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AUTODIN II MODE VI (ADCCP) LINE CONTROL PROCEDURES--ETC(U)
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AUTODIN II MODE VI (ADCCP)

LINE CONTROL PROCEDURES FUNCTIONAL SPECIFICATION

2 May 1978

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This document provides the functional specification for AUTODIN II Mode VI line control procedures. This line control is a subset of the Proposed American National Standard for Advanced Data Communication Control Procedures (ADCCP) as described in X3534/589 Draft 6 Revision 2. It serves as an implementation guide for AUTODIN II software designers, and provides implementation-related details which are not addressed in the standard. It delineates those areas where the AUTODIN II implementation of ADCCP differs from the standard.

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1.1 INTRODUCTION

This document provides the functional specification for AUTODIN II Mode VI line control procedures. This line control is a subset of the Proposed American National Standard for Advanced Data Communications Control Procedures (ADCCP) as described in X3S34/589 Draft 6 Revision 2, 11 August 1977, hereafter referred to as the "standard." Users of this document should be familiar with the standard.

The remaining sections of this document serve as an implementation guide for AUTODIN II software designers and provide implementation-related details which are not addressed in the standard. In addition, it delineates those areas where the AUTODIN II implementation of ADCCP differs from the standard. This document serves as the definitive source for the AUTODIN II ADCCP functional design; it supersedes all previous documents concerning AUTODIN II Mode VI (ADCCP) line control procedures. Deviations from the standard are permitted only in those cases explicitly addressed in this specification.

2.1 AUTODIN II ADCCP

AUTODIN II ADCCP uses the Balanced Asynchronous (BA) class of procedures. The basic mode of operation is Asynchronous Balanced Mode (ABM) with all stations supporting Two-Way Simultaneous (TWS) Operation. In addition, optional functions 1, 4, 7, 8, and 10 as described in Section 11.2 of the standard are supported. The ADCCP frame format, commands, responses, and optional functions implemented in the AUTODIN II system are discussed in the succeeding paragraphs; additional detail concerning BA, ABM, and TWS may be found in Sections 2 and 11 of the standard.

3.1 FRAME FORMAT

ADCCP transmissions are packaged into distinct sets of binary data called frames. Each frame contains the following:

- Flag Sequence (beginning)
- Address Field
- Control Field
- Information Field
- Frame Check Sequence
- Flag Sequence (ending)

3.1.1 Flag Sequence

This is a single octet field which always contains the binary value 01111110. Each frame must be bounded by Flag sequences and there must be two or more of these sequences between frames. The ending Flag sequence of a frame may not serve as the beginning Flag sequence of the succeeding frame. If the Flag sequence occurs in other fields, the zero bit insertion technique described in the standard is used to insure transparency.

3.1.2 Address Field

This field contains the address of either the local or remote station and is used by the receiving station to identify incoming frames as either command or response frames. The address field in a command frame contains the address of the remote (receiving) station; the address field in a response frame contains the address of the local (transmitting) station.

There are two addressing formats: Basic and Extended. The Basic addressing format requires an address space of one octet, thereby allowing a maximum of 255 unique addresses per station. The Extended addressing format allows two octets in the address field to provide additional addressing space for special applications. Optional function 7 (see Paragraph 3.2) implements the Extended addressing format.

AUTODIN II links using ADCCP control will be configured using Basic addressing. Extended addressing is included to provide for future growth and will not be used unless there is a valid requirement.

The two addressing formats are mutually exclusive, i.e. on any particular link, the addressing format used must be either Basic or Extended; a link may not alternate between Basic and Extended addressing.

3.1.3 Control Field

This field contains link control information such as commands, responses, and send/receive sequence number information. AUTODIN II links using terrestrial transmission paths use the Basic Control field format consisting of one octet of information. AUTODIN II links using satellite or other types of transmission media possessing long propogation delays use the Extended Control field format described in Optional function 10 of the standard. The Basic Control field format uses Modulo 8 sequence numbering; Extended Control field format uses Modulo 128 sequence numbering.

The Basic and Extended Control field formats are mutually exclusive. Links will use either Basic or Extended Control field formats and will not have the capability to alternate between the two formats.

3.1.3.1 Extended Address/Control Field Implementation Rules

In AUTODIN II ADCCP, the address and control fields are extended together, i.e., if the extended address field is implemented, the extended control field must also be implemented and vice versa. Extended address fields will be two bytes long; extended control fields will also be two bytes long. No other format is permitted.

3.1.4 Information Field

This field contains the actual information being transmitted over a link. The field size is variable and ranges from zero to a maximum of 5072 bits on access lines and 5168 bits on backbone links. The content of this field is transparent at the ADCCP level.

3.1.5 Frame Check Sequence

The Frame Check Sequence (FCS) field used in AUTODIN II deviates from that defined in the standard. It is based on a 32nd degree polynomial and occupies four octets (32 bits) rather than the two octet FCS given in the standard. The polynomial $X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^{8} + X^{7} + X^{5} + X^{4} + X^{2} + X + 1$ is used as a divisor for the FCS. This provides an undetected error probability of at least 2^{-32} and burst error detection of up to 32 bits.

3.2 SUPPORTED OPTIONS

AUTODIN II ADCCP supports the following Optional functions:

- Option 1 - provides the ability for stations to exchange identification
- Option 4 - provides the ability to exchange information fields without changing the send and receive sequence number variables
- Option 7 - provides extended addressing
- Option 8 - allows Information (I) frames as commands only
- Option 10 - provides extended (modulo 128) sequence numbering.

Further details concerning these options are contained in Section 11 of the standard.

3.3 COMMANDS

AUTODIN II ADCCP stations generate and service a subset of the Balanced Configuration command repertoire contained in the standard. In addition, certain commands needed to support Optional functions 1, 4, and 10 are supported.

3.3.1 Information (I) Command

I frames are considered commands when they contain the address of the remote station. In AUTODIN II, all I frames are sent as commands. Optional function 8 is implemented on all AUTODIN II ADCCP links.

3.3.2 Supervisory (S) Commands

AUTODIN II implements two S commands to perform supervisory link control.

3.3.2.1 Receiver Ready (RR) Command

The RR command is used to solicit a response from the remote station while indicating that the receiver is ready at the local station. In the AUTODIN II system, all RR commands must be answered with either an RR or Receiver Not Ready (RNR) response. During periods of link inactivity, RR or RNR commands will be interjected at periodic intervals to insure that the link is operating properly. The time period between initiation of RR commands during inactive periods is discussed in Section 8.

3.3.2.2 Receiver Not Ready Command

The RNR command is used to solicit a response from the remote station while indicating the local station receiver is busy. In the AUTODIN II system, all RNR commands must be answered with an RR or RNR response. During periods of link inactivity, RR or RNR commands will be interjected at periodic intervals. This procedure is discussed further in Section 8.

3.3.3 Unnumbered (U) Commands

AUTODIN II supports four U commands.

3.3.3.1 Mode-Setting Commands

There are two U commands which perform mode setting functions in the AUTODIN II system.

3.3.3.1.1 Set Asynchronous Balanced Mode (SABM) Command

The SABM command instructs the receiving station to reset all receive and transmit parameters and prepare to respond in the asynchronous balanced mode. Since AUTODIN II links always operate in the asynchronous balanced mode, the SABM serves only as a reset. Upon receipt of an SABM command, the send and receive sequence number variables are set to zero, existing error conditions are cleared, and the sequence number of the next expected frame is zero.

SABM commands are acknowledged via the Unnumbered Acknowledgement (UA) response.

3.3.3.1.2 Set Asynchronous Balanced Mode Extended (SABME) Command

The SABME command performs the same functions as the SABM command for those links which require the use of Optional function 10 (extended control field).

Receipt of an SABME command by a station which does not support Optional function 10 will result in the generation of a Frame Reject (FRMR) response.

SABME commands are acknowledged by the UA response using the extended control field format.

3.3.3.2 Information Transfer Commands

AUTODIN II ADCCP supports one U format information transfer command.

3.3.3.2.1 Unnumbered Information (UI) Command

The UI command permits the exchange of information fields without sequence number accountability. It supports Optional function 4.

UI commands are acknowledged by either UA, UI or RNR responses.

If a UI command with the P bit set is received, the next higher level of protocol is notified that a UI response is required.

The UI command will be implemented on a per link basis within the AUTODIN II system and is not considered part of the basic ADCCP service.

3.3.3.3 Recovery Commands

AUTODIN II ADCCP supports one U format recovery command.

3.3.3.3.1 Reset (RSET) Command

The RSET command causes the receiving station to reset all receive-related parameters. Upon receipt of this command, the receive sequence number variable is set to zero, all existing receive error conditions are cleared, and the sequence number of the next expected frame is zero.

RSET commands are acknowledged with a UA response.

The primary use of the RSET command within the AUTODIN II system is during frame sequence number error recovery. This is treated in detail in Section 7.

3.3.3.4 Miscellaneous Commands

AUTODIN II ADCCP supports one U format miscellaneous command.

3.3.3.4.1 Exchange Identification (XID) Command

This command implements a subset of Optional function 1. It permits the exchange of identification information between two stations. It is included solely for dial-in support and is not implemented on Mode VI SIP-to-SCM links or on SCM-to-SCM interswitch links.

XID commands will be acknowledged via XID responses.

The XID command is not considered part of the basic AUTODIN II ADCCP service and will be implemented on an as-required basis for dial-in links.

3.4 RESPONSES

AUTODIN II ADCCP stations generate and react to a subset of the Balanced configuration response repertoire contained in the standard. In addition, certain responses needed to support Optional functions 1 and 4 are implemented.

3.4.1 Supervisory Responses

AUTODIN II implements two S responses. They are used to acknowledge I command frames in certain instances, acknowledge receipt of S commands, and report certain error conditions.

3.4.1.1 Receiver Ready Response

RR responses are used to report the non-busy status of a receiving station. They also acknowledge receipt of all I command frames having sequence numbers less than that reported as the next send sequence number in the RR response frame control field. If a receiving station is not transmitting I command frames, the RR response is used to acknowledge receipt of I frames, provided the receiving station is non-busy. RR responses are also required as acknowledgements for RR or RNR commands, provided the receiving station is non-busy.

3.4.1.2 Receiver Not Ready Response

RNR responses are used to report the busy status of a receiving station. They also acknowledge receipt of all I command frames having sequence numbers less than that reported as the next send sequence number in the RNR response frame control field. If a receiving station is not transmitting I command frames, the RNR response is used to acknowledge receipt of I frames, provided the receiving station is busy. RNR responses are also required as acknowledgements for RR or RNR commands, provided the receiving station is busy.

3.4.2 Unnumbered Responses

AUTODIN II ADCCP supports four unnumbered responses.

3.4.2.1 Information Transfer Response

AUTODIN II ADCCP supports one U format information transfer response.

3.4.2.1.1 Unnumbered Information Response

The UI response permits the exchange of information fields without sequence number accountability and is used in conjunction with the UI command (see Paragraph 3.3.3.2.1) to provide support for Optional function 4. The UI response is generated by the next higher level of protocol if a UI command frame with the P bit set is received.

Optional function 4 (UI command/response) will be implemented on a per link basis within the AUTODIN II system and is not considered part of the basic ADCCP service.

3.4.2.2 Miscellaneous Responses

AUTODIN II ADCCP supports two miscellaneous responses.

3.4.2.2.1 Exchange Identification Response

This response is sent to acknowledge receipt of an XID command frame. It is included to provide support for Optional function 1 and is intended to support dial-in links (see Paragraph 3.3.3.4.1).

The request Disconnect (RD) response listed in the standard for Optional function 1 is not used in AUTODIN II.

3.4.2.2.2 Unnumbered Acknowledgement Response

UA responses are used to acknowledge receipt of SABM, SABME, UI, and RSET commands.

3.4.2.3 Error Recovery Response

AUTODIN II supports one error recovery response.

