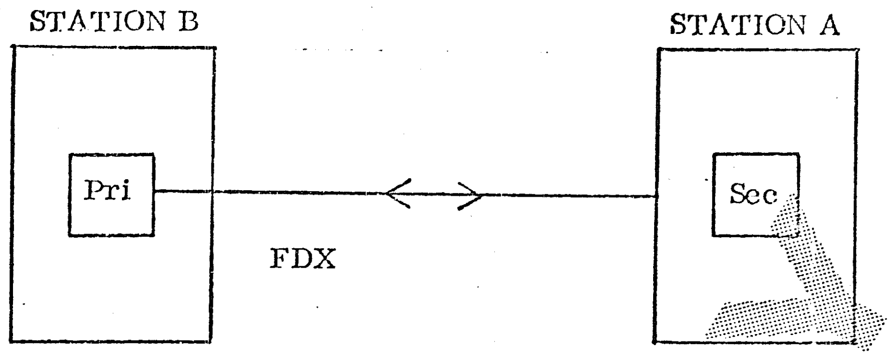
In this class, SARM and SARME commands reset only the N (S) number of the transmitting station and the N (R) number of the receiving station.

7.4 Additional Primary to Primary Modes

Although not specifically defined as classes, it is also possible to operate a balanced or near-balanced primary to primary link using Primary to Secondary classes of procedures. Two examples of such operation are defined in the paragraphs which follow.

7.4.1 Primary/Secondary (ARM) Operation

Paragraphs 7.1 and 7.2 define Primary/Secondary classes of operation that can be used in such a manner so as to provide a capability similar to "Primary/Primary" in which balanced information transfer in ARM is achieved with Primary function required in only one station and Secondary function required in the other.



Balanced information transfer is achieved by virtue of symmetrical functional equivalency of the I, RR, RNR, REJ, SREJ and CMDR/RSPR commands and responses. Only the station designated as Primary, however, has the functional use of the mode setting and DISC commands for resetting or disconnecting logical link functions. The capability offered by this type of operation may indeed be satisfactory and optional for a great many applications envisioned.

The independence of operation at each end of the link with regard to originating information transmission is illustrated in the examples of Appendix D for information frame transmission from Primary only, Secondary only, and simultaneous Primary and Secondary.

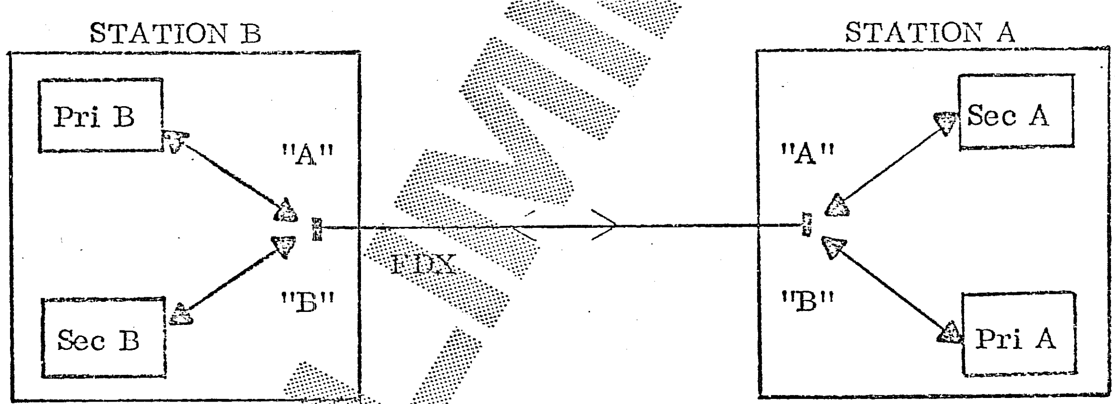
The two-station configuration illustrated above is extendable to a multipoint link configuration; i.e., one Secondary is placed in ARM (and operates point-to-point with the Primary) and all other Secondaries are sent a DISC command. Thus the Primary can perform "Primary/Primary - type" operation with one station at a time.

In case of failure of the 2-way simultaneous link, Primary/Secondary ARM 2-way simultaneous has the ability to substitute a single dial-up line and operate in ARM 2-way alternate.

7.4.2 Back-to-Back Primary/Secondary Operation

For those cases where completely balanced and independent operation is desirable, the capability exists within the definition of Primary/Secondary operation to accomplish a "Primary/Primary" arrangement. This can be done in the following manner.

A Primary and Secondary link control function is required in each station with the use of two address (and associated sequence numbers) to direct transmissions received to either the Primary or Secondary link control function.



Primary A has use of the full repertoire of commands relative to Secondary B and Secondary B has use of the full repertoire of responses relative to Primary A. The same is also applicable between Primary B and Secondary A. Transmissions from Primary A to Secondary B and transmission from Secondary A to Primary B are multiplexed on a frame by frame basis as required in one direction of the FDX facility (i.e., in the figure from right to left). Transmission from Primary B to Secondary A and transmission from Secondary B to Primary A are similarly multiplexed in the other direction (i.e., in the figure from left to right).

By this means, logical interaction between Primary A and Secondary B is independent of the logical interaction between Primary B and Secondary A. There is no procedural restriction that information (data) flow be only from Primary function to Secondary function (i.e., the Secondary function may transmit information frames, see example in Appendix D), although this constraint may be accomplished if desirable in several different ways, e.g., at link level by use of RNR to Poll for non-information responses only (see example in Appendix D) or by prior system agreement that the Secondary never transmit information frames (see example in Appendix D).

Back-to-Back Primary-Secondary operation offers the flexibility of response in that each sublink (one Primary to one Secondary) may optionally be operated in either ARM or NRM; i.e., one Primary-Secondary pair could be operated in ARM, where the Secondary responds asynchronously, and the other Primary-Secondary pair in NRN, where the Secondary only responds when it receives a command frame with the P bit set to "1". The choice of ARM or NRN is a system option; e.g., depends upon whether it is desired to obtain the most immediate Secondary acknowledgment (by using ARM) or to limit the number of Secondary overhead responses (by setting the P bit to "1" only in every nth frame).

APPENDIX A: GLOSSARY

ABORT: A function invoked by a sending (Primary or Secondary) station causing the recipient to discard (and ignore) all bit sequences transmitted by the sender since the preceding Flag Sequence.

ACCEPT: The condition assumed by a (Primary or Secondary) station upon accepting a correctly received Frame for processing.

ADDRESS FIELD (A): The sequence of eight (or any multiple of eight) bits immediately following the Opening Flag of a Frame identifying the Secondary Station sending (or designated to receive) the Frame.

ADDRESS FIELD EXTENSION: Enlarging the address field to include more addressing information.

CDCCP: Control Data Communication Control Procedures

COMMAND: The content of the Control Field, of a Command Frame sent by the Primary instructing the addressed Secondary to perform some specific function.

COMMAND FRAME: All Frames that may be transmitted by the Primary Station are referred to as Command Frames.

CONTROL FIELD (C): The sequence of eight (or sixteen if extended control field) bits immediately following the Address Field of a Frame. The content of the Control Field is interpreted by the receiving:

(a) Secondary, designated by the Address Field, as a Command instructing the performance of some specific function.

(b) Primary, as a Response from the Secondary, designated by the Address Field, to one or more Commands.

CONTROL FIELD EXTENSION: Enlarging the Control Field to include additional control information.

EXCEPTION CONDITION: The condition assumed by a secondary upon receipt of a command which it cannot execute due to either a transmission error or an internal processing malfunction.

FLAG SEQUENCE (F): The unique sequence of eight bits (01111110) employed to delimit the beginning and ending of a Frame.

FRAME: The sequence of contiguous bits, bracketed by and including beginning and ending Flag sequences. A valid Frame contains at least 32 bits between Flags and contains an Address Field, a Control Field, and a Frame Check Sequence. A Frame may or may not include an Information Field.

FRAME CHECK SEQUENCE (FCS): The field, immediately preceding the ending Flag of a Frame, containing the bit sequence that provides for the detection of transmission errors by the receiver.

HIGH LEVEL (HL): The conceptual level of control or processing logic existing in the hierarchical structure of a (Primary or Secondary) station that is above the Link Level and upon which the performance of Link Level functions are dependent, e.g., device control, buffer allocation, station management, etc.

INFORMATION FIELD (INFO): The sequence bits, occurring between the last bit of the Control Field and the first bit of the Frame Check Sequence. The Information Field contents are not interpreted at the Link Level.

INVALID FRAME: A sequence of bits, following the receipt of an apparent beginning Flag Sequence that either:

(a) Is terminated by an Abort Sequence, or

(b) Contains less than 32 bits before an apparent ending Flag Sequence is detected.

LINK LEVEL: The conceptual level of control or processing logic existing in the hierarchical structure of a (Primary or Secondary) station that is responsible for maintaining control of the data link. The Link Level functions provide an interface between the station High Level logic and the data link; these functions include (transmit) bit injection and (receive) bit extraction, Address/Control Field interpretation, Command/Response generation and transmission, and Frame Check Sequence computation and interpretation.

PRIMARY: That portion of the Primary station responsible for control of the data communication link. The Primary generates Commands and interprets Responses. Specific responsibilities assigned to the Primary include:

(a) Initialization of (data and control) information interchange

(b) Organization and control of data flow

(c) Retransmission control

(d) All recovery functions at the Link Level

RESPOND OPPORTUNITY: The Link Level control condition during which a given Secondary may transmit a Response Frame(s).

RESPONSE: The content of the Control Field of a Response Frame advising the Primary with respect to the processing by the secondary of one or more Command Frames.

RESPONSE FRAME: All Frames that may be transmitted by a Secondary Station are referred to as Response Frames.

SECONDARY: That portion of a Secondary station responsible for performing Link Level operations, as instructed by the Primary. A Secondary interprets Commands and generates Responses.

SECONDARY STATUS: The current condition of a Secondary with respect to processing the series of Commands received from the Primary.

BASIC STATUS: A Secondary Station's capability to send or receive a Frame containing an Information Field.

INTER-FRAME TIME FILL: The sequence of bits transmitted between Frames. This standard does not provide for time fill within a Frame.

UNNUMBERED COMMANDS: The commands that do not contain sequence numbers in the Control Field.

UNNUMBERED RESPONSES: The responses that do not contain sequence numbers in the Control Field.

APPENDIX B: THE CDCCP FCS TECHNIQUE

B.0 Frame Check Sequence Generation and Checking

This appendix is intended to provide additional information to those responsible for implementation of the FCS technique described in Section 4.6.

These FCS requirements are formulated to detect frame length changes due to erroneous addition or deletion of zero bits at the end of the frame as well as to detect errors introduced within the frame.

B.1 FCS Generation

The equations for FCS generation are:

$$\frac{X^{16}\ G(X) + X^{\kappa}\ L(X)}{P(X)} = Q(X) + \frac{R(X)}{P(X)} \quad \text{and,}$$

$$FCS = L(X) + R(X) = \overline{R(X)}$$

The division is modulo 2 and,

$$L(X) = X^{15} + X^{14} + X^{13} + X^{12} + X^{11} + X^{10} + X^{9} + X^{8} + X^{7}$$
$$X^{6} + X^{5} + X^{4} + X^{3} + X^{2} + X^{1} + 1,$$

$R(X)$ = The remainder which is of degree less than 16,

κ = The number of bits represented by $G(X)$,

$P(X)$ = The CCITT V.41 generator polynomial $(X^{16} + X^{12} + X^{5} + 1)$, and

G (X) = The message polynomial. It includes the contents of the address, control and information fields, excluding the zero bits inserted for transparency.

The generation of the remainder R (X) differs from that used in conventional check sequence generation by the presence of the X^K L (X) term in the generation equation. When the FCS generation is by the usual shift register technique, the X^K L (X) term is added in either of two ways:

1. Preset the shift register to all ones rather than to all zeros as in conventional generation procedures. Otherwise, shift the data (G (X)) through the register as in conventional procedures, or,

2. Invert the first 16 bits of G (X) before shifting into the register and shift the remaining part of G (X) through uninverted. This requires that G (X) contain at least 16 bits.

Whether 1 or 2 is used, the shift register contents, after shifting through G (X), is R (X). These contents are inverted bit-by-bit and transmitted as the FCS sequence.

The transmitted sequence is always (in algebraic notation):

$$M (X) = X^{16} G (X) + FCS.$$

B.2 FCS Checking

The received sequence will be denoted M* (X), which differs from M (X) if transmission errors are introduced. The checking process always involves dividing the received sequence by P (X) and testing the remainder. Direct division, however, does not yield a unique remainder and it is expected that in most cases the received sequenced will be modified for checking purposes by addition of terms which will cause the division to yield such a unique remainder when M* (X) = M (X), i.e., when the frame is error free.