3.4.2.3.1 Frame Reject Reponse

The FRMR response is used to report error conditions which are not recoverable by retransmission of the errored frame. FRMR is generated by the following conditions:

- Receipt of an invalid command or response
- Receipt of an I or UI frame which contains an information field which exceeds the maximum length

Further details concerning implementation of the FRMR response are given in Section 7 of the standard and Section 7 of this document.

3.5 COMMAND/RESPONSE SUMMARY

The basic ADCCP service provided on all AUTODIN II Mode VI links includes the following command/response repertoire:

Command	Valid Responses
I	I command frame RR, RNR, FRMR
RR	RR, RNR, FRMR
RNR	RR, RNR, FRMR
RSET	UA, FRMR
SABM(E)	UA, FRMR

Mode VI links which do not support Optional function 10 will generate FRMR responses for SABME commands.

ADCCP commands and responses which will be supported on a per link basis and are considered enhancements to the basic repertoire are:

Command	Valid Responses
UI	UA, UI, RNR, FRMR
XID	XID, FRMR

Mode VI links which do not support these enhancements will generate FRMR responses for the XID and UI commands.

4.1 SELF-TEST MODE

All AUTODIN II ADCCP stations are capable of operating in the Self-Test mode upon command from the higher level protocol. Self-Test Mode is defined as "loop back" operation, i.e., data sent by the local station transmit logic will "loop back" to the receive logic.

Given an ADCCP controlled link AB with ADCCP station A at one end and ADCCP station B at the other end, Self-Test mode can be described as follows:

- In the "normal" mode of operation, when station A sends a command to Station B, the command frame will contain B in the address field. However, in the Self-Test mode this command frame will appear to be a response frame from station B to station A.
- In the "normal" mode of operation, when station A sends a response to station B, the response frame will contain an A in the address field. However, in the Self-Test mode this response frame will appear to be a command frame from station B to station A.
- It can be stated, when a station is in Self-Test mode a command will appear to be a response and a response will appear to be a command.

An AUTODIN II ADCCP station operating in Self-Test mode is also considered to be off-line and will discard frames received from the remote station.

5.1 INITIALIZATION REQUIREMENTS

The higher level protocol may initialize AUTODIN II ADCCP links by requesting that the local ADCCP station transit an SABM(E) command. Upon acceptance of the request, the local ADCCP station will transmit the SABM(E) at the earliest opportunity and notify the higher level protocol that link initialization is in progress. All service requests from the higher level protocol will then be denied until the local ADCCP station receives a UA response to the SABM(E) command. Upon receipt of the UA response, the local ADCCP station will initialize its variables and data structures; the local send and receive sequence number variables will be set to zero, and the higher level protocol will be informed that the link is initialized and normal operations may commence.

6.1 ACKNOWLEDGEMENT REQUIREMENTS

AUTODIN ADCCP stations acknowledge receipt of error-free command frames without waiting for a stimulus from the transmitting station. At the ADCCP level, the state of the P bit does not have any significance. The F bit in all response frames assumes the state of the P bit in the command frame which provoked the response.

6.1.1 Information Frame Acknowledgement

Acknowledgement of I frames is accomplished by one of two methods. These are:

- Updating the N(R) count in an outgoing I frame. If the station is currently transmitting I frames, the updated N(R) count is inserted in the next outgoing I frame.
- Generating an RR or RNR response containing the updated N(R) count in the case where the station has no I frames to transmit.

In either case, the N(R) count acknowledges all I frames having sequence numbers up to and including N(R) - 1.

ADCCP stations using the Basic Control field format can send a maximum of seven I frames prior to acknowledgement. Those using the Extended Control field format can send a maximum of 127 I frames prior to acknowledgement. In either case, however, the actual number of I frames sent prior to acknowledgement can be decreased if existing station resources will not support the preceding values. Once set, however, this parameter remains constant and cannot be changed via ADCCP level commands.

6.1.2 Supervisory Frame Acknowledgement

AUTODIN II ADCCP requires that all S command frames be acknowledged by an S response frame. Only one S command may be outstanding at any one time. Stations do not queue S commands at the ADCCP level.

6.1.3 Unnumbered Frame Acknowledgement

All U command frames are acknowledged by generating a UA response at the earliest opportunity. Only one U command may be outstanding at any one time. Stations do not queue U commands at the ADCCP level.

6.1.4 Miscellaneous Frame Acknowledgements

The miscellaneous command XID is acknowledged via an XID response. Only one XID command may be outstanding at any one time.

7.1 EXCEPTION CONDITION AND ERROR RECOVERY

ADCCP level exception condition reporting and error recovery procedures are discussed in the following paragraphs. AUTODIN II ADCCP uses the Time-Out Recovery method described in Section 8 of the standard to initiate recovery procedures. The Reject (REJ), Selective Reject (SREJ), and Checkpoint recovery methods discussed in the standard are not implemented.

7.1.1 Busy Condition

A busy condition occurs when a station temporarily cannot receive or continue to receive I frames due to internal constraints, e.g., receive buffer limitations. The busy condition is reported by transmission of an RNR response frame with the N(R) of the next I frame that is expected.

Upon receipt of an RNR response, the transmitting station will generate either an RR or RNR command. The transmitting station will continue sending the RR or RNR command until the busy condition clears (an RR response is received).

7.1.2 Frame Check Sequence Error

All frames which contain FCS errors are discarded by the receiving station and no further processing occurs.

7.1.3 Frame Sequence Number Errors

I frames having sequence number errors, i.e., N(S) is not equal to the R variable of the receiving station, will be discarded after the N(R) value is extracted from the frame. Since the I frame does not have an FCS error, the N(R) information is assumed to be valid.

7.1.4 Time-Out Recovery

AUTODIN II ADCCP requires that various response timers be maintained at each transmitting station in order to implement the Time-Out Recovery.

7.1.4.1 Unnumbered Command Timer

This timer is started when a U command is sent. If a valid response is not received prior to expiration of the timer, the command is retransmitted. If the command is sent three times without a response, the next higher level of protocol is notified. The ADCCP level will, however, continue to retransmit the command until told otherwise by the next higher level of protocol.

The optimal U timer interval is dependent on particular link characteristics such as transmission speed and distance. As a general rule, the U timer value should be determined using the following:

- Mean U command frame transmission time
- Mean U response frame transmission time
- Mean U response generation time
- Propagation delays
- Some delta value which can be varied in order to arrive at an optimal U timer value for each particular link.

7.1.4.2 Supervisory Command Timer

This timer is started when an S command is sent. If a valid response is not received prior to timer expiration, the command is retransmitted. If the command is sent three times without a response, the next higher level of protocol is notified. The ADCCP level will, however, continue to retransmit the command until told otherwise by the next higher level of protocol.

The optimal S timer interval is dependent on particular link characteristics such as transmission speed and distance. As a general rule, the S timer value should be determined using the following:

- Mean S command frame transmission time
- Mean S response frame transmission time
- Mean S response generation time
- Propagation delays
- Some delta value which can be varied in order to arrive at an optimal S timer value for each particular link.

7.1.4.3 Information Frame Timer

This timer is started on the occurrence of one of the following conditions:

- There are no more I frames to send
- The maximum number of unacknowledged I frames have been sent.

If the timer expires and the I frames are still outstanding (unacknowledged), the appropriate S command frame is sent to solicit an acknowledgement and the S timer is started. If the RR or RNR command is transmitted three times without a response, the next higher level of protocol is notified of this condition. The ADCCP level then continues to send the RR or RNR command until instructed otherwise by the higher level of protocol.

If a response to the S command frame is received prior to S timer expiration, its N(R) will satisfy one of three cases:

- N(R) acknowledges all outstanding I frames
- N(R) acknowledges a subset of the outstanding I frames
- N(R) is unbelievable, i.e., out of range.

In the first case, the error recovery is successful and complete. The outstanding I frames are no longer candidates for retransmission and are purged. Any pending I frames are assigned sequence numbers starting with the value of N(R) and scheduled for transmission.

In the second case, the error recovery is partial. The acknowledged I frames are purged and the remaining outstanding I frames are scheduled for transmission. In addition, pending I frames may also be scheduled for transmission at this time, provided that the maximum outstanding frame count is not exceeded.

In the third case, it is assumed that the remote station has lost synchronization. A RSET command is sent and the U timer is started. If a UA response is received prior to U timer expiration, the outstanding I frames are assigned new sequence numbers starting with zero and normal I frame transmission resumes. If the RSET command is sent three times without receiving a response, the next higher level of protocol is notified that the RSET has failed. The ADCCP level then sends an SABM command and starts the U timer. If the SABM is sent three times without receiving a response, the next higher level of protocol is notified that the SABM has failed. The ADCCP level continues sending SABM commands until instructed otherwise by the next higher level of protocol. If a response is received prior to the third U timer expiration, the higher level of protocol is notified, the outstanding I frames are assigned new sequence numbers starting with zero, and normal I frame transmission resumes.

The optimal I timer value is dependent on particular link characteristics such as transmission speed and distance. In addition, the distribution of I frame lengths is a contributing factor. The I timer value must be of a long enough duration to insure that excessive retransmissions do not occur due to acknowledgements arriving after timer expiration.

I timer values should be determined during installation and test of AUTODIN II ADCCP-controlled links on a per link basis.

7.1.5 Frame Reject Conditions

AUTODIN II ADCCP stations initiate a FRMR response upon receipt of an error-free frame (FCS is valid) containing the following:

- An invalid command or response
- An I field which exceeds the maximum length.
- An invalid frame format, e.g., a frame which does not conform to the structure implied by the command/response contained in its control field.

The AUTODIN II ADCCP implementation does not generate an FRMR response to frames containing invalid N(R) fields. Recovery from this condition is discussed in Paragraph 7.1.6.

Upon receipt of an FRMR, an indication is sent to the next higher level of protocol.

Additional details concerning the FRMR response are contained in Sections 7.5.3.1 and 8.4 of the standard.

7.1.6 Invalid N(R) Resolution

An invalid N(R) is defined as a number 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 (see Section 7.5.3.1 of the standard).

Receipt of a frame containing an invalid N(R) implies that synchronization has been lost, i.e., the send sequence number variable S at the local station does not match the receive sequence number variable R at the remote station.

When an AUTODIN II ADCCP station receives a frame containing an invalid N(R) value, it will send a RSET command to the remote station and start the U timer. If the RSET command is acknowledged prior to U timer expiration, any outstanding I frames are assigned new sequence numbers starting with zero and normal I frame transmission resumes. If the RSET is sent three times without receiving a response, the next higher level of protocol is notified and the ADCCP level sends an SABM command. If the SABM command is sent three times and no acknowledgement is received, the next higher level of protocol is notified. The ADCCP level continues sending the SABM until told otherwise. If a response to the SABM is received prior to the third time-out, the higher level of protocol is notified, any outstanding I frames are assigned new sequence numbers starting with zero, and normal I frame transmission resumes.

Additional detail concerning the RSET command is contained in Section 7.4.3 of the standard.

7.1.7 Mode-Setting Contention

A mode-setting contention situation exists when a station issues a mode-setting command, i.e., SABM or SABME and receives a mode-setting command from the remote station prior to receiving the proper response to the issued command. In the AUTODIN II system, this contention is resolved as follows:

- Each station sends a UA response and enters the indicated mode.

8.1 TIMING AND SYNCHRONIZATION

AUTODIN II ADCCP uses continuous Flag sequences for interframe time fill, frame recognition and synchronization.

8.1.1 Idle-Link State

AUTODIN II ADCCP does not recognize the idle link time fill described in Section 3.9 of the standard. AUTODIN II ADCCP-controlled links operate only in the Active state described in Section 3.8 of the standard.

8.1.2 Abort Sequence

AUTODIN II ADCCP stations generate and recognize the abort sequence described in Section 3.6 of the standard.

8.1.3 <u>Inactive Link Timer</u>

AUTODIN II ADCCP stations maintain a timer which monitors link activity. If the local station is inactive, i.e., sending Flag sequences only during the interval of the timer, a Supervisory command will be sent upon timer expiration and the timer will be restarted.

The interval of this timer must be greater than that of the S command timer discussed in Paragraph 7.1.4.2 and S timer expiration will cause this timer to be restarted if it is running.

The optimal value for this timer interval is dependent on particular link characteristics and should be determined in conjunction with the S timer interval value (see Paragraph 7.1.4.2).

9.1 DETAILED FUNCTIONAL DESCRIPTION

This section contains a detailed functional description of AUTODIN II ADCCP. The description is presented as a group of functional modules, each of which is described using a high-level structured design language. It assumes that the top level ADCCP module communicates with a higher level protocol module and a line control module which performs basic line buffering and transmit/receive functions. A pictorial representation of these interactions is shown in Figure 9.1-1.

For purposes of this description, each ADCCP station is assumed to contain a transmitter, a receiver, and a controller which coordinates the actions of the transmitter and receiver. An illustration of this concept is shown in Figure 9.1-2.

9.1.1 Structured Design Language

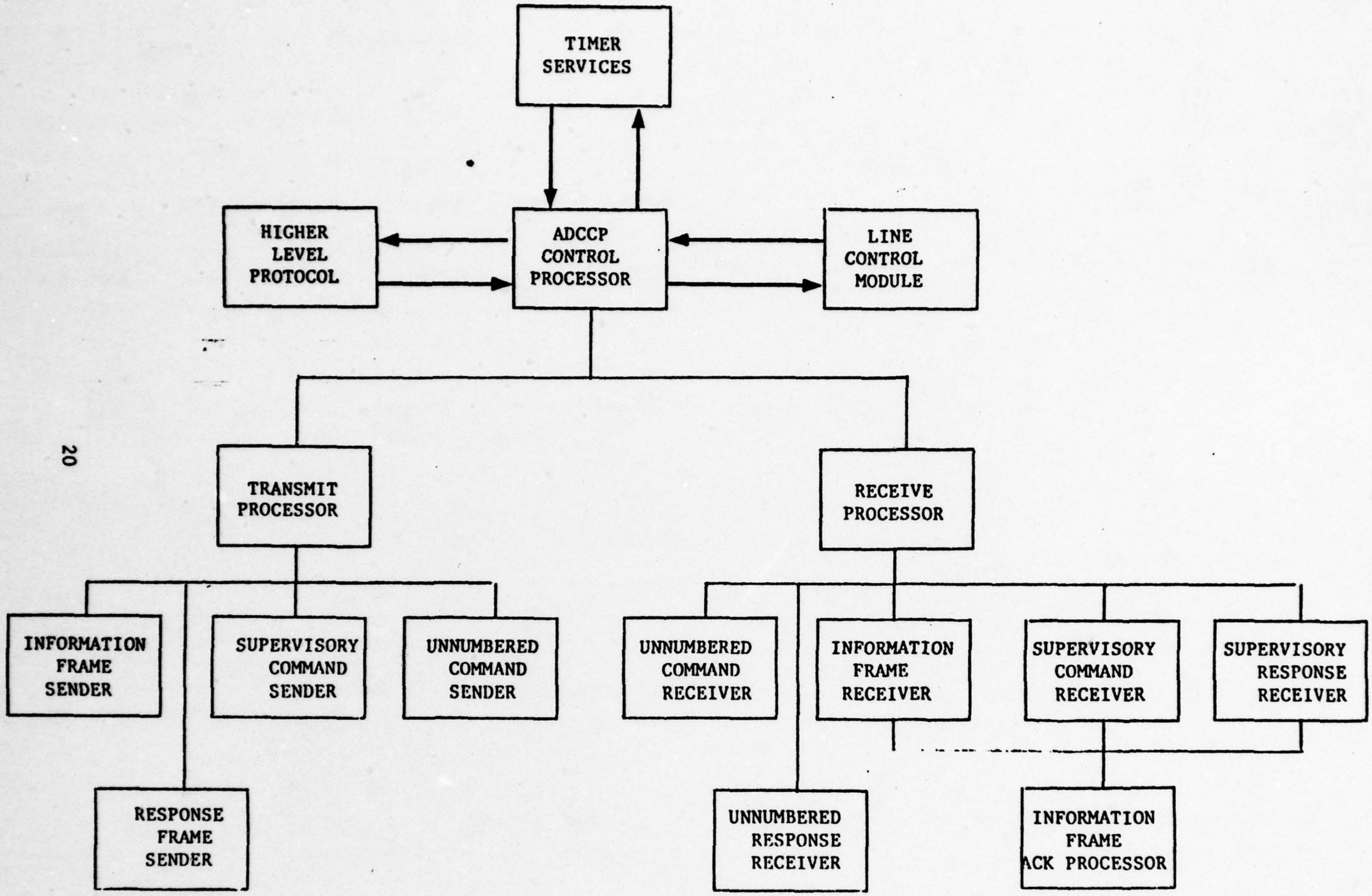
The structured design language consists of four basic constructs. These are:

- BEGIN [procedure]
- END [procedure]
- IF [condition] THEN [action]
  ELSEIF [condition] THEN [action] (optional)
  •
  •
  •
  ELSE [action] (optional)
  ENDIF
- CALL [procedure]

BEGIN statements are used to delineate the beginning of a functional procedure; END statements are used to denote the end of a functional procedure.

IF statements are the main vehicle used to describe the AUTODIN II ADCCP functions. Each IF statement must consist of at least the following:

- IF [condition] THEN [action] ENDIF



FIGU   I-1 ADCCP Functional Speci   Block Diagram

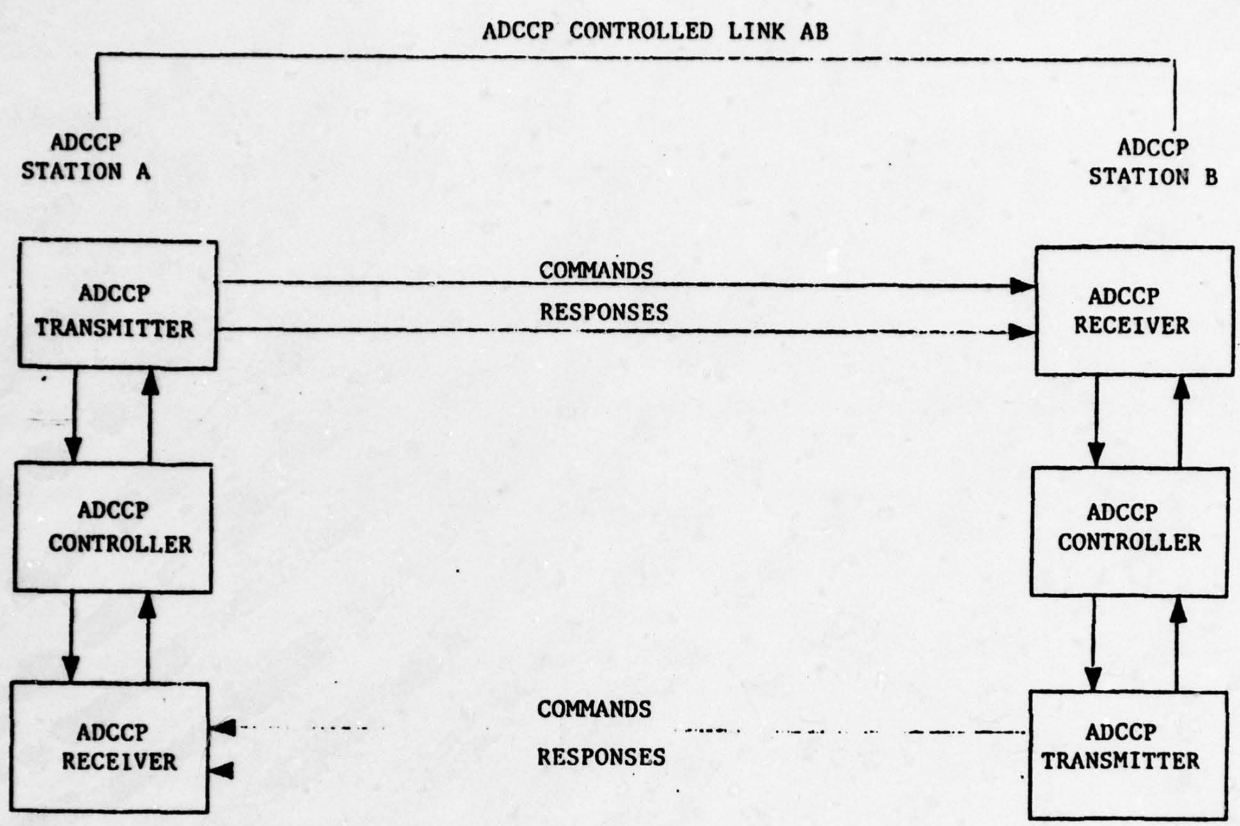


FIGURE 9.1-2 ADCCP Station Functional Representa

IF statements may contain any number of ELSEIF constructs. Only one ELSE construct may be present and it must immediately precede the ENDIF keyword.

CALL statements are used to pass control to subroutines which execute and then return control to the CALLing routine at the next sequential statement.

9.1.2 ADCCP Control Processor States

The ADCCP Control Processor's reaction to stimuli from the Higher Level Protocol or Line Control Module is a function of the existing Control Processor state. The Control Processor may assume the following states:

- Normal
- Acknowledgement Required
- Acknowledgement Solicited
- Reset Outstanding
- Set Asynchronous Balanced Mode (Extended) Outstanding
- Supervisory Command Lock
- *Unnumbered Command* Lock

The Normal state indicates that no exception or error conditions exist.

The Acknowledgement Outstanding state indicates that the information frame transmission queue is full, i.e., the maximum allowed number of information frames are outstanding.

The Acknowledgement Solicited state indicates that the Information Frame Timer has expired prior to reception of an acknowledgement for outstanding information frames.

The Reset Outstanding state indicates that a RSET command has been sent back but not yet acknowledged.

The Set Asynchronous Balanced Mode (Extended) Outstanding state indicates that a SABM(E) command has been sent but not yet acknowledged.

The Supervisory Command Lock state indicates that a Supervisory command has been transmitted three or more times and has not been acknowledged.

The Unnumbered Command Lock state indicates that an Unnumbered command has been transmitted three or more times and has not been acknowledged.

9.1.3 Flag Variables

The logical flow through all functional procedures is controlled by testing the value of certain variables which are used as flags, or switches. These flag variables are considered active when set and inactive when reset.

9.1.4 Data Structures

The major data structure referenced in the functional description is the Information Frame Transmission Queue, a First-In-First-Out (FIFO) queue which holds outstanding I frames, i.e., those which have not been acknowledged by the remote station. I frames are placed on this queue by the Information Frame Sender module and removed by the Information Frame Acknowledgement Processor module.

Other significant data structures which are either referenced or implied by the functional description are:

- Supervisory Command Frame Buffer
- Supervisory Response Frame Buffer
- Unnumbered Command Frame Buffer
- Unnumbered Response Frame Buffer

The Supervisory Command Frame Buffer holds S command frames waiting for transfer to the line control module. Once the frame is transferred to the line control module, the buffer is released since S commands can change state (RR versus RNR) when retransmitted depending on the conditions at the local receiver.

The Supervisory Response Frame Buffer holds S response frames waiting for transfer to the line control module. Once the frame is transferred to the line control module, the buffer is released.

The Unnumbered Command Frame Buffer holds U command frames waiting for transfer to the line control module. In the case of the SABM(E) and RSET command frames this buffer may be released since these frames contain no variable data and may be easily reconstructed if retransmission is necessary.

In the case of the UI and XID command frames, however, the frames must be held in the buffer for possible retransmission since their information content may vary as determined by the higher level protocol.

The Unnumbered Response Frame Buffer holds U response frames waiting for transfer to the line control module. Once the frame is passed to the line control module, the buffer is released.