Two classes of checking equations are given below:

1. $$\frac{X^{\gamma}\ M^*(X) + X^{\kappa}\ L(X)}{P(X)} = Q(X) + \frac{R(X)}{P(X)}$$

In this case the unique remainder is the remainder of the division $X^{\gamma}\ \frac{L(X)}{P(X)}$

When $\gamma = 0$ the remainder is L (X) (16 ones).

When $\gamma = 16$ the remainder is $X^{12} + X^{11} + X^{10} + X^{8} + X^{3} + X^{2} + X + 1$

(0001110100001111 X^{15} through X^{0} respectively)

2. $$\frac{X^{\gamma}\ M^*(X) + (X^{\kappa} + 1)\ L(X)}{P(X)} = Q(X) + \frac{R(X)}{P(X)}$$

In this case the unique remainder is always zero regardless of the value of γ.

Shift register implementation of the above equations normally use $\gamma = 16$ (pre-multiplication). When this is the case, the added term X^{κ} L (X) in both 1 and 2 is added by either inverting the first 16 received bits of M* (X) before shifting them through the checking register or by presetting the register to all 1's and shifting all of M* (X) through normally. Thus the receiver action on the leading protion of a frame is the same with either 1 or 2.

The + 1 of the term $(X^K + 1)$ L (X) of the generation equation of 2 is added by inverting the FCS. This implies a 16 bit storage delay by the FCS function at the receiver since the location of the FCS is not known until the closing flag is received.

APPENDIX C STANDARDS COMPATIBILITY

C.1 Scope

This appendix is intended to detail, to the greatest extent possible, the differences between CDCCP and other existing bit-oriented procedures. The standards considered for compatibility include:

IBM - SDLC

ANSI - ADCCP

ISO - HDLC

The material here is intended to provide the designer with information which will permit him to evaluate the impact of differences in the standards and to take a flexible approach so as not to preclude compatibility with standards which he might be required to interface.

Since the bit-oriented standards situation is highly volatile as of this writing, the information presented here is subject to change. While every attempt will be made to keep the procedure up to date, it is the responsibility of the designer to maintain liaison with current situations.

C.2 Frame Structure

C.2.1 Frame Definition: CDCCP defines a frame as including opening and closing flags. Thus, the minimum frame length is 48 bits including flags and 32 bits excluding flags.

ADCCP is ambiguous in this respect. Flags are included as part of the frame structure but frame definition calls for a minimum of 32 bits.

NCR defines a frame as the sequence of bits between the opening and closing flags.

IBM includes the flags as part of the frame.

C.2.2 Address Extension: CDCCP has adopted the ISO/ECMA position of permitting address extension on a bilateral agreement basis. CDCCP thus requires that stations be capable of extending the address field beyond a single octet.

ANSI presently uses mandatory extension capability by limiting the first octet to 128 addresses. This position is expected to change to become ISO/ECMA compatible.

IBM's SDLC deals with a single octet address field and does not mention address extension. Nothing in the SDLC frame structure would preclude extension.

C.2.3 Group and Global Addressing: CDCCP permits group or global addresses in an unextended octet only. This is the ANSI position and the SDLC position. ISO permits group or global addressing without further restriction. ECMA implicitly does not permit group or global addressing.

C.2.4 Control Field Extension: CDCCP, ANSI, and ISO permit control field extension to enlarge the sequence number modulus. SDLC does not mention C field extension.

C.2.5 Abort: SDLC specifies eight contiguous one bits as signalling an abort. IBM has, however, supported the "more than seven, less than 15 position" used by CDCCP, ISO, and ANSI.

(ADDITIONAL MATERIAL TO BE SUPPLIED)

APPENDIX D PARAMETERS SUBJECT TO BILATERAL AGREEMENT

CDCCP is designed to cover a wide range of applications. As with any protocol, this flexibility of application results in a requirement that certain parameters must be established by bilateral agreement for the specific application.

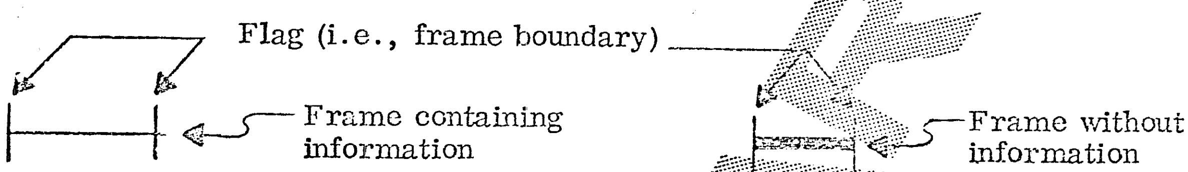
NOTE

Future revisions of this document will present precise definitions of these bilateral agreement parameters. Such parameters include but are not limited to:

- Operation Mode NRM or ARM
- Use of extended address field
- Use of control field extension
- Configuration of address field
- Subsets of Commands/Responses
- Error Recovery procedures
- Timer values

APPENDIX E EXAMPLES OF CDCCP PROTOCOL

The examples presented in this section are illustrative of the exchanges which would take place under the condition given for the example. The notation used and most of the examples are those which have been adopted by ANSI and ISO. The notation is illustrated below:



Information Frame: I N (S) N (R) P/F

- I — Information Format Frame
- N (S) — Send Sequence Number
- N (R) — Receive Sequence Number (next expect frame)
- P/F — Poll or Final Bit set to "1"

Example: Pri xmits: I2,6P This denotes a Primary information format frame with sequence number 2, the next expected frame from the Secondary is sequence number 6 (frames numbered 5 and below are therefore acknowledged) and the Poll bit is set to "1" (i.e., the Secondary is to initiate transmission with information format frames if available).

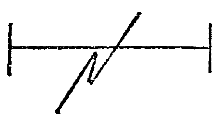
Supervisory command/response (XXX)

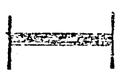
Supervisory Frame: XXX N (R) P/F ← Poll or Final bit set to "1"

N (R): Receive Sequence Number

Example: Pri xmits: RR2P. This denotes a Receive Ready (RR) command, N (R) = 2 (i.e., the next expected frame from the Secondary is sequence number 2), and the Poll bit is set to "1".

In the examples time moves from left to right. The left frame is, therefore, transmitted first. An errored or missing frame is denoted as follows:


errored or missing Information frame

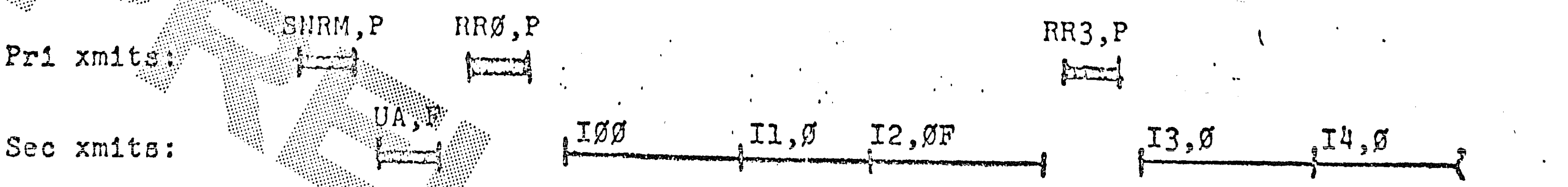

errored or missing S or U frame

Examples are provided for error free as well as errored frame conditions for Normal and Asynchronous Response Modes in TWA and TWS operation. Mode changing and ending operations are also illustrated.

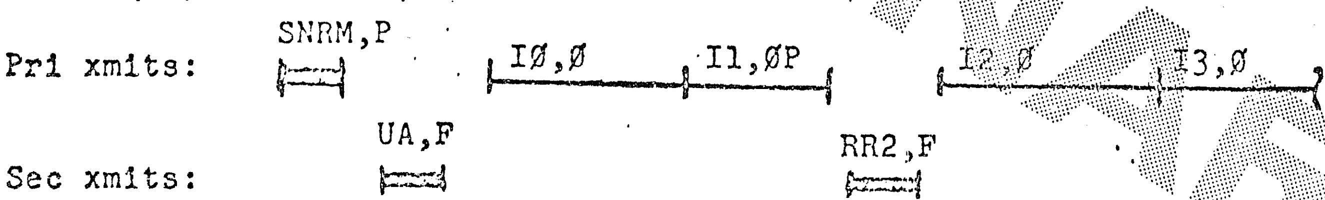
1. Examples of Normal Response Mode (NRM) 2 Way Alternate (HDX) Transmission

1.1 Normal Response Mode (NRM) HDX Without Transmission Errors

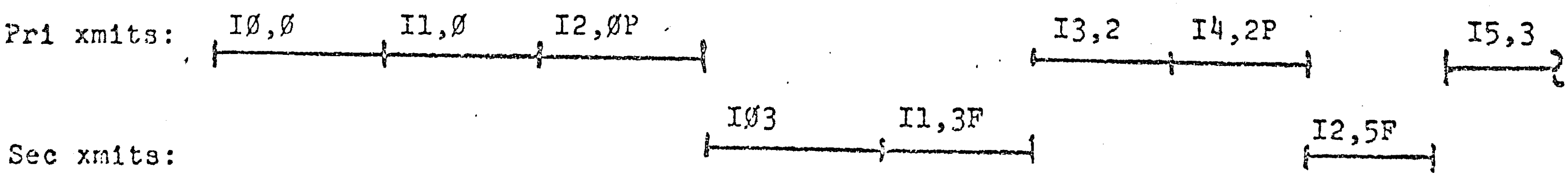
1.1.1 NRM Start-up procedure and Secondary only information transfer (NB/NS CLASSES)



1.1.2 NRM Start-up procedure and Primary only information transfer (NB/NS CLASSES)



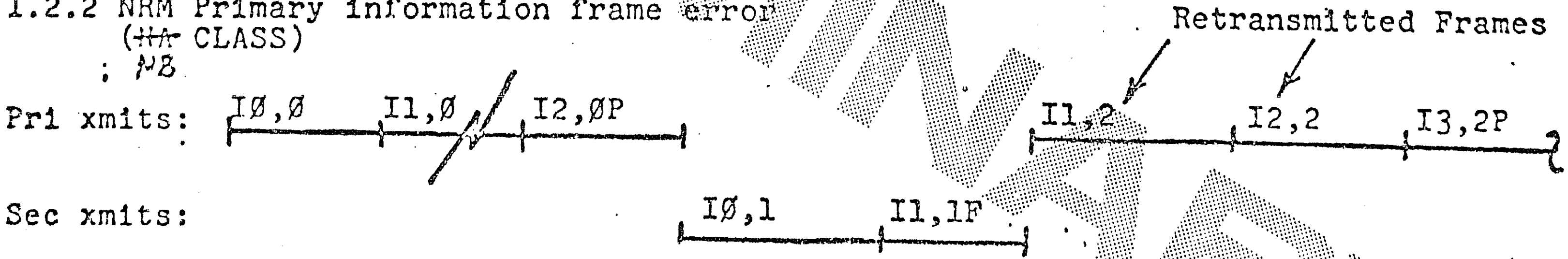
1.1.3 NRM Information transfer by Primary and Secondary (NB/NS CLASSES)



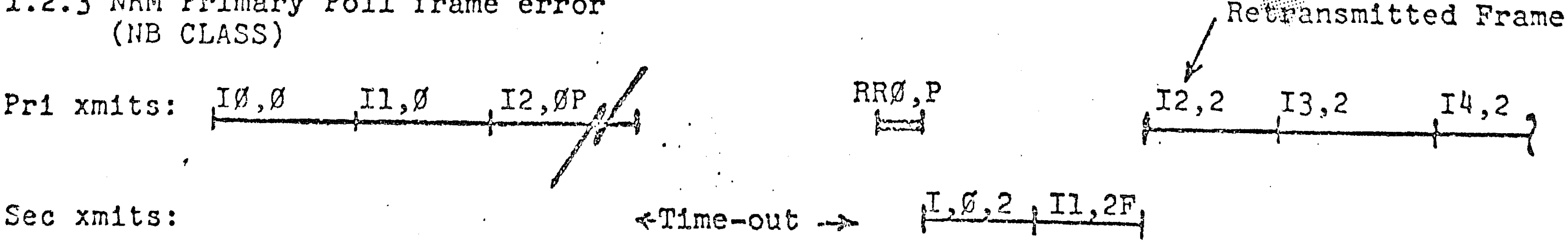
1.2 Normal Response Mode (NRM) HDX with transmission errors in command frames