9.1.5 Functional Procedures

The remainder of this section contains the structured design language functional descriptions.

```
BEGIN ADCCP Control Processor
IF line control module transmit buffer available signal THEN
    IF supervisory frame waiting for transmission THEN
        insert current value of local receive variable into
        control field; copy frame into line control module buffer;
        IF supervisory command outstanding flag is set THEN
            start supervisory command timer
        ENDIF
    ELSEIF unnumbered command frame waiting for transmission THEN
        copy frame into line control module transmit buffer;
        start unnumbered command timer
    ELSEIF unnumbered response frame waiting for transmission THEN
        copy frame into line control module transmit buffer
    ELSE IF remote receiver not ready flag is reset THEN
        IF unnumbered information frame waiting for transmission THEN
            IF unnumbered command outstanding flag set THEN
                start unnumbered command timer
            ENDIF
            copy frame into line control module transmit buffer
        ELSEIF information frame waiting in information frame
            transmission queue THEN insert current value of
            local receive variable into control field; copy
            frame into line control module transmit buffer
            IF information frame timer is running THEN
                restart information frame timer
            ELSE start information frame timer
            ENDIF
        ENDIF
    ENDIF
ELSEIF no line control module receive buffer available signal THEN
    set local receiver not ready flag; set response required
    flag; set supervisory response required flag;
    CALL Transmit Processor
ELSEIF line control module receive buffer available signal THEN
    reset local receiver not ready flag
ELSEIF information frame transmission request from higher level protocol THEN
    IF normal state THEN
        CALL Transmit Processor
        IF information frame acknowledgement required flag set THEN
            enter acknowledgement required state
        ENDIF
        send request honored signal to higher level protocol
    ELSE send request denied signal to higher level protocol
    ENDIF
ELSEIF information frame timer has expired THEN
    IF normal state THEN
        CALL Transmit Processor;
        enter acknowledgement solicited state
    ELSEIF acknowledgement required state THEN
        CALL Transmit Processor;
        enter acknowledgement solicited state
    ENDIF
ELSEIF supervisory command timer has expired THEN
    IF normal or acknowledgement required state THEN
        CALL Transmit Processor
        IF no supervisory response received flag is set THEN
            enter supervisory command lock state;
            notify higher level protocol
        ENDIF
    ELSEIF acknowledgement solicited state THEN
```

```
        CALL Transmit Processor
        IF no unnumbered response received flag set THEN
            enter supervisory command lock state;
            notify higher level protocol
        ENDIF
    ENDIF
ELSEIF unnumbered command timer has expired THEN
    CALL Transmit Processor
    IF no unnumbered response received flag set THEN
        enter unnumbered command lock state;
        notify higher level protocol
    ENDIF
    IF reset outstanding state THEN
        IF no unnumbered response received flag is set THEN
            enter asynchronous balanced mode (extended) outstanding
            state; notify higher level protocol
        ENDIF
    ELSEIF set asynchronous balanced mode (extended) outstanding state THEN
        IF no unnumbered response received flag set THEN
            enter unnumbered command lock state; notify
            higher level protocol
        ENDIF
    ENDIF
ELSEIF unnumbered command frame transmission request from higher
    level protocol THEN
    IF normal or acknowledgement required or
        acknowledgement solicited state THEN
        CALL Transmit Processor; send request honored signal
        to higher level protocol
    ELSE send request denied signal to higher level protocol
    ENDIF
ELSEIF unnumbered response frame transmission request from higher
    level protocol THEN
    IF normal  or acknowledgement required or acknowledgement solicited
        state THEN
        CALL Transmit Processor; send request honored signal to
        higher level protocol
    ELSE send request denied signal to higher level protocol
    ENDIF
ELSEIF initialization request from higher level protocol THEN
    set send set asynchronous balanced mode (extended) command
    flag; CALL Transmit Processor; enter set asynchronous
    balanced mode outstanding state; send request honored
    signal to higher level protocol
ELSEIF inactive link timer expiration THEN
    CALL Transmit Processor
ELSEIF frame received from remote station THEN
    CALL Receive Processor
    IF response required flag set THEN
        CALL Transmit Processor
    ELSEIF send supervisory command flag set THEN
        CALL Transmit Processor
    ELSEIF remote receiver ready flag set THEN
        CALL Transmit Processor; reset remote receiver
        ready flag
    ELSEIF frame reject response required flag set THEN
        CALL Transmit Processor
    ELSEIF send reset command flag set THEN
        IF supervisory command outstanding flag set THEN
            reset send reset command flag;
```

```
                enter acknowledgement solicited state
            ELSEIF unnumbered command outstanding flag reset THEN
                CALL Transmit Processor;
                enter reset outstanding state;
                reset send reset command flag;
                stop information frame timer;
                notify higher level protocol
            ENDIF
        ELSEIF frame discard flag set THEN
            discard frame; reset frame discard flag
        ELSEIF frame reject received THEN
            IF  outstanding information frame rejected  THEN
                notify higher level protocol
            ELSEIF outstanding supervisory frame rejected THEN
                notify higher level protocol
            ELSEIF outstanding unnumbered frame rejected THEN
                notify higher level protocol
            ENDIF
        ENDIF
        IF acknowledgement required state THEN
            IF one or more outstanding information frames have
                been acknowledged THEN
                enter normal state; notify higher level protocol of
                number of free slots in information frame transmission queue
            ENDIF
        ELSEIF acknowledgement solicited state THEN
            IF one or more outstanding information frames have
                been acknowledged THEN enter normal state;
                notify higher level protocol of number of free
                slots in information frame transmission queue
            ENDIF
        ELSEIF reset outstanding state THEN
            IF reset command outstanding command flag is reset THEN
                enter normal state; notify higher level protocol
            ELSE discard frame
            ENDIF
        ELSEIF set asynchronous balanced mode (extended) outstanding
            state THEN
            IF set asynchronous balanced mode (extended) command
                outstanding flag is reset THEN
                enter normal state; notify higher level protocol
            ELSE discard frame
            ENDIF
        ELSEIF supervisory command lock state THEN
            IF supervisory command outstanding flag is reset THEN
                enter normal state; notify higher level protocol
                IF one or more outstanding information frames have
                    been acknowledged THEN notify higher level protocol
                    of free slots in information frame transmission
                    queue
                ENDIF
            ELSE discard frame
            ENDIF
        ELSEIF unnumbered command lock state THEN
            IF unnumbered command outstanding flag is reset THEN
                enter normal state; notify higher level protocol
            ELSE discard frame
            ENDIF
        ENDIF
    ENDIF
```

```
$$$INDE$$nSoAtrBtoRcessor
IF response required flag is set THEN
    CALL Response Frame Sender
    restart inactive link timer
ELSEIF unnumbered command timer has expired THEN
    IF command has been sent three times THEN
        set no unnumbered response received flag
    ENDIF
    CALL Unnumbered Command Sender
    restart inactive link timer
ELSEIF supervisory timer has expired THEN
    IF command has been sent three times THEN
        set no supervisory response received flag
    ENDIF
    CALL Supervisory Command Sender

    restart inactive link timer
ELSEIF inactive link timer has expired THEN
    CALL Supervisory Command Sender;
    start inactive link timer
ELSEIF information frames waiting for transmission THEN
    CALL Information Frame Sender
    restart inactive link timer
ELSEIF unnumbered command to be sent THEN <=
    CALL Unnumbered Command Sender
    restart inactive link timer
ELSEIF supervisory command to be sent THEN
    CALL Supervisory Command Sender
    restart inactive link timer
ELSEIF information frame timer has expired THEN
    CALL Supervisory Command Sender
    restart inactive link timer
ENDIF
IF line control module transmit buffer available THEN
    IF supervisory frame waiting for transmisson THEN
        insert current value of local receive variable into
        control field; copy frame into line control module
        transmit buffer
        IF supervisory command outstanding flag is set THEN
            start supervisory command timer
        ENDIF
    ELSEIF unnumbered command frame waiting for transmission THEN
        copy frame into line control module transmit buffer;
        start unnumbered command timer
    ELSEIF unnumbered response waiting for transmission THEN
        copy frame into line control module transmit buffer
    ELSE IF remote receiver not ready flag is reset THEN
        IF unnumbered information frame waiting for transmission THEN
            IF unnumbered command outstanding flag set THEN
                start unnumbered command timer
            ENDIF
            copy frame into line control module transmit buffer
        ELSEIF information frame waiting in information frame
            transmission queue THEN insert current value of local
            receive variable into frame control field; copy
            frame into line control module transmit buffer
            IF information frame timer is running THEN
                restart information frame timer
            ELSE start information frame timer
            ENDIF
```

```
        ENDIF
    ENDIF
ENDIF
END ADCCP Transmit Processor
```

```
BEGIN Response Frame Sender
IF required response is unnumbered THEN
     IF response to set asynchronous balanced mode (extended) command THEN
          reset local send and receive variables; reset all flags
     ENDIF
     IF response to reset command THEN
          reset local receive variable; reset all receive-related flags
     ENDIF
     IF required response is unnumbered acknowledgement THEN
          reset unnumbered acknowledgement response required flag
     ELSEIF required response is frame reject THEN
          reset frame reject response required flag;
          insert control field of rejected frame into response
     ELSEIF required response is exchange identification THEN
          reset exchange identification response required flag;
          get identification data from ADCCP Control Processor
     ELSEIF required response is unnumbered information THEN
          set f bit in response frame control field;
          get data for information field from ADCCP Control Processor
     ENDIF
     build appropriate unnumbered response frame; schedule frame for
     transmission
ELSE IF required response is supervisory THEN
     IF local receiver not ready flag reset THEN
          generate receiver ready response
     ELSE generate receiver not ready response
     ENDIF
     insert current value of local receive variable in frame control
     field; build appropriate supervisory response frame;
     schedule frame for transmission
ENDIF
reset response required flag
END Response Frame Sender
```

```
BEGIN Information Frame Sender
insert frame at tail of information frame transmission queue
IF information frame transmission queue is full THEN
    set information frame acknowledgement required flag
ENDIF
END Information Frame Sender
```

```
BEGIN Supervisory Command Sender
IF local receiver not ready-flag reset THEN
    generate receiver ready command
ELSE generate receiver not ready command
ENDIF
insert current local receive variable in frame control field;
reset send supervisory command flag;
schedule frame for transmission;
set supervisory command outstanding flag;
END Supervisory Command Sender
```

```
BEGIN Unnumbered Command Sender
IF send set asynchronous balanced mode (extended) command flag set THEN
    reset send asynchronous balanced mode (extended) command flag;
    set asynchronous balanced mode (extended) command outstanding flag
ELSEIF send reset command flag set THEN
    reset send reset command flag
    IF no unnumbered response received flag is set THEN
        set set asynchronous balanced mode (extended) command
        outstanding flag; reset reset command outstanding flag
    ELSE set reset command outstanding flag
    ENDIF
ELSEIF send unnumbered information command flag set THEN
    set unnumbered information command outstanding flag;
    reset send unnumbered command flag;
    build information field with data from ADCCP Control Processor;
    IF ADCCP Control Processor wants unnumbered information response THEN
        set p bit in frame control field;
        set unnumbered information response required flag
    ELSE set unnumbered acknowledgement response required flag
    ENDIF
ELSEIF send set exchange identification command flag THEN
    reset send exchange identification command flag;
    set exchange identification command outstanding flag;
    build frame with identification data from ADCCP Control Processor
ENDIF
generate proper command;
schedule frame for transmission;
END Unnumbered Command Sender
```

```
BEGIN Receive Processor
restart inactive link timer;
IF frame check sequence is valid THEN
     IF address field contains local station address THEN
          IF not in self-test mode THEN
               set command received flag; reset response received flag
          ELSE set response received flag; reset command received flag
          ENDIF
     ELSEIF address field contains remote station address THEN
          IF not in self-test mode THEN
               set response received flag; reset command received flag
          ELSE set command received flag; reset response received flag
          ENDIF
     ELSE set frame reject flag; set invalid frame format flag; save
          control field of rejected frame
     ENDIF
     IF command received flag is set THEN
          IF information frame THEN
               CALL Information Frame Receiver
          ELSEIF supervisory command frame THEN
               CALL Supervisory Command Receiver
          ELSEIF unnumbered command frame THEN
               CALL Unnumbered Command Receiver
          ELSE set frame reject flag; set invalid command flag;
               save control field of rejected frame
          ENDIF
          reset command received flag
     ELSEIF response received flag is set THEN
          IF Supervisory Response THEN
               CALL Supervisory Response Receiver
          ELSEIF Unnumbered Response THEN
               CALL Unnumbered Response Receiver
          ELSE set frame reject flag; set invalid response flag;
               save control field of rejected frame
          ENDIF
          reset response received flag
     ENDIF
     IF frame reject flag is set THEN
          reset frame reject flag; set frame reject response required flag;
          set response required flag
     ENDIF
ELSE discard frame with invalid frame check sequence
ENDIF
END ADCCP Receive Processor
```

```
BEGIN Information Frame Receiver
IF information field exceeds maximum allowed length THEN
     set frame reject flag; set information field maximum length
     exceeded flag
ENDIF
IF send sequence number of received information frame is not equal
     to value of local receive variable THEN
     set frame discard flag
ENDIF
CALL Information Frame Acknowledgement Processor
IF frame discard flag is reset THEN
     IF frame reject flag is reset  THEN
          schedule information field contents for transfer to
          higher level protocol via ADCCP Control Procedure
          IF no information frames waiting for transmission
               or remote receiver not ready flag is set THEN
               set response required flag; set supervisory response
               required flag
          ENDIF
     ENDIF
ENDIF
END Information Frame Receiver
```

```
BEGIN Supervisory Command Receiver
IF valid frame format THEN
    set response required flag; set supervisory response required flag
    CALL Information Frame Acknowledgement Processor
ELSE set frame reject flag; set invalid frame format flag; save
    control field of rejected frame
ENDIF
END Supervisory Command Receiver
```

```
.GIN Supervisory Response Receiver
.F valid frame format THEN
    IF receiver ready response THEN
        IF remote receiver not ready flag is set THEN
            set remote receiver ready flag;
            reset remote receiver not ready flag
        ENDIF
    ELSEIF receiver not ready response THEN
        set send supervisory command flag
        IF remote receiver not ready flag is reset THEN
            set remote receiver not ready flag
        ENDIF
    ENDIF
    IF no supervisory response received flag is set THEN
        reset no supervisory response received flag
    ENDIF
    IF supervisory response required flag is set THEN
        reset supervisory response required flag;
        stop supervisory command timer
    ENDIF
    CALL Information Frame Acknowledgement Processor
ELSE set frame reject flag; set invalid frame format flag;
    save control field of rejected frame
ENDIF
END Supervisory Response Receiver
```

```
BEGIN Unnumbered Command Receiver
IF  set asynchronous balanced mode(extended) command THEN
    IF valid frame format THEN
        reset local send and receive variables; reset all flags;
        set unnumbered acknowledgement required flag;
        resequence all outstanding information frames;
        discard any outstanding supervisory or unnumbered
        commands;
    ELSE set frame reject flag; set invalid frame format flag; save
        control field of rejected frame
    ENDIF
ELSEIF reset command THEN
    IF valid frame format THEN
        reset local receive variable; reset receive-related flags;
        set unnumbered acknowledgement required flag
    ELSE set frame reject flag; set invalid frame format flag; save
        control field of rejected frame
    ENDIF
ELSEIF unnumbered information command THEN
    IF invalid frame format THEN
        set frame reject flag; set invalid frame format flag; save
        control field of rejected frame
    ELSEIF information field exceeds maximum allowed length THEN
        set frame reject flag; set information field maximum
        length exceeded flag; save control field of rejected
        frame
    ELSE IF p bit is set THEN
        notify higher level protocol via ADCCP Control
        Processor that an unnumbered information response is
        required
    ELSE set unnumbered acknowledgement response required flag
    ENDIF
    schedule information field contents for transfer to higher
    level protocol via ADCCP Control Procedure
ELSEIF exchange identification command THEN
    IF valid frame format THEN
        set exchange identification response required flag;
        schedule identification information for transfer to
        higher level protocol via ADCCP Control Procedure
    ELSE set frame reject flag; set invalid frame format flag;
        save control field of rejected frame
    ENDIF
ENDIF
set response required flag
END Unnumbered Command Receiver
```

```
BEGIN Unnumbered Response Receiver
IF unnumbered response required flag is set THEN
    IF unnumbered acknowledgement response THEN
        IF valid frame format THEN
            IF set asynchronous balanced mode (extended) command outstanding
                flag is set THEN
                reset set asynchronous balanced mode (extended) command
                outstanding flag; reset local send and receive variables;
                stop unnumbered command timer;
                reset all flags
            ELSEIF reset command outstanding flag is set THEN
                reset local receive variable; reset receive-related
                flags; reset reset command outstanding flag;
                stop unnumbered command timer
            ELSEIF unnumbered information command outstanding flag is set THEN
                IF unnumbered acknowledgement response required flag is set THEN
                    reset unnumbered information command outstanding flag;
                    stop unnumbered command timer
                ENDIF
            ENDIF
        ELSE set frame reject flag; set invalid frame format flag; save
            control field of rejected frame
        ENDIF
    ELSEIF unnumbered information response THEN
        IF valid frame format THEN
            IF unnumbered information response required flag is set THEN
                reset unnumbered information command outstanding flag;
                reset unnumbered information response required flag;
                stop unnumbered command timer;
                schedule information field contents for transfer to
                higher level protocol via ADCCP Control Procedure
            ELSE discard frame
            ENDIF
        ELSE set frame reject flag; set invalid frame format flag; save
            control field of rejected frame
        ENDIF
    ELSEIF exchange identification response THEN
        IF valid frame format THEN
            IF exchange identification response required flag is set THEN
                reset exchange information response required flag;
                stop unnumbered command timer;
                schedule identification information for transfer to
                higher level protocol via ADCCP Control Procedure
            ELSE discard frame
            ENDIF
        ELSE set frame reject flag; set invalid frame format flag; save
            control field of rejected frame
        ENDIF
    ELSEIF frame reject response THEN
        IF valid frame format THEN
            IF rejected control field matches that of outstanding
                unnumbered command THEN
                reset appropriate outstanding unnumbered command flag
            ELSEIF rejected control field matches that of outstanding
                information frame THEN notify ADCCP Control
                Processor
            ELSEIF rejected control field matches that of outstanding
                supervisory command frame THEN notify ADCCP
                Control Processor
            ENDIF
```

```
        ELSE set frame reject flag; set invalid frame format flag; save
            control field of rejected frame
        ENDIF
    ENDIF
ELSE IF frame reject response THEN
    IF valid frame format THEN
        IF rejected frame is outstanding supervisory command THEN
            notify ADCCP Control Procedure
        ELSEIF rejected frame is outstanding information frame THEN
            notify ADCCP Control Procedure
        ENDIF
    ELSE discard frame
    ENDIF
ENDIF
END Unnumbered Response Receiver
```

```
BEGIN Information Frame Acknowledgement Processor
IF receive sequence number is valid THEN
    remove any outstanding information frames with send sequence
    numbers less than the receive sequence number from transmission
    queue; save count of number of free slots in transmission
    queue
    IF information frame acknowledgement required flag set THEN
        reset information frame acknowledgement required flag
    ELSEIF information frame acknowledgement solicited flag is set THEN
        reset information frame acknowledgement solicited flag
    ENDIF
ELSE set send reset command flag
ENDIF
END Information Frame Acknowledgement Processor
```