1.2.1 NRM Start-up command error
(NB/NS CLASSES)

1.2.2 NRM Primary information frame error
(NB CLASS)

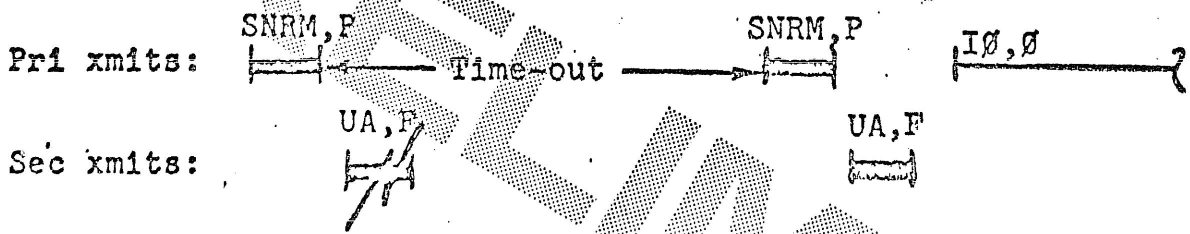


1.2.3 NRM Primary Poll frame error
(NB CLASS)

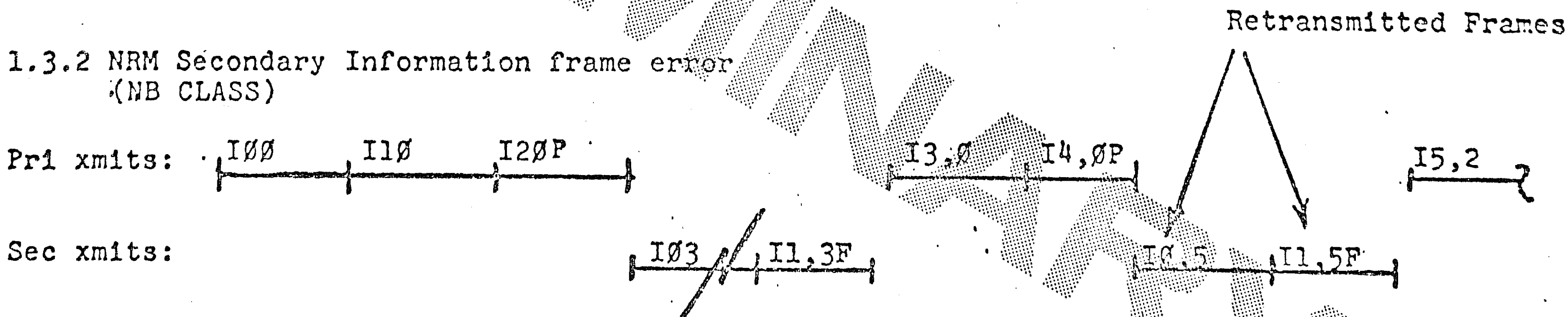


1.3 NRM HDX with transmission errors in response frames

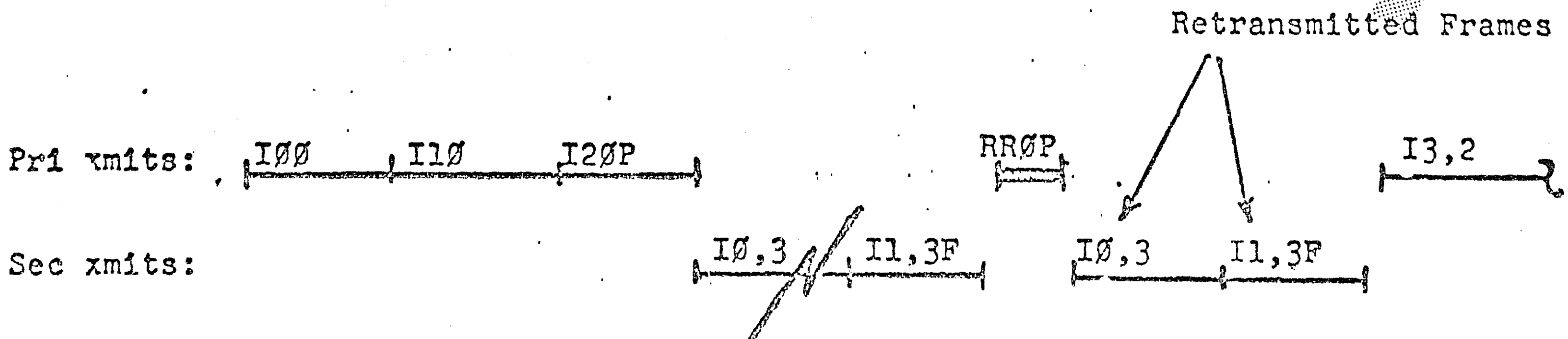
1.3.1 NRM Start-up response error
(NB/NS CLASSES)



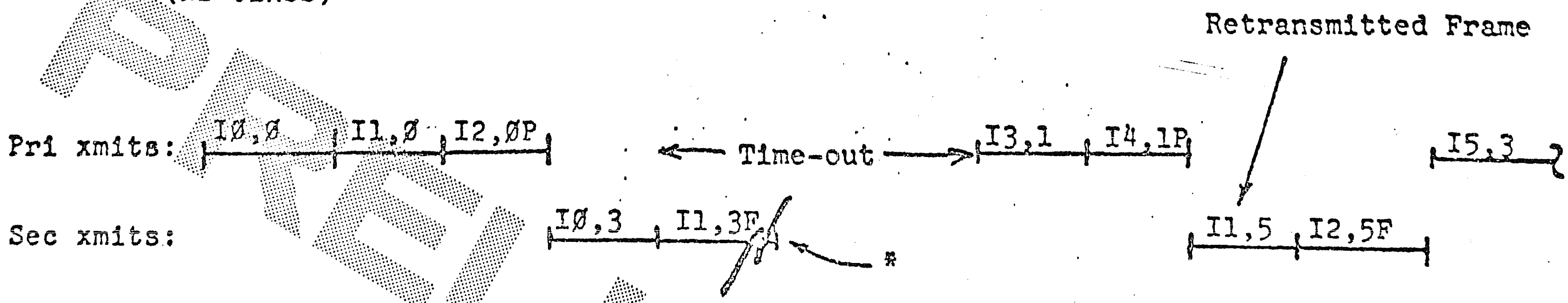
1.3.2 NRM Secondary Information frame error
(NB CLASS)



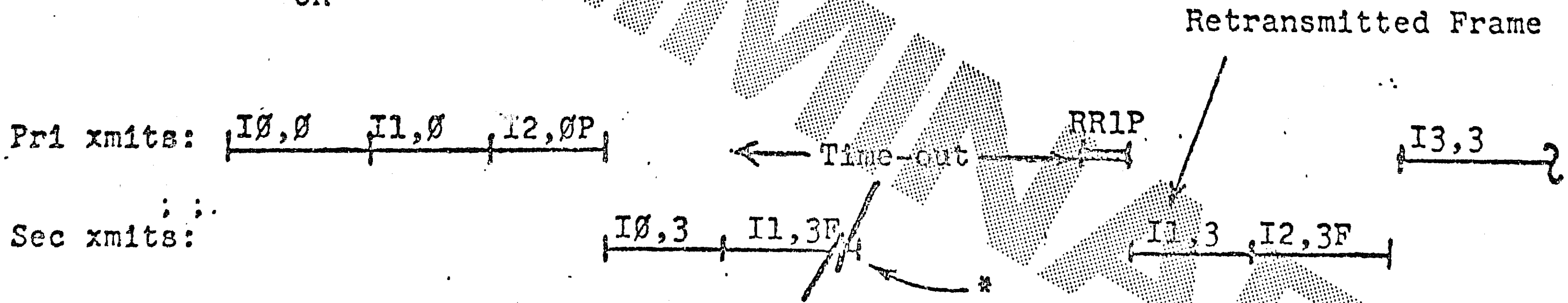
OR



1.3.3 NRM Secondary "Final" frame error
(NB CLASS)



OR

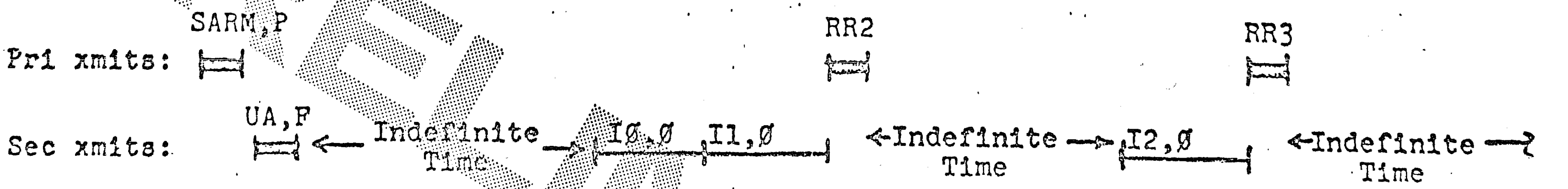


* Idle Link State detection may be used in place of a Time-out to initiate Primary Transmission

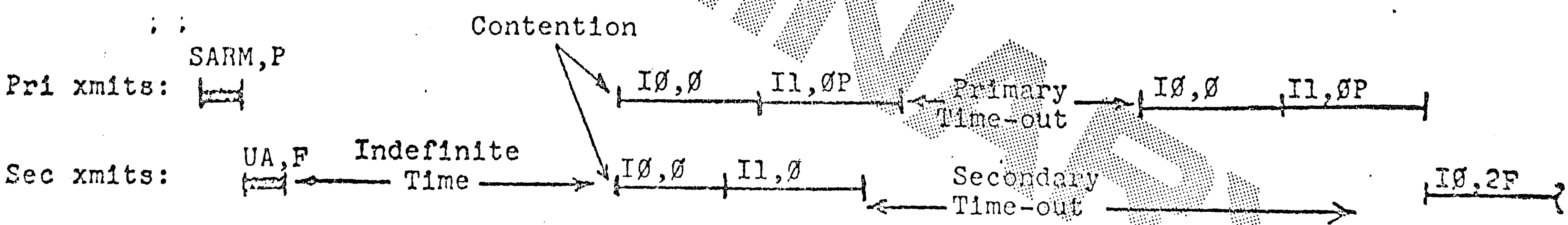
2. Examples of Asynchronous Response Mode (ARM) 2-Way Alternate (HDX) Transmission

2.1 Asynchronous Response Mode (ARM) HDX without transmission error

2.1.1 ARM Start-up procedure and Secondary only information transfer

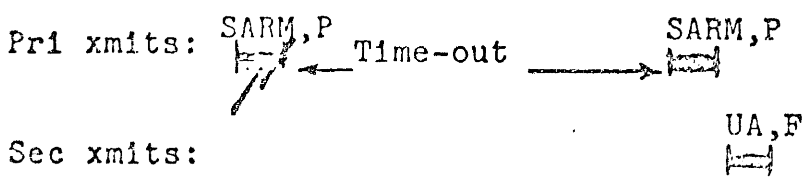


2.1.2 ARM Primary and Secondary information transfer with contention situation (NAB/CLASS)

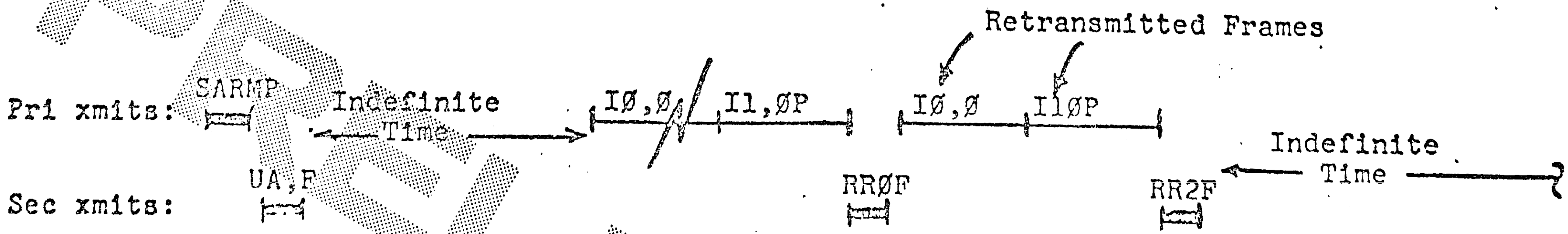


2.2 Asynchronous Response Mode (ARM) HDX with transmission errors in command frames

2.2.1 ARM Start-up command error (NAB/NAS CLASSES)



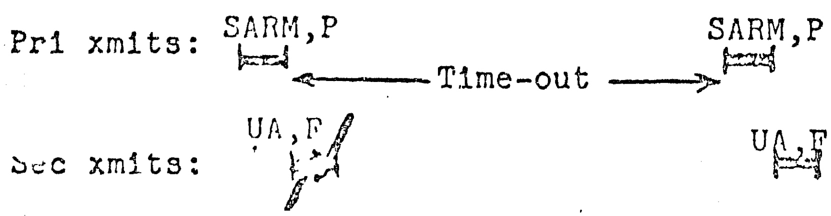
2.2.2 ARM Primary information frame error (Note: recovery procedure is identical to NRM operation) (NAB CLASS)



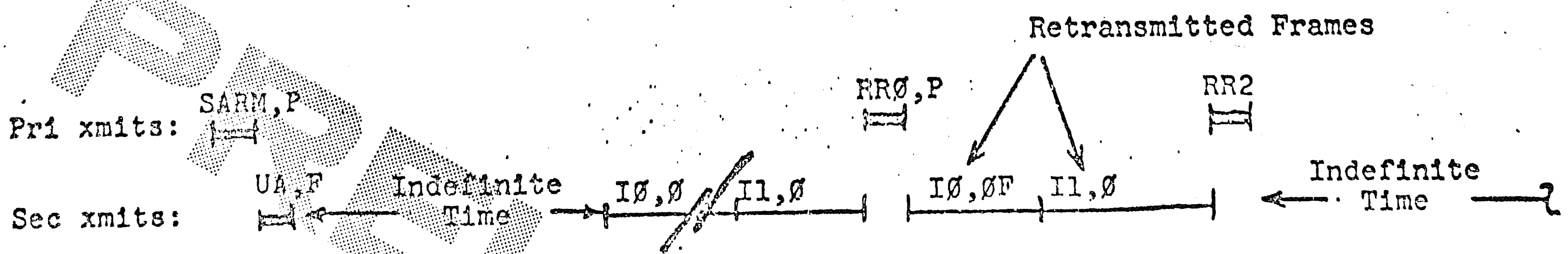
2.2.3 ARM Primary "Poll" information frame error (Note: recovery procedure is identical to NRM operation) (NAB CLASS)

2.3 Asynchronous Response Mode (ARM) HDX with transmission errors in response frames

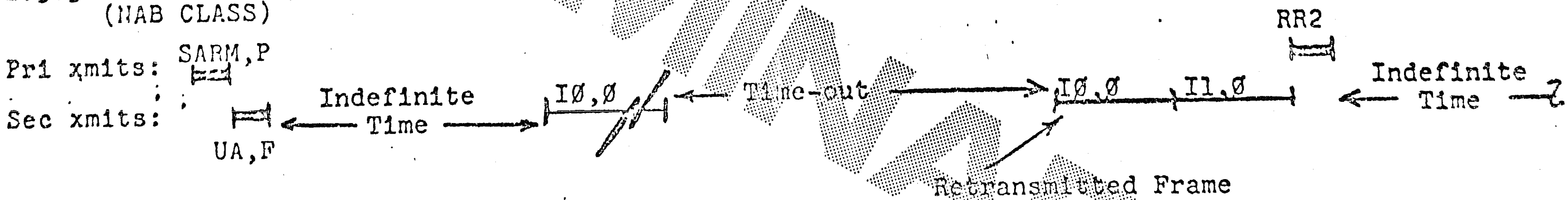
2.3.1 ARM Start-up (NAB/NAS CLASSES)



2.3.2 ARM Secondary information frame error
(NAB CLASS)



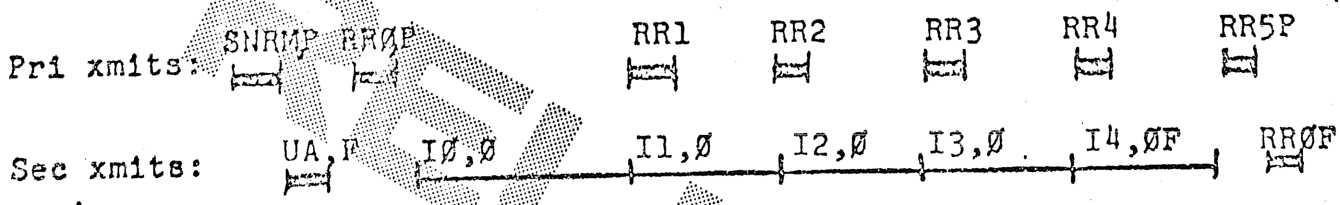
2.3.3 ARM Secondary "Final" information frame error
(NAB CLASS)



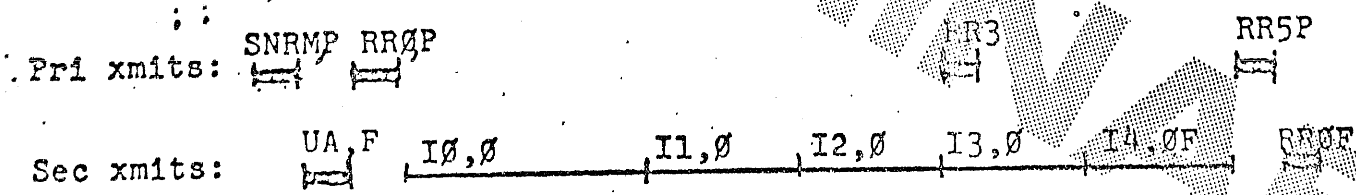
3. Examples of Normal Response Mode (NRM) 2-Way Simultaneous (FDX) Transmission

3.1 Normal Response Mode (NRM) FDX Without Transmission Errors

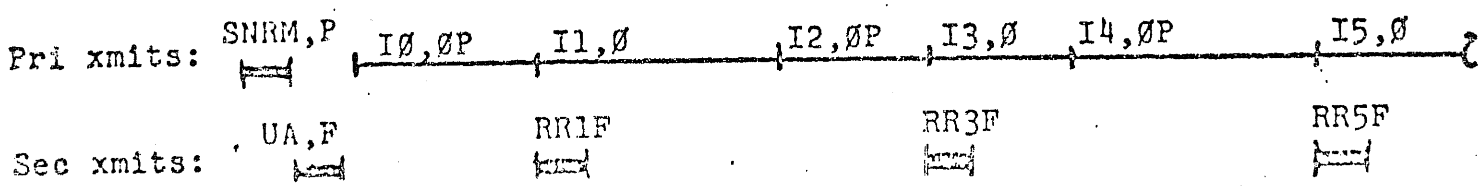
3.1.1 NRM Start-up procedure and Secondary only information transfer (NB/NS CLASSES)



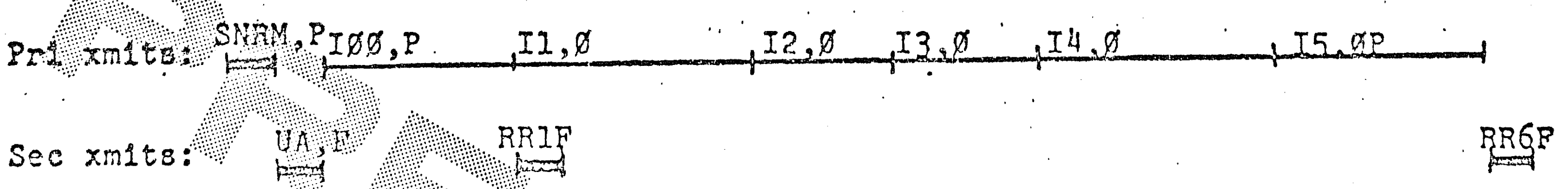
OR (where Primary acknowledgements are returned for several response frames)



3.1.2 NRM Start-up procedure and Primary only information transfer (NB/NS CLASSES)



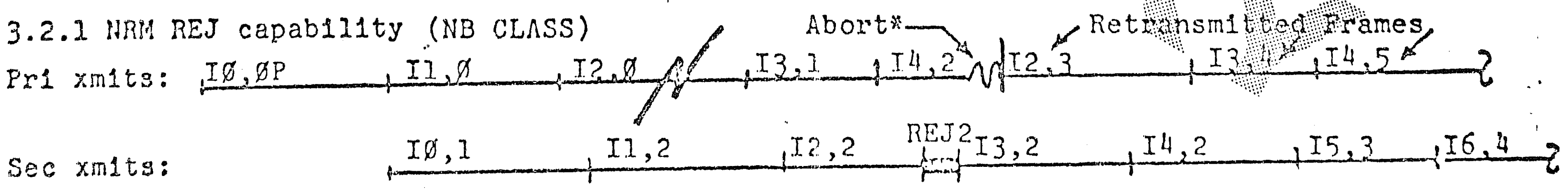
OR (where Primary sets Poll bit to "1" to solicit acknowledgement for several frames)



3.1.3 NRM Start-up procedure and Primary/Secondary information transfer
(NB/NS CLASSES)

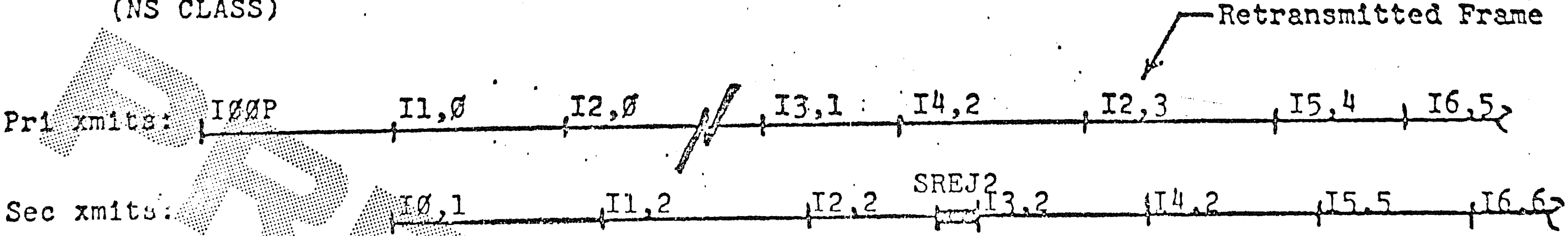
3.2 Normal Response Mode (NRM) FDX With Transmission Errors in Command Frames

3.2.1 NRM REJ capability (NB CLASS)



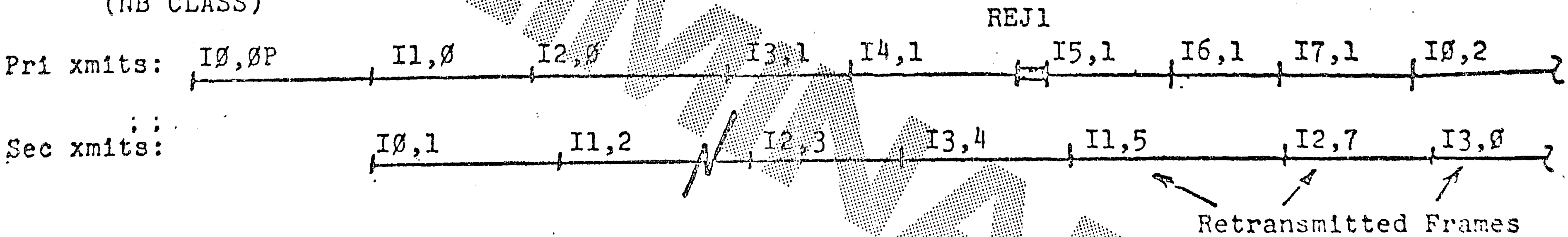
* Optional: Frame maybe completed or aborted

3.2.2 NRM SREJ capability
(NS CLASS)

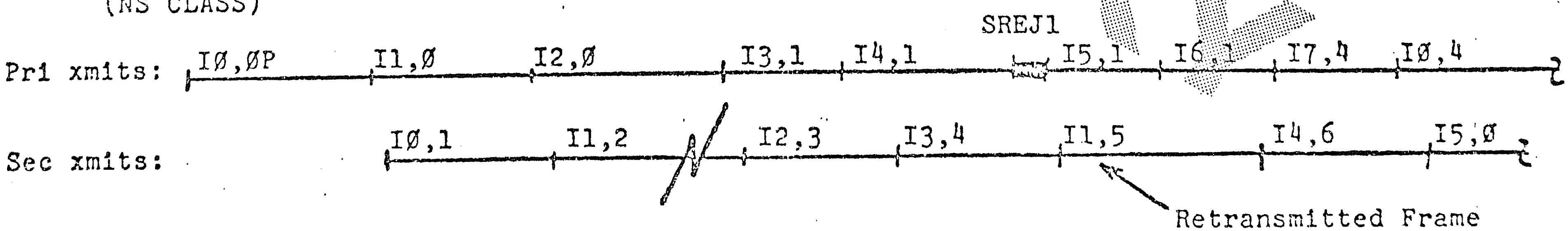


3.3 Normal Response Mode (NRM) FDX with Transmission Errors in Response Frames

3.3.1 NRM REJ capability
(NB CLASS)



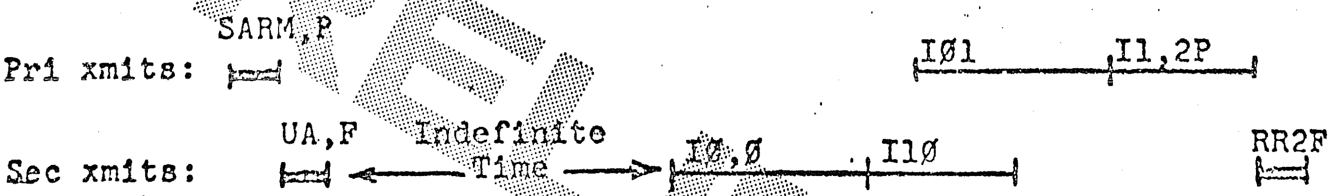
3.3.2 NRM SREJ capability
(NS CLASS)