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SIXTH DRAFT

REVISION-2

PROPOSED
AMERICAN NATIONAL STANDARD
FOR
ADVANCED DATA COMMUNICATION
CONTROL PROCEDURES (ADCCP)

Prepared by
Task Group X3S34
on
Control Procedures
Technical Committee X3S3 on Data Communications
Committee X3 on Computers & Information Processing

BSR X3.66
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11 August 1977

Proposed

American National Standard

For Advanced Data Communication

Control Procedures (ADCCP)

Secretariat

Computer and Business Equipment Manufacturers Association

Approved ______________________

AMERICAN NATIONAL STANDARDS INSTITUTE

ABSTRACT Data Communication Control Procedures define the means for exchanging data between business machines (e.g., computers, concentrators and terminals) over communication circuits. The advanced data communication control procedures described in this standard are synchronous, bit oriented (i.e., use bit patterns instead of ASCII characters for control), code independent (i.e., capable of handling any data code or pattern) and interactive (i.e., have relatively high efficiency in an interactive application). Batch operation is handled with efficiency comparable to previous standards. Improvements have also been made with respect to previous standards in the areas of reliability and modularity.

FOREWORD (This Foreword is not a part of the American National Standard for Advanced Data Communication Control Procedures, BSR X3.66, 9 June 1977).

The development of advanced data communication control procedure standards began in late 1969 during final work on the American National Standard, Procedures for the Use of the Communication Control Characters of American National Standard Code for Information Interchange in Specified Data Communication Links, X3.28 - 1971. At that time, it was recognized that X3.28 lacked certain desirable capabilities that would be impractical to incorporate due to the basic philosophy of the standard. Consequently, several proposals were submitted by members of the Task Group for new and improved ways to perform the necessary link control functions. One of the most significant proposals was a bit-oriented approach that utilized dependent single sequence numbering. Out of this activity evolved a proposal for an American National Standard for ADCCP - Dependent Numbering. In late 1971 an approach was proposed based on an independent/dual numbering philosophy. Acceptance of this approach resulted in this American National Standard for ADCCP.

The basic objectives of the Advanced Data Communication Control Procedures are to provide:

a) Full transparency and code independence;
b) Efficient interactive and batch operation;
c) A high level of reliability;
d) Two-way alternate and two-way simultaneous operation;
e) A high level of modularity.

Suggestions for improvement of this standard will be welcome. They should be sent to the American National Standards Institute, 1430 Broadway, New York, New York 10019.

CONTENTS

LIST OF ABBREVIATIONS

A - Address field
ABM - Asynchronous Balanced Mode
ADCCP - Advanced Data Communication Control Procedures
ADM - Asynchronous Disconnect Mode
ARM - Asynchronous Response Mode
ARO - Asynchronous Respond Opportunity
BA - Balanced, Asynchronous Class
C - Control Field
C - Combined Station (Figure 10-1 only)
CCITT - International Telegraph and Telephone Consultative Committee
Comb - Combined (station)
DISC - Disconnect (Command)
DM - Disconnect Mode (Response)
ECMA - European Computer Manufacturers Association
F - Flag
F bit - Final Bit
FCS - Frame Check Sequence
FRMR - Frame Reject (Response)
I - Information (command, response)
I - Information Format (frame)
I frame - Information Format frame
ID - Identification
IM - Initialization Mode
Info - Information Field
IS - Initialization State
ISO - International Standards Organization
ITS - Information Transfer State
LDS - Logically Disconnected State
LSB - Least Significant Bit
M - Modifier Function Bit
MSB - Most Significant Bit
N - An integer variable
NA - Not Applicable
NDM - Normal Disconnect Mode
N(R) - Receive Sequence Number
NRM - Normal Response Mode
NRO - Normal Respond Opportunity
N(S) - Send Sequence Number
P bit - Poll Bit
P - Primary Station (Figure 10-1 only)
P/F bit - Poll or Final Bit
Pri - Primary (station)
P/S/C - Primary or Secondary or Combined (station)
Pri/Sec - Primary or Secondary (station)
R - Receive Variable
RD - Request Disconnect (Command)
RSET - Reset (Command)
REJ - Reject (Command, Response)
RIM - Request Initialization Mode (Response)

RNR - Receive Not Ready (Command, Response)
RR - Receive Ready (Command, Response)
S - Depending upon usage: - Send Variable
- Supervisory Function Bit
- Supervisory Format (frame)
S frame - Supervisory Format frame
S - Secondary Station (Figure 10-1 only)
SABM - Set Asynchronous Balanced Mode (Command)
SABME - Set Asynchronous Balanced Mode Extended (Command)
SARM - Set Asynchronous Response Mode (Command)
SARME - Set Asynchronous Response Mode Extended (Command)
Sec - Secondary (station)
SIM - Set Initialization Mode (Command)
SNRM - Set Normal Response Mode (Command)
SNRME - Set Normal Response Mode Extended (Command)
SREJ - Selective Reject (Command, Response)
TO - Timeout
TWA - Two-Way Alternate
TWS - Two-Way Simultaneous
U - Unnumbered Format (frame)
U frame - Unnumbered Format frame
UA - Unnumbered Acknowledgement (Response)
UA - Unbalanced, Asynchronous Class
UI - Unnumbered Information (Command, Response)
UN - Unbalanced, Normal Class
UP - Unnumbered Poll (Command)
XID - Exchange Identification (Command, Response)
W,X,Y,Z - bits in FRMR Status Field

NOTE: The mathematical symbols and abbreviations used in Section 12.0, Frame Check Sequence (FCS) Generation and Checking, and Appendix D, Frame Check Sequence (FCS), are not included above; they are defined as introduced in Section 12 and Appendix D.