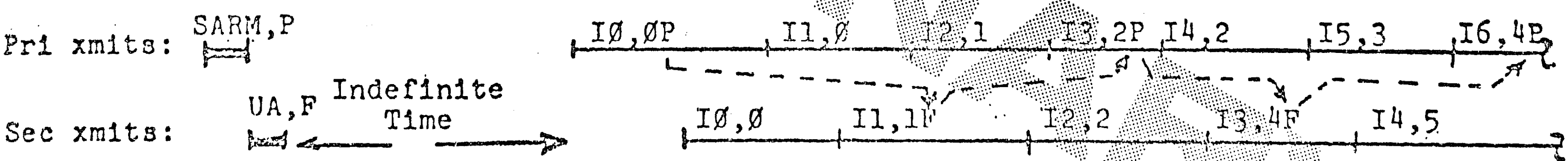
4. Examples of Asynchronous Response Mode (ARM) 2-Way Simultaneous (FDX) Transmission

4.1 Asynchronous Response Mode FDX Without Transmission Errors

4.1.1 ARM Start-up procedure and intermittent Secondary or Primary information transfer (NAB/NAS CLASSES)

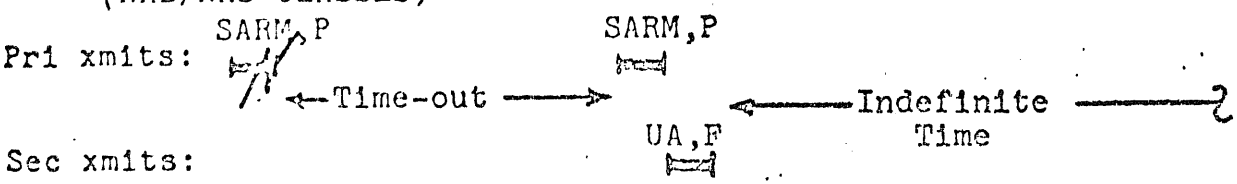


4.1.2 ARM Start-up procedure and continuous Primary Secondary information transfer (NAB/NAS CLASSES)

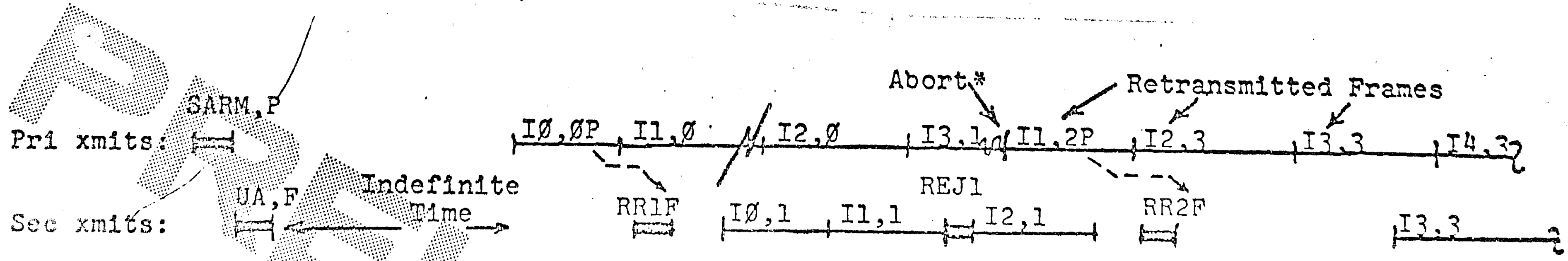


4.2 Asynchronous Response Mode (ARM) FDX With Transmission Errors in Command Frames

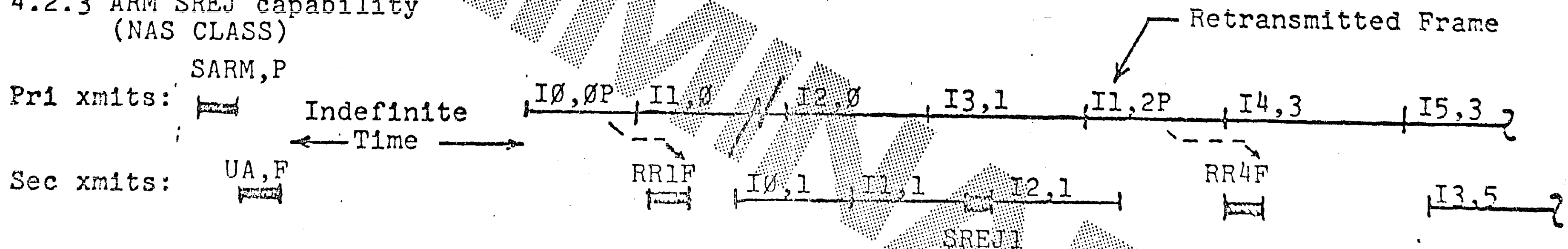
4.2.1 ARM Start-up command error (NAB/NAS CLASSES)



4.2.2 ARM REJ capability
(NAB CLASS)

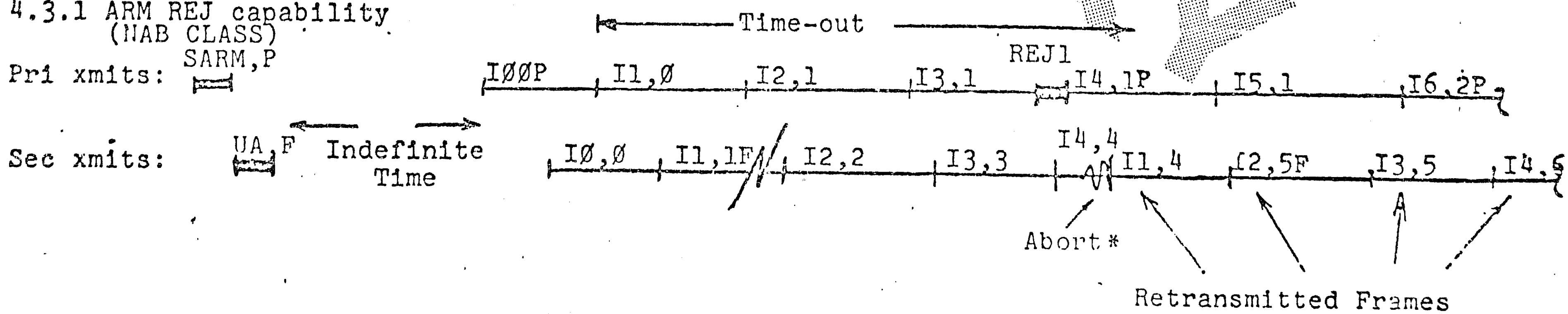


4.2.3 ARM SREJ capability
(NAS CLASS)



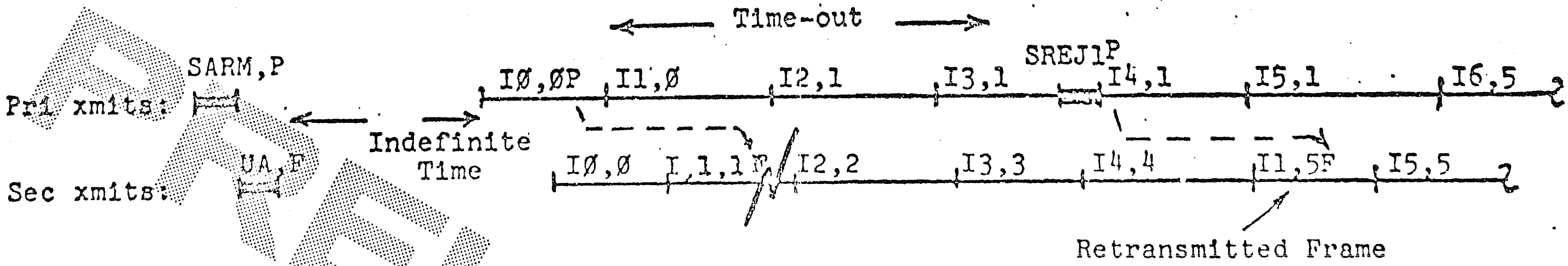
4.3 Asynchronous Response Mode (ARM) FDX With Transmission Errors in Response Frames

4.3.1 ARM REJ capability
(NAB CLASS)

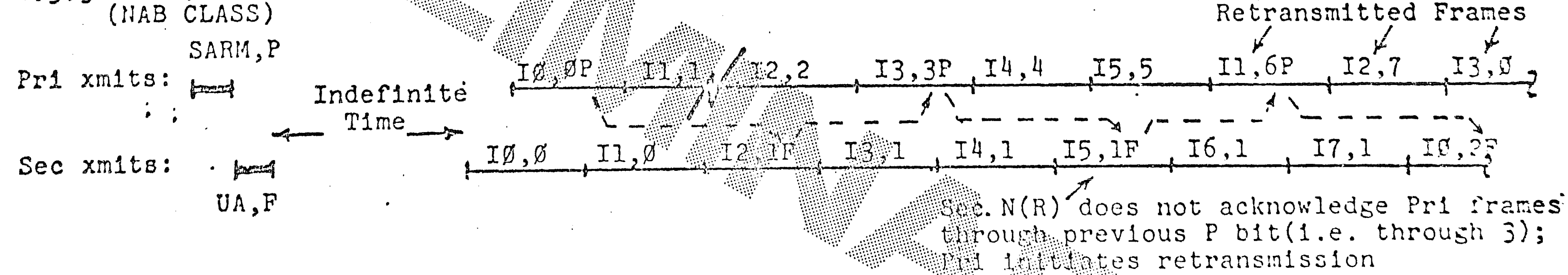


* Optional: Frame may be completed or aborted

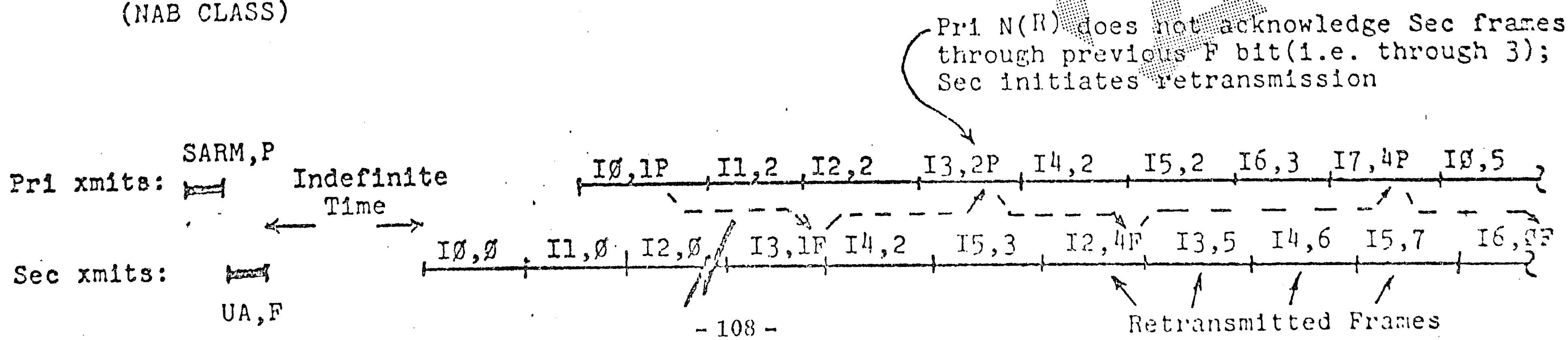
4.3.2 ARM SREJ capability
(NAS CLASS)



4.3.3 ARM P/F bit recovery with transmission error in command frame
(NAB CLASS)



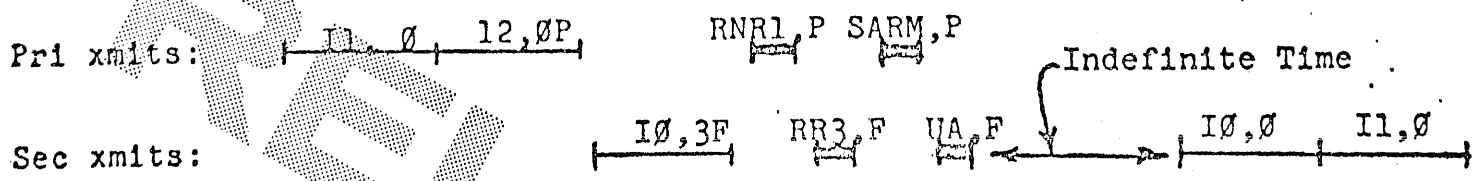
4.3.4 ARM P/F bit recovery with transmission error in response frame
(NAB CLASS)



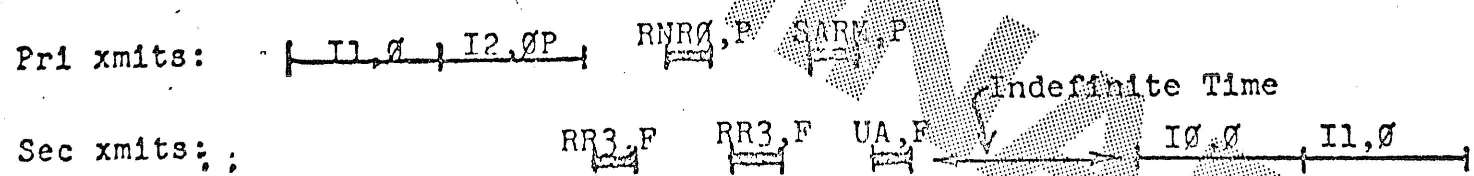
5.0 Examples of Changing Control Mode

5.1 Normal Response Mode (NRM) to Asynchronous Response Mode (ARM) Change 2-way Alternate

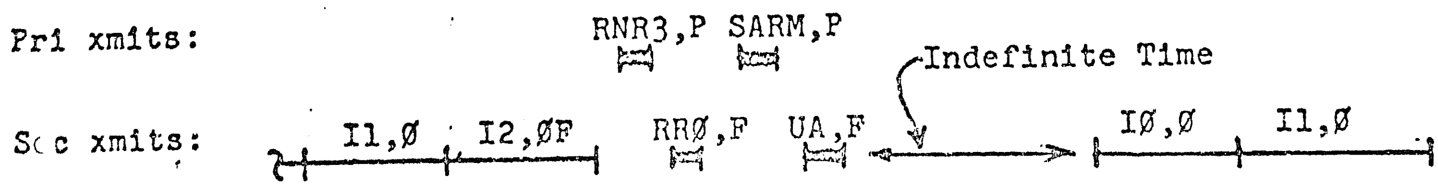
5.1.1 2-Way Alternate (HDX) Transmission NRM to ARM Mode Change (NAB/NAS CLASSES)



5.1.2 2-Way Alternate (HDX) Transmission NRM to ARM Mode Change (NAB/NAS CLASSES)

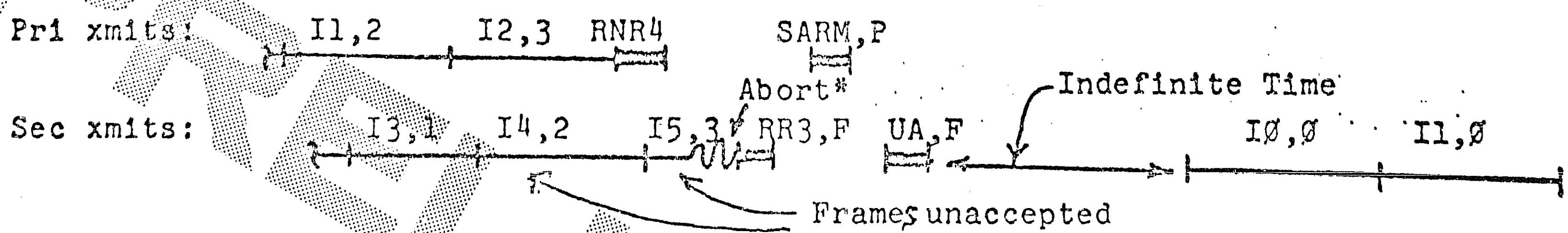


5.1.3 2-Way Alternate (HDX) Transmission NRM to ARM Mode Change (NAB/NAS CLASSES)

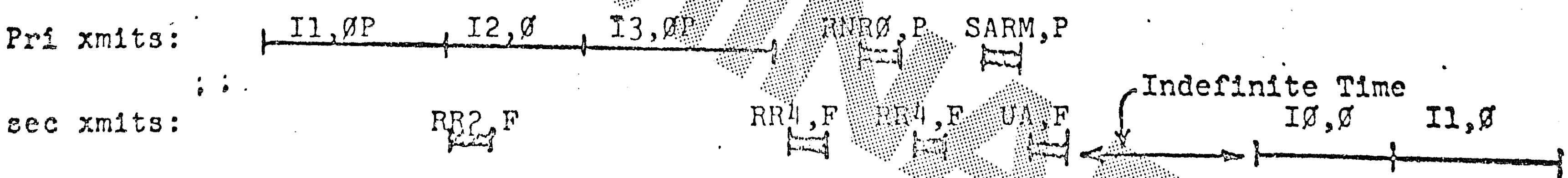


5.2 Normal Response Mode (NRM) to Asynchronous Response Mode (ARM) Change 2-Way Simultaneous

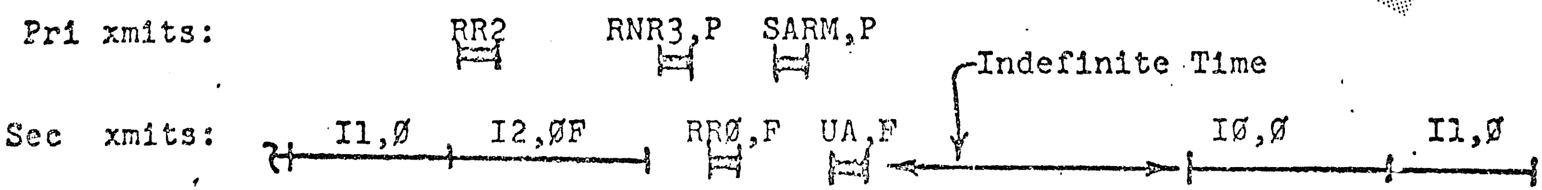
5.2.1 2-Way Simultaneous (FDX) Transmission NRM to ARM Mode Change (NAB/NAS CLASSES)



5.2.2 2-Way Simultaneous (FDX) Transmission NRM to ARM Mode Change (NAB/NAS CLASSES)



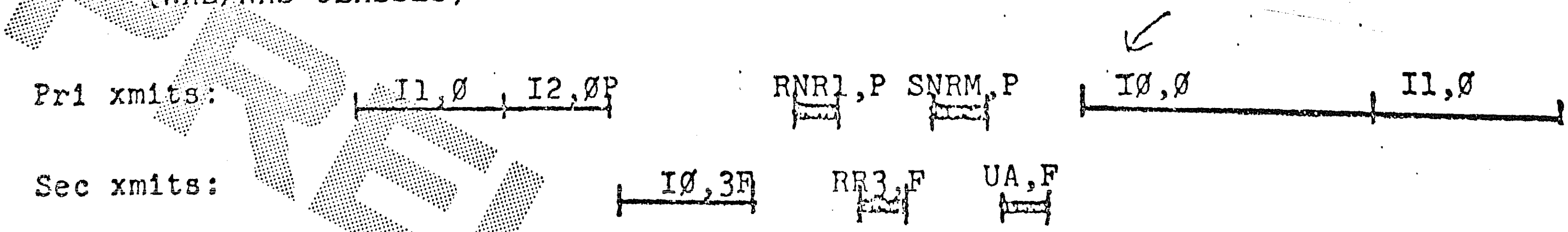
5.2.3 2-Way Simultaneous (FDX) Transmission NRM to ARM Mode Change (NAB/NAS CLASSES)



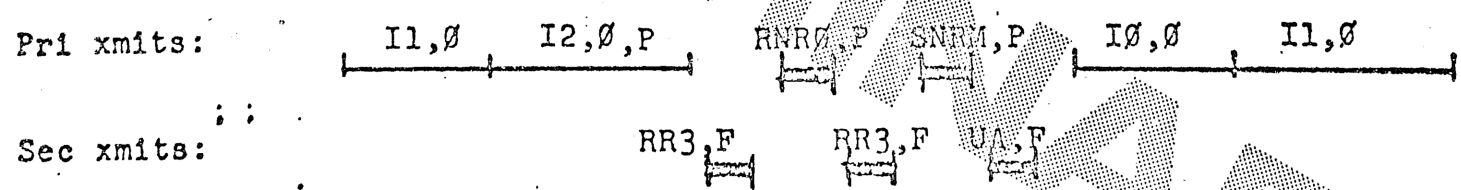
* Optional: Frame may be completed or aborted

5.3 Asynchronous Response Mode (ARM) to Normal Response Mode (NRM) Change 2-Way Alternate

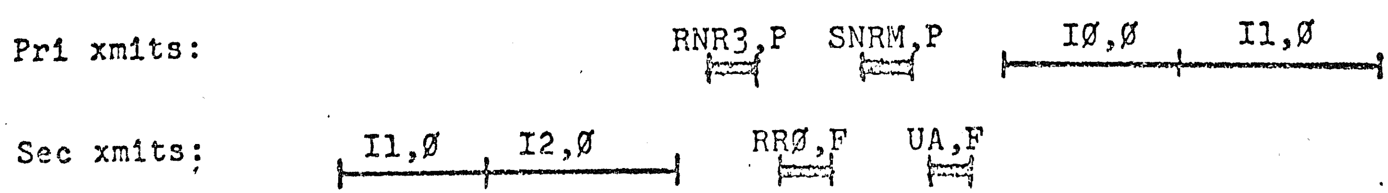
5.3.1 2-Way Alternate (HDX) Transmission ARM to NRM Mode Change (NAB/NAS CLASSES)



5.3.2 2-Way Alternate (HDX) Transmission ARM to NRM Mode Change (NAB/NAS CLASSES)

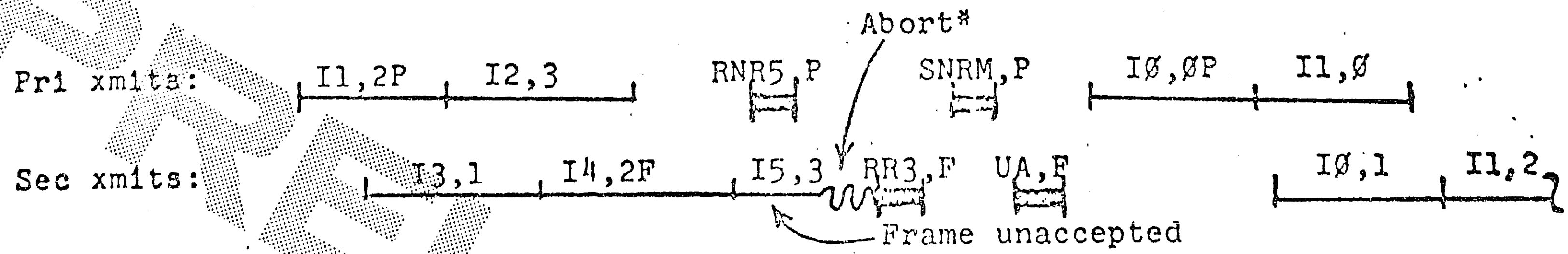


5.3.3 2-Way Alternate (HDX) Transmission ARM to NRM Mode Change (NAB/NAS CLASSES)

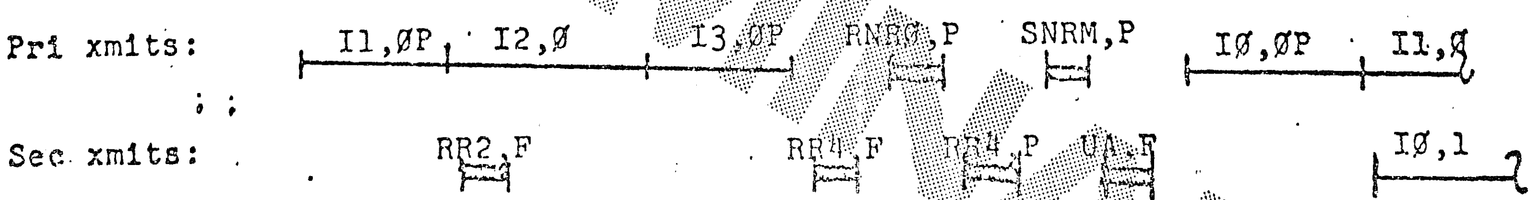


5.4 Asynchronous Response Mode (ARM) to Normal Response Mode (NRM) Change 2-Way Simultaneous

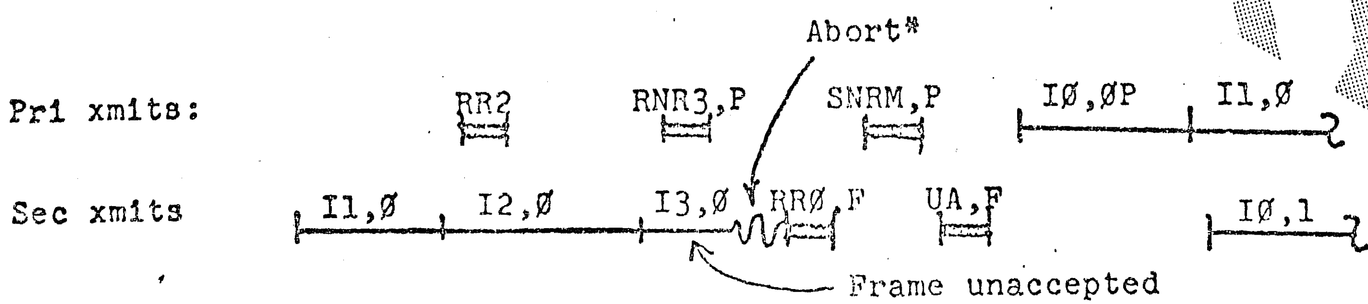
5.4.1 (NAB/NAS CLASSES)
2-Way Simultaneous (FDX) Transmission ARM to NRM Mode Change



5.4.2 (NAB/NAS CLASSES)
2-Way Simultaneous (FDX) Transmission ARM to NRM Mode Change



5.4.3 (NAB/NAS CLASSES)
2-Way Simultaneous (FDX) Transmission ARM to NRM Mode Change



*Optional: Frame may be completed or aborted.