1.0 SCOPE

This standard establishes the procedures to be used on synchronous communication links using ADCCP. This standard does not define any single system and should not be regarded as a specification for a data communications system.

This standard is intended to cover a wide range of applications (e.g., two-way alternate and two-way simultaneous data communication between computers, concentrators and terminals which are normally buffered) and a wide range of data link configurations (e.g., full and half-duplex, multi-point, point-to-point, switched or non-switched).

This standard is defined specifically in terms of the actions that occur on receipt of commands at Secondary stations and Combined stations.

In order to provide a high degree of standardization (and, therefore, of compatibility), any equipment intended to be operated within the constraints of this standard shall implement all features of a stipulated basic class of the procedures.

2.0 GENERAL

ADCCP defines a method of data link control in terms of the various combinations of primary link control functions (referred to as Primary station) and secondary link control functions (referred to as a Secondary station) and balanced link control functions (referred to as a Combined station) that make up the control functions and protocols at three types of logical data link control stations:

- Primary station
- Secondary station
- Combined station

In particular, the logical functions and protocols of Secondary stations and Combined stations are specified identically with respect to the action taken and the response frame(s) transmitted as the result of receiving a given command frame(s). The Primary station and Combined station procedures for managing and scheduling the data link, via the transmission of command frames, are the responsibility of the system designer and are not specified.

Since this standard is defined in terms of logical stations it should be noted that a given physical station may be composed of one or more logical stations. For example, a physical station implementation may: 1) have the capability of providing more than one type of logical station capability on a given link at different times (see configurable station Section 2.1.4); 2) have the capability of providing more than one logical station capability on different links at the same time (e.g., a multiplexor that serves several links); 3) house or serve multiple logical stations (e.g., a cluster controller).

2.1 Station Types

In ADCCP there are three types of stations: Primary Station; Secondary station; Combined station.

NOTE: As used in this document the word station (by itself) refers to Primary, Secondary and Combined Stations.

2.1.1 Primary Station

A Primary station has (only) a primary link control capability. The Primary station transmits command frames (commands) to and receives response frames (responses) from the Secondary station(s) on the link. A Primary station maintains a separate information transmitting ability and/or information receiving ability with each Secondary station on the link.

2.1.2 Secondary Station

A Secondary station has (only) a secondary link control capability. The Secondary station transmits response frames (responses) to and receives command frames (commands) from the Primary station. It maintains one information transmitting ability and/or one information receiving ability with the Primary station.

2.1.3 Combined Station

A Combined station has balanced link control capability. The Combined station transmits both command frames (commands) and response frames (responses) to, and receives both commands and responses from, another Combined station. It maintains one information transmitting ability to and one information receiving ability from the other Combined station.

2.1.4 Stations Capable of Being Configured

A station is defined as configurable if it has, as the result of mode-setting action, the capability to be, at different times, more than one type of logical station; i.e., Primary station, Secondary station or Combined station.

2.2 Logical Data Link Configurations

In ADCCP there are two logical data link configurations:

- Unbalanced configurations which have a Primary station and one or more Secondary stations.

- Balanced configurations which have two Combined stations.

2.2.1 Unbalanced Configurations

An Unbalanced configuration has one Primary station and one or more Secondary stations connected to the link. The link may be point-to-point or multipoint, two-way alternate or two-way simultaneous, switched or non-switched. In the Unbalanced configuration the Primary station is responsible for setting each Secondary station in a logical state and mode as appropriate. See Section 6. Additionally, both Primary and Secondary stations are responsible for exchanging data and control information with each other, and initiating the link level error recovery functions defined in this standard. See Figure 2-1.

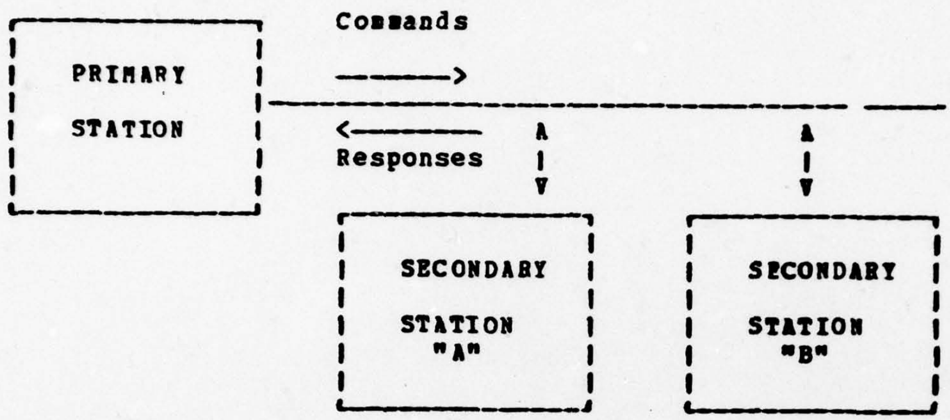


FIGURE 2-1 Unbalanced Configuration

2.2.2 Balanced Configuration

A Balanced configuration is two Combined stations connected point-to-point, two-way alternate or two-way simultaneous, switched or non-switched. Both Combined stations have identical data transfer and link control capability. See Figure 2-2.

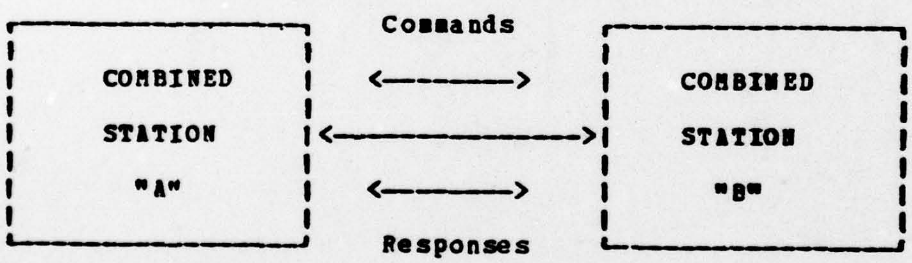


Figure 2-2 Balanced Configuration

2.2.3 Symmetric Configurations

Two independent point-to-point Unbalanced logical station configurations may be connected in a Symmetric manner and multiplexed on a single link. This configuration may be two-way alternate or two-way simultaneous, switched or non-switched. In this configuration there are two independent Primary station-to-Secondary station logical channels where the Primary stations have overall responsibility for mode setting. Each of the four stations maintains one information transmitting ability and/or one information receiving ability. See Figure 2-3.

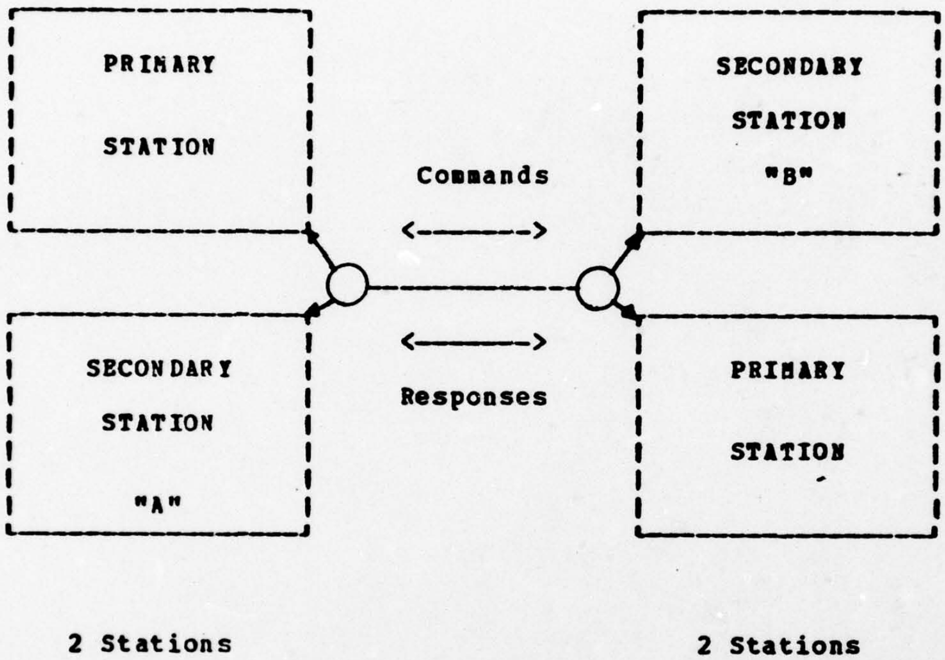


Figure 2-3 Symmetric Configuration

2.3 Logical States and Modes

Communication between two stations is conducted in three logical states: Information Transfer State, Initialization State, or Logically Disconnected State.

2.3.1 Information Transfer State (ITS)

While in ITS the Secondary/Combined station may transmit and receive information. Communications shall observe the constraints of a mode established in a Secondary/Combined station by the remote Primary/Combined station. Each mode specifies a respond opportunity and a logical data link configuration. See Section 6.2.

2.3.1.1 Normal Response Mode (NRM)

NRM is an Unbalanced configuration operational mode in which the Secondary station may initiate transmission of frames containing information only as the result of receiving explicit permission to do so from the Primary station. After receiving permission, the Secondary station shall initiate a response transmission. The response transmission may consist of one or more frames while maintaining an active channel state. The last frame of the response transmission will be explicitly indicated by the Secondary station. Following the indication of the last frame, the Secondary station will stop transmitting until explicit permission is again received from the Primary station.

2.3.1.2 Asynchronous Response Mode (ARM)

ARM is an Unbalanced configuration operational mode in which the Secondary station may initiate transmission without receiving explicit permission from the Primary station. Such an asynchronous transmission may contain single or multiple frames and is used for information field transfer and/or to indicate status changes in the Secondary station (e.g., the number of the next expected frame, transition from a ready to a busy condition or vice versa, occurrance of an exception condition).

2.3.1.3 Asynchronous Balanced Mode (ABM)

ABM is a Balanced configuration operational mode in which a Combined station may initiate transmission without receiving permission from the other Combined station. Such an asynchronous transmission may contain single or multiple frames for information transfer and/or to indicate status changes at the transmitting Combined station (e.g., the number of the next expected frame, transition from a ready to a busy condition or vice versa, occurrance of an exception condition).

2.3.2 Initialization State (IS)

While in IS communications shall observe the constraints of a system-defined procedure. The system-defined procedure may, for example, cause the Secondary/Combined station's link control to be initialized or regenerated by the remote Primary/Combined station. See Section 6.4.

2.3.3 Logically Disconnected State (LDS)

While in LDS the Secondary/Combined station is logically disconnected from the link and is not permitted to transmit or receive information. Communications shall observe the constraints of a mode selected by system definition; each mode specifies a respond opportunity. See Section 6.3.

2.3.3.1 Normal Disconnected Mode (NDM)

NDM is an Unbalanced configuration non-operational mode in which the Secondary station is logically disconnected from the link and is not permitted to initiate or receive information. The Secondary station may initiate transmission only as the result of receiving explicit permission to do so from the Primary station. After receiving permission, the Secondary station shall initiate a single frame transmission indicating its status.

2.3.3.2 Asynchronous Disconnected Mode (ADM)

ADM is an Unbalanced or Balanced configuration non-operational mode in which the Secondary/Combined station is logically disconnected from the link and is not permitted to initiate or receive information. A station in ADM may initiate transmission without receiving explicit permission from the Primary/Combined station but the transmission shall be a single frame indicating the station status.