5.5 Normal Disconnected Mode (NDM) Examples

5.5.1 (NAB/NAS CLASSES) 2-Way Alternate (HDX) Transmission; NDM (or ADM) to ARM Change

Pri xmits: SNRM,P IØ,Ø I1,ØP

Sec xmits: UA,F IØ,2

5.5.2 (NAB/NAS CLASSES) 2-Way Alternate (HDX) Transmission; Secondary in NDM (or ADM) indicates it is unable to change to NRM

Pri xmits: SNRM,P

Sec xmits: DM,F

5.5.3 (NAB/NAS CLASSES) 2-Way Alternate (HDX) Transmission; Secondary in ADM indicates it is disconnected and Primary sends set mode command

Pri xmits: (Poll) SARM,P

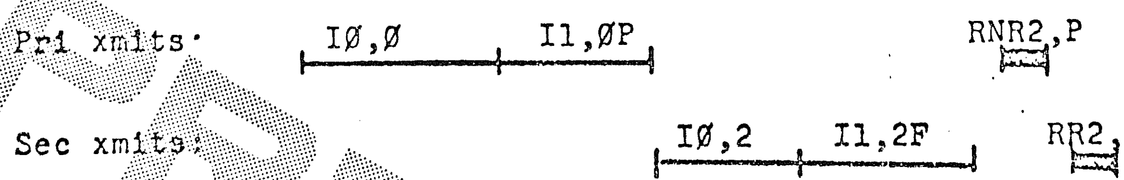
Sec xmits: DM,F UA,F

5.5.4 (NAB/NAS CLASSES) 2-Way Alternate (HDX) Transmission; Secondary in NDM (or ADM) indicates it is disconnected, and Primary refuses to send set mode command

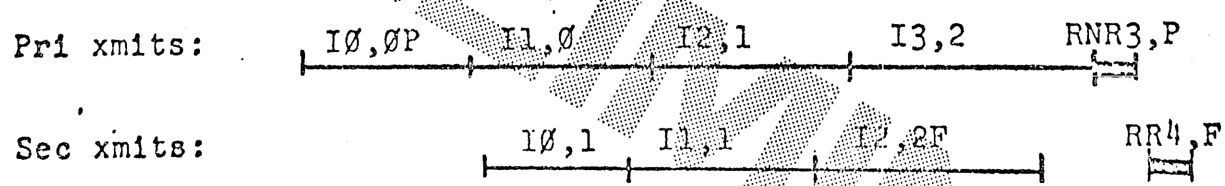
```
                      DISC,P
Pri xmits:  (Poll)     |--|
                  DM,F      UA,F
Sec xmits:        |--|      |--|
```

6.0 Examples of End of Operation (General Closing Procedure)

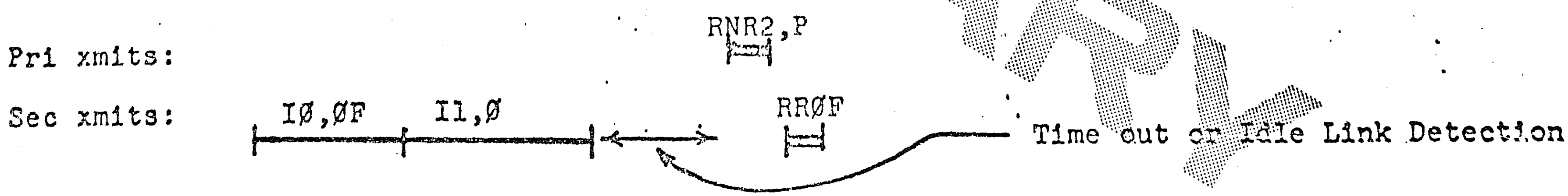
6.1 Normal Response Mode (NRM), 2-Way Alternate (HDX) Transmission (NB/NS CLASSES)



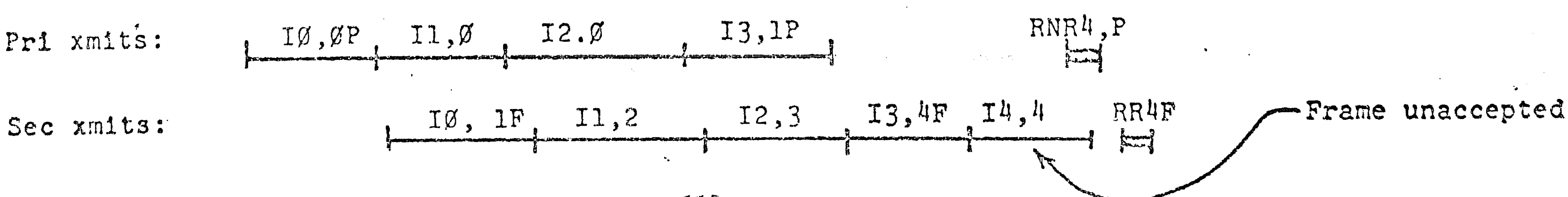
6.2 Normal Response Mode (NRM), 2-Way Simultaneous (FDX) Transmission (NB/NS CLASSES)



6.3 Asynchronous Response Mode (ARM), 2-Way Alternate (HDX) Transmission NAB/NAS CLASSES)



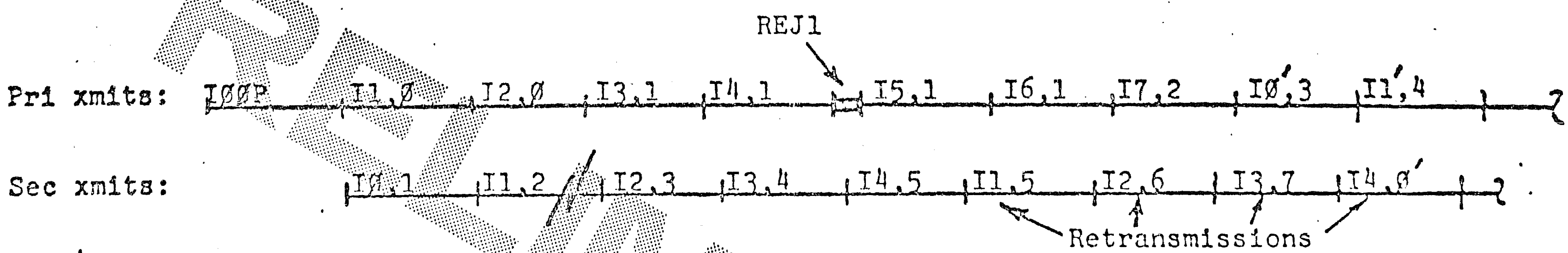
6.4 Asynchronous Response Mode (ARM), 2-Way Simultaneous (FDX) Transmission (NAB/NAS CLASSES)



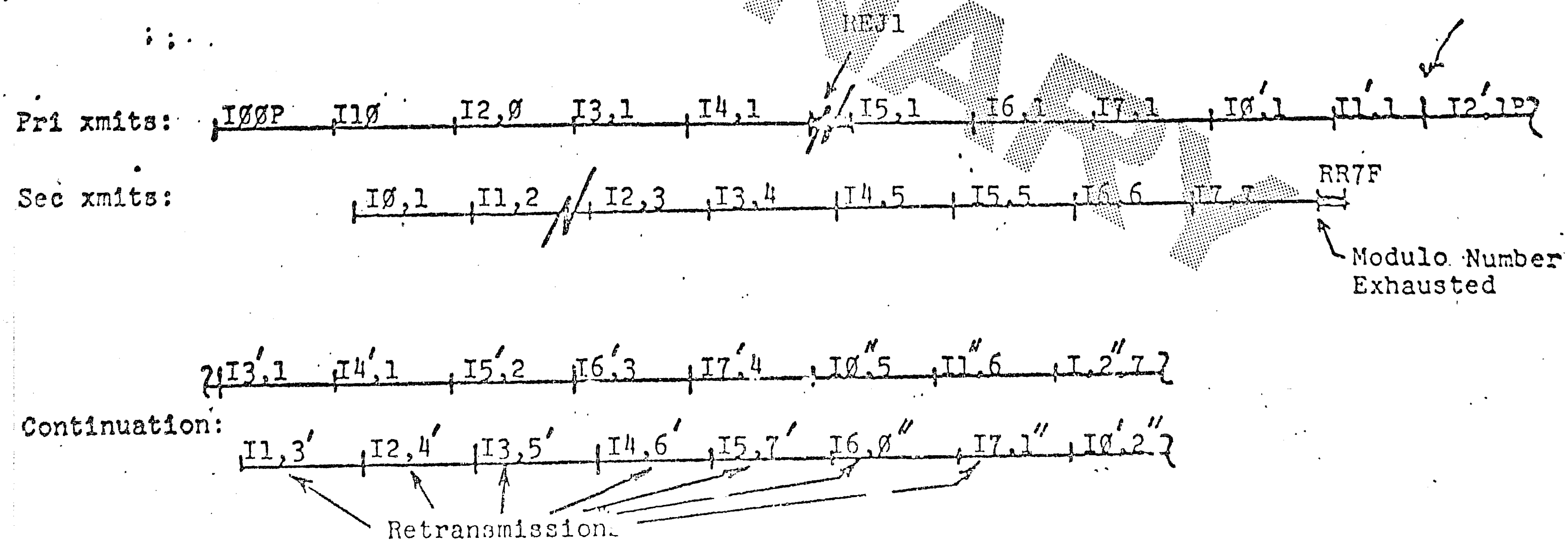
7. Examples of Exception Recovery Procedures

7.1 REJ and Poll/Final Bit Exception Recovery for FDX Operation

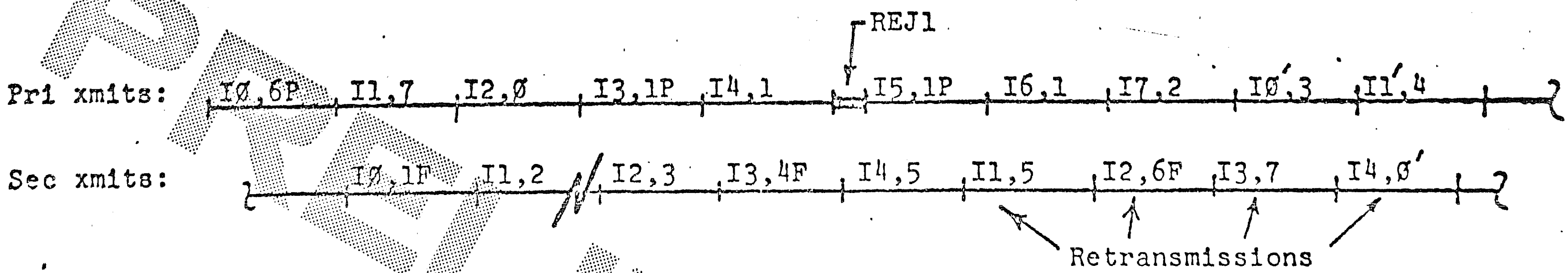
7.1.1 NRM - FDX with Information Frame Exception (NB CLASS)