3.0 FRAME STRUCTURE

In ADCCP, all transmissions are in frames and each frame conforms to the following structure:

F, A, C, Info, FCS, F
Where:
F = Flag Sequence
A = Address Field
C = Control Field
Info = Information Field
FCS = Frame Check Sequence

Frames containing only data link control sequences form a special case where there is no Info field. The short frame structure is therefore:

F, A, C, FCS, F

The elements of the frame are described in the following paragraphs. See also Figure 3-1.

3.1 Flag Sequence (F)

All frames start and end with the flag sequence. This sequence is a zero bit followed by 6 one bits followed by a zero bit (01111110). All stations attached to the data link continuously hunt, on a bit-by-bit basis, for this sequence. A transmitter must send only complete eight-bit flag sequences, however the sequence of 011111101111110 at the receiver is two flag sequences. The flag is used for frame synchronization.

In order to achieve transparency the flag sequence is prohibited from occurring in the Address, Control, Information and FCS fields via a "zero bit insertion" procedure described in Section 3.7.

The flag sequence which closes a frame may also be the opening flag sequence for the next frame. Any number of complete flags may be used between frames. See also Appendix B3.1.

3.2 Address Field (A)

The Address field contains the link level address of a Secondary station or a Combined station. The length of this field (A) is N octets (N greater than or equal to 1). The encoding of this field is described in Section 4.

3.3 Control Field (C)

The Control field contains a command or response and may contain sequence numbers. The control field is used by the transmitting Primary/Combined station to instruct the addressed Secondary/Combined station what operation it is to perform. It is also used by the Secondary station or Combined station to respond to the remote Primary station or Combined station. The length of this field (C) is one octet in the case of the basic control field. It is two octets in length in the case of the extended control field. See Section 5.2.2.

Sequence numbers and the formatting of the Control Field are described in Section 5. Commands and responses are functionally described in Section 7.

3.4 Information Field (Info)

The Information field may be any number and sequence of bits; the data link procedures are completely transparent. Data contained in the information field is unrestricted with respect to code or grouping of bits. See Appendix B3.4 for examples of typical limitations on maximum length.

3.5 Frame Check Sequence (FCS)

All frames include a 16-bit frame check sequence (FCS) just prior to the closing flag for error detection purposes. The contents of the Address, Control and Information fields, excluding the zeros inserted to maintain transparency per Section 3.7, are included in the calculation of the FCS sequence.

The FCS is the remainder of a modulo 2 division process utilizing a generator polynomial as a divisor. The generator polynomial is that used in CCITT Recommendation V.41 and is: $X^{16} + X^{12} + X^{5} + 1$.

Section 12 gives a complete description of the FCS generation process and the error checking process which utilizes the FCS. Appendix D gives an example of FCS generation and error detection.

NOTE: If future applications show that a higher degree of protection is needed, the length of the FCS shall be increased by multiples of eight bits. This requires a higher degree generator polynomial the implementation and use of which is outside of this standard.

3.6 Abort

Abort is the procedure by which a station in the process of sending a frame, ends the frame in an unusual manner such that the receiving station will ignore the frame.

Aborting a frame is performed by transmitting at least seven, but less than fifteen, contiguous one bits (with no inserted zeros). Receipt of seven contiguous one bits is interpreted as an abort. Receipt of fifteen or more contiguous one bits is interpreted as an abort and Idle Link State. See Section 3.9.

3.7 Transparency

ADCCP provides transparency for data coded in the Information field. The occurrence of the flag sequence within a frame is prevented via a "zero bit insertion" procedure as follows:

> The transmitter inserts a zero bit following five contiguous one bits anywhere between the opening flag and the closing flag of the frame. The insertion of the zero bit thus applies to the contents of the Address, Control, Info and FCS fields (including the last 5 bits of the FCS). The receiver continously monitors the received bit stream; upon receiving a zero bit followed by five contiguous one bits, the receiver inspects the following bit: If a zero, the 5 one bits are passed as data and the zero bit deleted. If the sixth bit is a one, the receiver inspects the seventh bit; if it is zero, a flag sequence has been received; if it is a one an abort has been received. See Section 3.6.

3.8 Active Link State and Interframe Time Fill

A link is in an ACTIVE state when a Primary station, Secondary station, or Combined station is actively transmitting a frame, an abort sequence, or interframe time fill. When the link is in the active state, the right of the transmitting station to continue transmission is reserved.

Interframe time fill is accomplished by transmitting continuous flags between frames. There is no provision for intraframe time fill. See also Appendix B.

3.9 Idle Link State

A link is defined to be in an IDLE state when a continuous ones state is detected that persists for at least 15 bit times.

Idle link time fill is defined to be a continuous one condition on the link.

3.10 Invalid Frame

An invalid frame is defined as one that is not properly bounded by two flags (thus an aborted frame is an invalid frame) or one which is too short (i.e., shorter than 32 bits between flags). A Secondary station or Combined station will ignore any invalid frame.

3.11 Order of Bit Transmission

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

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

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

```
|                                                                         |
|                                 FRAME                                   |
|<---------------------------------------------------------------------->-|
|                                                                         |
|                                                                         |
|r---First Bit                                                            |
||   Transmitted                                                          |
||                                                                        |
||                                                                        |
||                                                                        |
|V                                                                        |
|   F           A           C           (Info)          FCS            F  |
|-------------------------------------------------------------------------|
|01111110 |   Note 1   |  Note 2   |  Note 3   | X16--------X0 | 01111110 |
|         |            |           |           |               |          |
---------------------------------------------------------------------------

Flag            Address      Control     Information   Frame Check    Flag
Sequence        Field        Field       Field         Sequence       Sequence
```

Note 1. Address Field formats described in Sections 4.3.1 & 4.3.2.

Note 2. Control Field formats described in Section 5.2.

Note 3. Information Field size may be any number of bits.

STRUCTURAL RELATIONSHIP OF DEFINED FIELDS IN ADCCP FORMAT

FIGURE 3-1

4.0 ADDRESS FIELD

4.1 Unbalanced Operation

A unique address is associated with every Secondary station on a link. Additionally, a Secondary station may be capable of accepting frames which utilize a group or global address; however, when such a Secondary station responds, it will utilize its unique address.

The address field in a command frame transmitted by a Primary station contains the address of the (remote) Secondary station. The address field in a response frame transmitted by a Secondary station contains the address of the (local) Secondary station.

4.2 Balanced Operation

A unique address is associated with each Combined station on the link. Additionally, a Combined station may be capable of accepting frames which utilize a group or global address; however, when such a Combined station responds it will utilize its unique address.

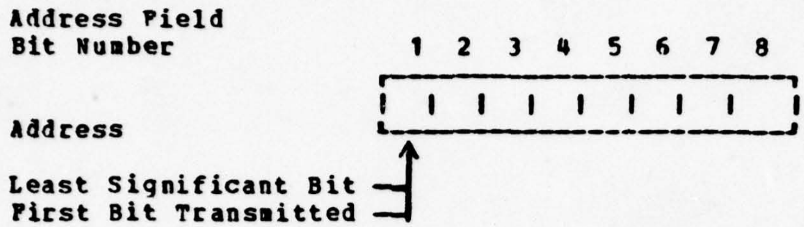
The address field in a command frame transmitted by a Combined station contains the address of the remote Combined station. The address field in a response frame transmitted by a Combined station contains the address of the local Combined station.

4.3 Address Encoding

Two addressing encoding formats are defined for the address field: Basic and Extended. These formats are mutually exclusive for any given Secondary station or Combined station on a link and, therefore, the addressing format must be explicitly specified.

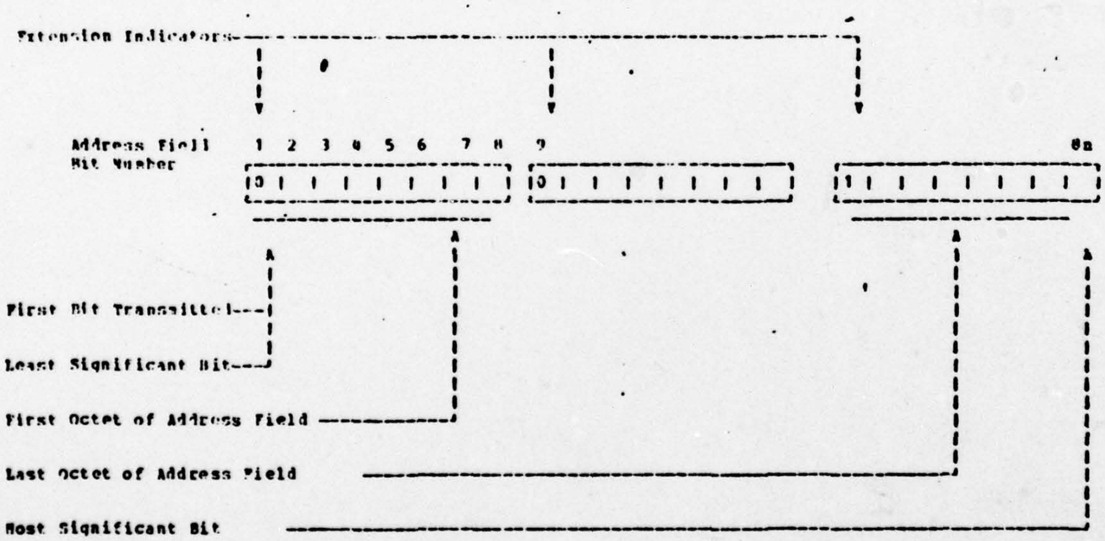
4.3.1 Basic Address Format

In basic address format, the address field contains one address, which may be a single Secondary/Combined station address, or a group or global Secondary/Combined station address. This field consists of one octet with the following format:



4.3.2 Extended Address Format

In extended format, the address field is a sequence of octets which comprises one address which may be a single Secondary/Combined station address, or a group or global Secondary/Combined station address. When the first bit of an address octet is "0", the following octet is an extension of the address field. See Section 4.5 for exception. The address field is terminated by an octet having a "1" in bit position one. Thus, the address field is recursively extendable. The format of the extended address field is:



4.4 Global Address

The single octet address of eight "1" bits (11111111) is reserved as the global (universal, or broadcast) address in the basic and extended address formats.

The global address is used in situations where a specific Secondary station or Combined station address is not known (e.g., switched connection) or is not necessary to the situation (e.g., broadcast transmission).

4.5 Null Address

When the first octet of the address field appears as eight "0" bits (00000000) the address is considered to be a null (no station) address and the frame will be ignored.

5.0 TRANSMISSION PARAMETERS AND FORMATS

For definitions of the following commonly used terms see Glossary, Appendix A.

- Accept/Acceptance
- Action
- Discard
- Invalid
- Implement
- Receive
- Respond Opportunity

5.1 Parameters

The various parameters associated with frames are described in the following sections. Figure 5-1 shows the position of parameters within a frame.

5.1.1 Modulus

Each Information (I) frame is sequentially numbered and may have the value 0 through modulus - 1 (where modulus is the modulus of the sequence numbers). Modulus equals 8 for the basic control field format and 128 for the extended control field format. The sequence numbers cycle through the entire range.

The maximum number of sequentially numbered I frames that a station 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 transmitted I frames with sequence numbers during normal operation and/or error recovery action. The number of outstanding I frames may be further restricted by either the sending or receiving station storage capability; e.g., the number of I frames that can be stored for transmission and/or retransmission in the event of a transmission error.

5.1.2 Frame Variables and Sequence Numbers

Every Secondary station in an Information Transfer State maintains a Send Variable on the I frames it transmits to, and a Receive Variable on the I frames it correctly receives from, the Primary station. Every Primary station maintains an individual Send Variable on the I frames it transmits to, and an individual Receive Variable on the I frames it correctly receives from, each Secondary station in an Information Transfer State. Every Combined station in an Information Transfer State maintains one Send Variable on the I frames it transmits to, and one Receive Variable on the I frames it correctly receives from, the remote Combined station.