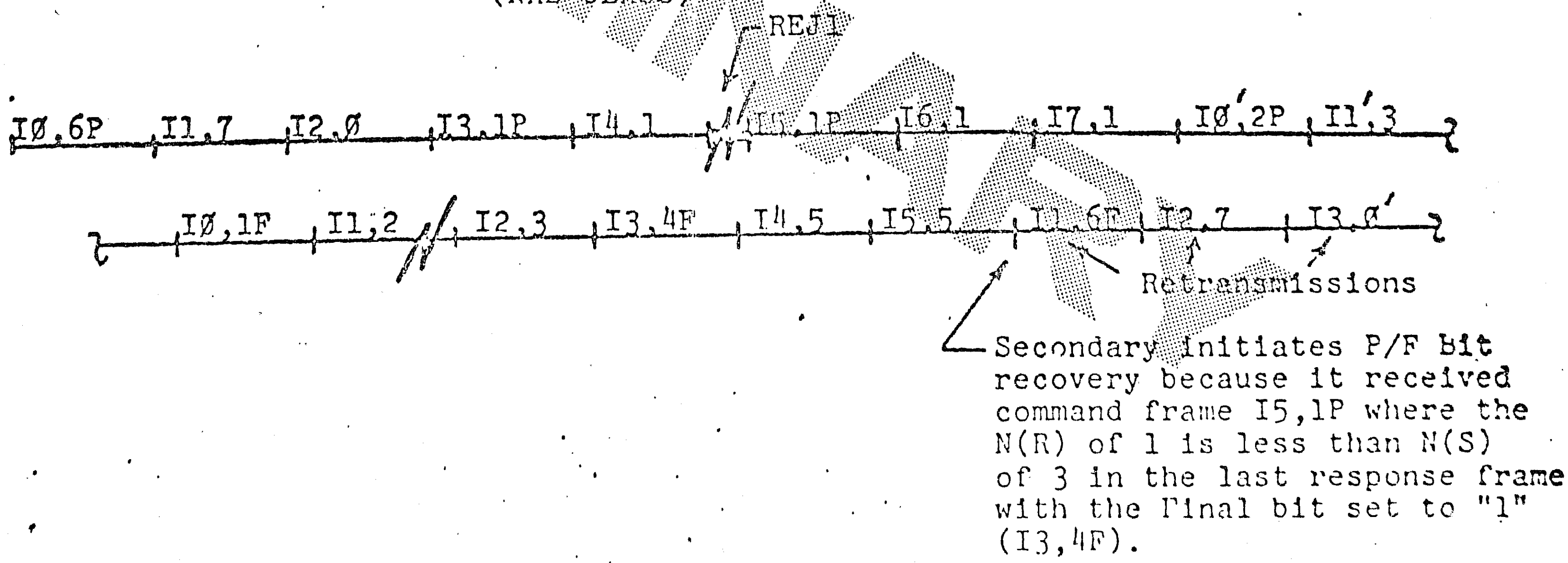
7.1.2 Example 7.1.1 above except REJ is not received correctly. (NB CLASS)



7.1.3 ARM - FDX with Information Frame Exception (NAB CLASS)

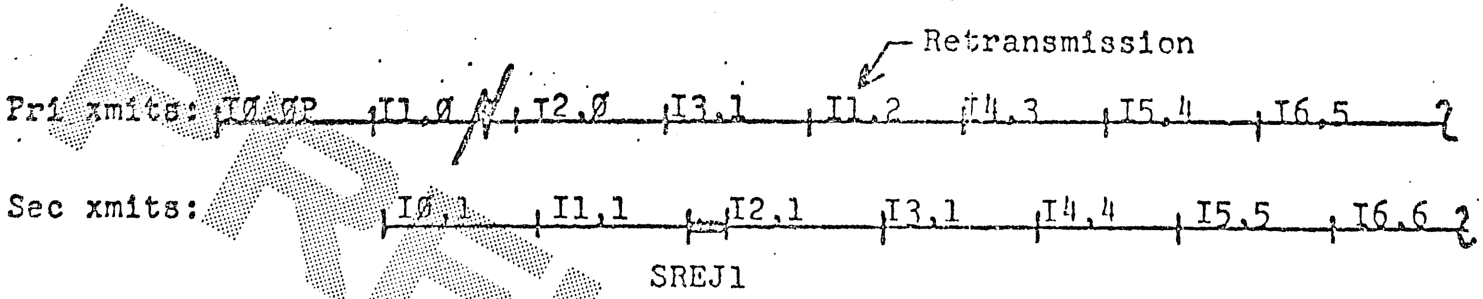


7.1.4 Example 7.1.3 above except REJ is not received correctly (NAB CLASS)

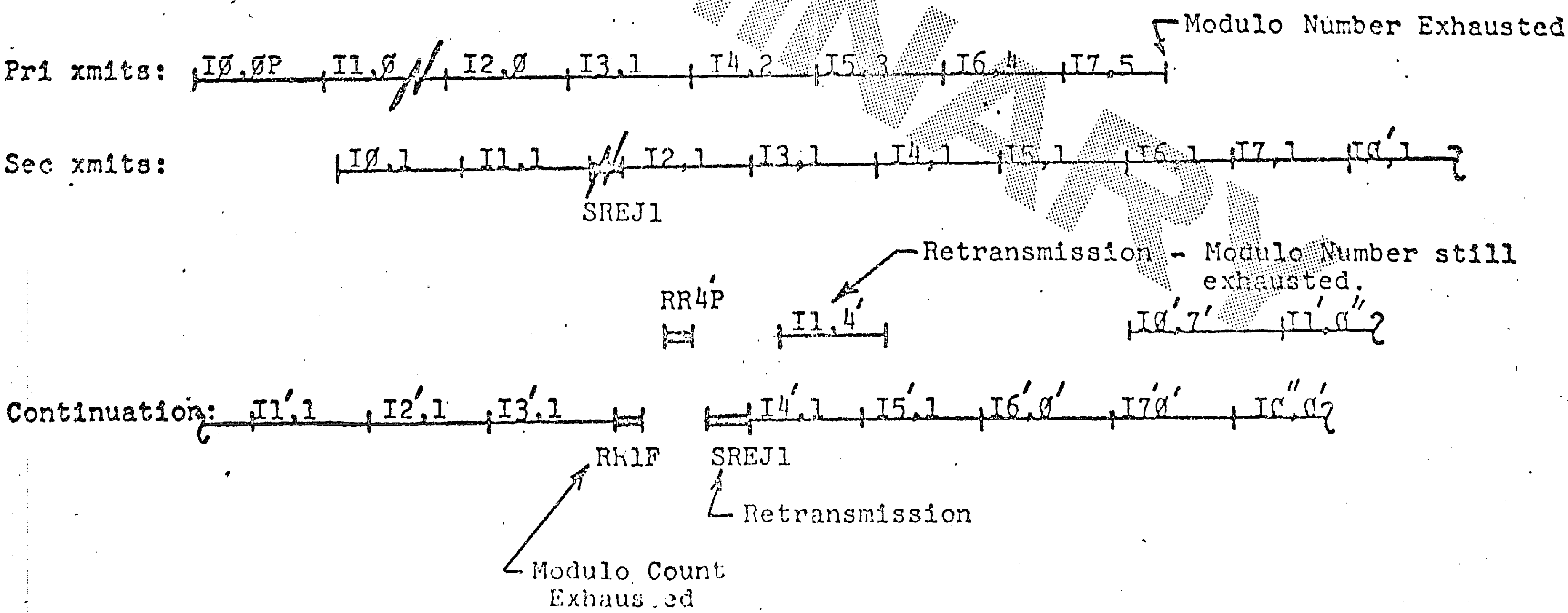


7.2 SREJ/REJ Exception Recovery for FDX Operation

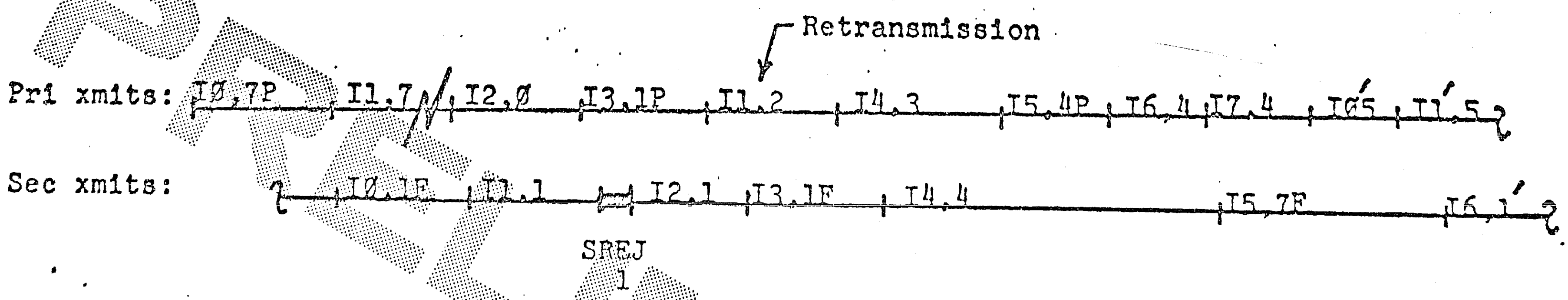
7.2.1 NRM - FDX with Information Frame Exception (NS CLASS)



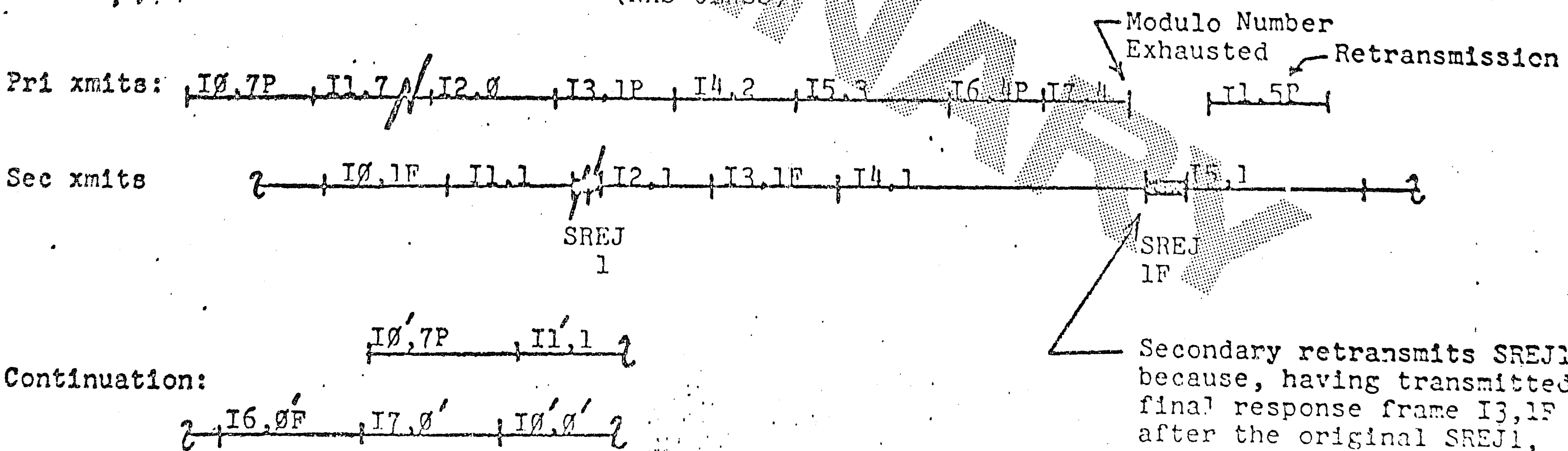
7.2.2 Example 7.2.1 above except SREJ is not received correctly (NS CLASS)



7.2.3 ARM - FDX with I Frame Exception Condition (NAS CLASS)



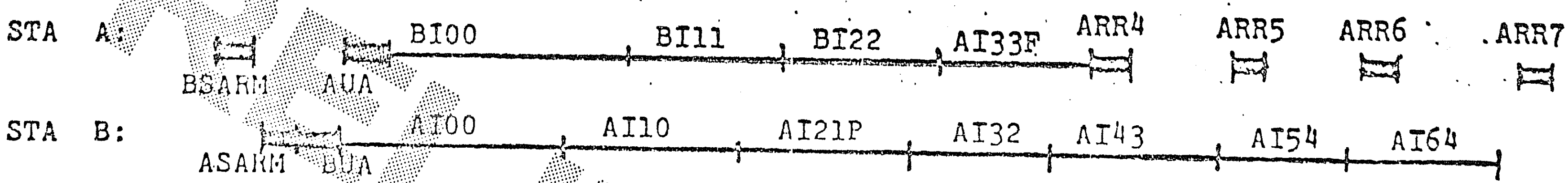
7.2.4 Example 7.2.3 above except SREJ is received in error (NAS CLASS)



Secondary retransmits SREJ1F because, having transmitted final response frame I3,1F after the original SREJ1, the requested I frame (with N(S) equal 1) was not received prior to or concurrent with the next poll command frame I6,4P.

8.0 Examples of Primary-to-Primary Operation

8.1 Simultaneous Information Frames (PPB/PPS CLASSES)



8.2 Discontinuous ~~Secondary~~ Information Frames (PPB/PPS CLASSES)