5.1.2.1 Send Variable (S)

Each station capable of transmitting I frames has a Send Variable S which indicates the sequence number of the next I frame to be transmitted. S shall take on the value 0 through modulus-1. S is incremented by one with each completed I frame transmission (i.e., S will not be incremented when an I frame transmission is aborted).

5.1.2.2 Send Sequence Number (N(S))

Only I frames contain N(S), the sequence number of the transmitted frame. Prior to transmission of an I frame, N(S) is set equal to S.

5.1.2.3 Receive Variable (R)

Each station capable of receiving I frames shall have a Receive Variable R equal to the expected N(S) contained in the next I frame received. R is incremented by one upon receipt of an error-free I frame whose N(S)=R.

5.1.2.4 Receive Sequence Number (N(R))

All I frames and Supervisory (S) frames contain an N(R), the expected sequence number of the next received I frame. Immediately before transmitting or retransmitting an I or S frame, N(R) is set equal to R. N(R) thus indicates that the station transmitting the N(R) has correctly received all I frames numbered up to and including N(R)-1.

5.1.3 Poll/Final (P/F) Bit

Poll and Final bits are used for:

1) indicating when a Secondary station may begin and has finished a response transmission under NRM. See Section 6.2.1.

2) checkpointing to determine if error recovery is required. See Section 6.5.2.

3) obtaining a response from a Secondary station or Combined station. See Section 6.1.

The Poll (P) bit set to "1" is used by the Primary station or Combined station in command frames to solicit (poll) a response or sequence of response frames from a Secondary station(s) or a Combined station.

The Final (F) bit is used by a Secondary station to:

1) indicate in ARM the response frame sent in reply to the receipt of a poll command.

2) in NRM to indicate the final frame transmitted as the result of a previous poll command.

The Final (F) bit is used by a Combined station to indicate in ABM the response frame sent in reply to the receipt of a poll command.

See Section 6.1 for further description of the P/F bit operation.

5.2 Control Field Formats

The three formats defined for the Control field are used to perform information transfer, basic supervisory control functions, and special or infrequent control functions.

5.2.1 Basic Control Field

The basic control field accommodates modulo 8 N(S) and N(R) sequence numbering.

```
                                             |                               |
                                             |                               |
                                             |<--------Control Field-------->|
First Bit Transmitted -----------------------+,                              |
                                             |V                              |
                                             |                               |
Control Field Bits:                          |1   2   3   4   5   6   7   8  |
                                             |-   -   -   -   -   -   -   -  |
                                             |-------------------------------|
Information Transfer, I                      |0 | N(S)      | P/F |  N(R)    |
                                             |  |           |     |          |
                                             |-----------+-----+-------------|
Supervisory Commands/Responses, S            |1   0 | S   S| P/F |  N(R)     |
                                             |      |      |     |           |
                                             |------+------+-----+-----------|
Unnumbered Commands/Responses, U             |1   1 | M   M| P/F |M   M   M  |
                                             |      |      |     |           |
                                             |_______________________________|
```

Where: N(S) = Transmitting station send sequence number.
(Bit 2 = low order bit)
N(R) = Transmitting station receive sequence number.
(Bit 6 = low order bit)
S = Supervisory function bits
M = Modifier function bits
P/F = Poll bit - Primary station or Combined station command frame transmissions.

Final bit - Secondary station or Combined station response frame transmissions.
(1 = Poll/Final)

5.2.2 Extended Control Field

The extended control field accommodates modulo 128 N(S) and N(R) sequence numbering. (On long propagation delay links (e.g., satellite transmission) it is desirable for reasons of efficiency to extend the modulus of the sequence numbers N(S) and N(R). The method of extension is defined below.)

Control field extension for the three formats is as follows:

```
                        |                                                  |
                        |<----------------Control  Field------------------>|
                        |                        |                         |
                        |<----1st Octet--------->|<--------2nd Octet------>|
                        |                        |                         |
First Bit Transmitted---,                        |                         |
                        ||                       |                         |
                        |V                       |                         |
Control Field Bits      |1  2  3  4  5  6  7  8  |  9   10 11 12 13 14 15 16|
                        |-----------------------,  ,-------------------------,
Information Format      |0|       N(S)          |  |P/F |       N(R)         |
                        |-----------------------|  |----|--------------------|
Supervisory Format      |1 0 | S S | X  X  X  X|  |P/F |       N(R)         |
                        |----|-----|-----------|  |----|--------------------|
Unnumbered Format       |1 1 | M M |P/F|M  M  M|  |P/F | X  X  X  X  X  X  X|
                        '-----------------------'  '-------------------------'
```

where X bits are reserved and set to "0"

In extended control field format the transmitter sets the P/F bits in bit positions 5 and 9 for Unnumbered format commands and responses. A receiver in extended control field format interprets the P/F bit in bit position 9. A receiver in basic control field format receiving an extended control field format interprets the P/F bit in bit position 5.

5.3 Information Transfer Format (I)

The I format is used to perform an information transfer.

The functions of N(S), N(R), and P/F are independent; i.e., each

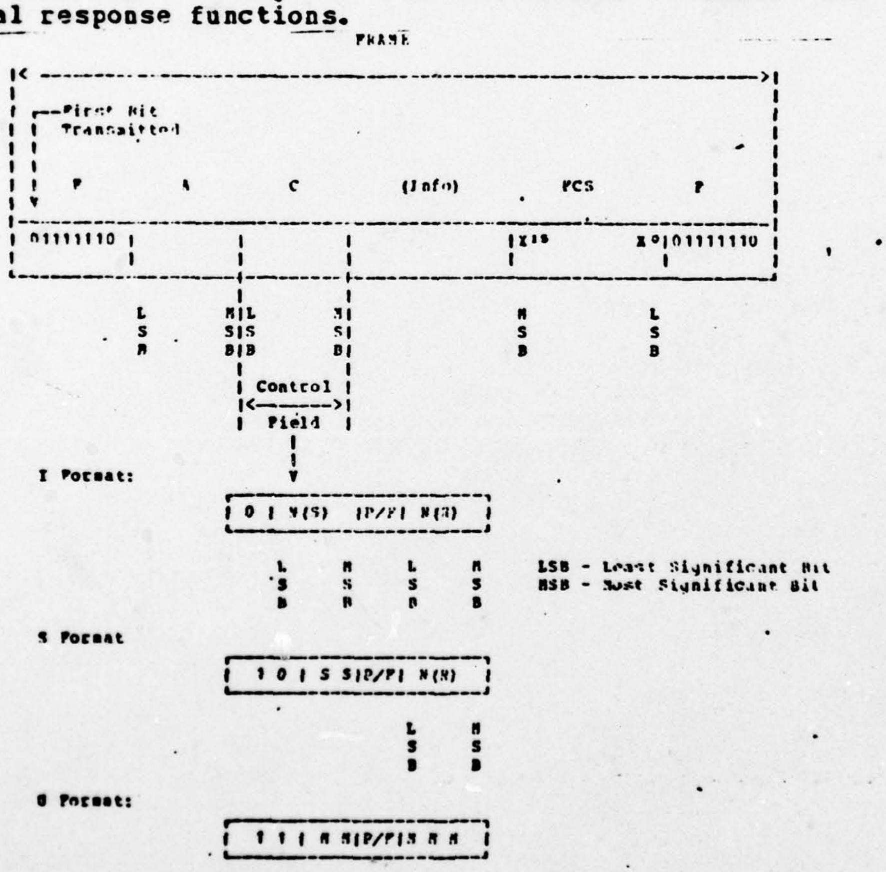
I frame has an N(S) sequence number, the N(R) sequence number may or may not acknowledge additional I frames at the receiving station, and the P/F bit may or may not be set to "1".

5.4 Supervisory Format (S)

The S format is used to perform link supervisory control functions such as acknowledge I frames, request retransmission of I frames, and indicate temporary interruption of capability to receive I/UI frames. The functions of N(R) and P/F are independent.

5.5 Unnumbered Format (U)

The U format is used to provide additional link control functions. This format contains no sequence numbers and consequently 5 "modifier" bit positions are available which allows definition of up to 32 additional command and 32 additional response functions.



POSITIONAL SIGNIFICANCE OF BITS IN FIELDS OF ADCCP BASIC FORMAT

Figure 5-1

6.0 SECONDARY/COMBINED STATION STATES AND MODES

A Secondary/Combined station transmits response frames to a Primary/Combined station based on previous receipt of a command frame. In certain cases, a Secondary/Combined station can also initiate transmission of response frames to a Primary/Combined station. The characteristics of a Secondary/Combined station response are determined by: 1) the type of respond opportunity which exists at the Secondary/Combined station, 2) the current state of the Secondary/Combined station, and 3) the particular mode within the Secondary/Combined station. Secondary/Combined stations do not queue sequential responses for command frames received. A Secondary/Combined station response is predicated on: 1) station status at the time the response is transmitted, 2) an exception condition previously established, or 3) the previous receipt of a command which requires a specific response format.

6.1 Poll/Final Bit Usages

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

The P bit is used to solicit a response frame with the F bit set to "1" from the Secondary/Combined station at the earliest opportunity. A response frame with the F bit set to "1" also indicates the end of transmission under Normal Respond Opportunity.

For each Primary-Secondary pair on Unbalanced links and each direction on Balanced links only one frame with a P bit set to "1" may be outstanding at a given time. Before a Primary/Combined station can issue another frame with P bit set to "1" it must receive a response frame from the Secondary/Combined station with the F bit set to "1". If no valid response frame is obtained within a system defined time-out, the retransmission of a command with the P bit set to "1" for error recovery purposes is permitted.

6.2 Respond Opportunities

6.2.1 Normal Respond Opportunity (NRO)

NRO is a Secondary station respond opportunity in which the Secondary station initiates transmission of response frames only as the result of receiving a command frame with the P bit set to "1" or a UP command. See Section 7.4.2.2.

The response transmission may consist of one or more frames while maintaining an Active Link State. In all cases the last frame of the response transmission will have the F bit set to "1". When the response frame with the F bit set to "1" is transmitted the Secondary station will stop transmitting response frames and not initiate any additional transmission of response frames until a subsequent command frame is received with the P bit set to "1" or a UP command is received.

6.2.2 Asynchronous Respond Opportunity (ARO)

ARO is a Secondary/Combined station respond opportunity in which the Secondary/Combined station initiates transmission of response frames without regard to the receipt of a command frame with the P bit set to "1". Asynchronous transmission of response frames may be initiated at the first opportunity. In two-way simultaneous (TWS) transmission the opportunity is immediately. In two-way alternate (TWA) transmission the opportunity is the detection of an Idle Link State. An asynchronous transmission may contain multiple frames and is used to initiate information transfer (I/UI) and/or to report status changes in the Secondary/Combined Station, (e.g., N(R) number change, transition from a ready to a busy condition or vice versa, establishment of an exception condition.)

The Secondary/Combined station must transmit a frame with the F bit set to "1" only in response to a received command frame with the P bit set to "1". The F bit is not to be interpreted as the end of transmission by the Secondary/Combined station. Additional response frames with the F bit set to "0" may be transmitted following the response frame which had the F bit set to "1".

In TWS operation a Secondary/Combined station in the process of transmitting when the command frame with the P bit set to "1" is received will set the F bit to "1" in the earliest possible response frame to be transmitted.

When a station has Asynchronous Respond Opportunity, it shall utilize a response time-out function which will cause initiation of appropriate recovery procedures if previously transmitted unsolicited response frames have not been acknowledged within a system-defined time-out period. Since simultaneous contention may occur, in TWA configurations the response timers at each end of the link shall be unequal. In TWA, the interval employed by a Secondary station shall be greater than that employed by the Primary station to permit contention situations to be resolved in favor of the Primary station.

6.3 Logically Disconnected State (LDS)

The LDS is provided to prevent a Secondary/Combined station from appearing on the link in a fully operational sense during unusual situations or exception conditions since such operations could cause 1) unintended contention, 2) sequence number mismatch or 3) ambiguity as to the Secondary/Combined station status or mode.

While in LDS the Secondary station, or response capability of a Combined station, is logically disconnected from the data link; i.e., no Information (I), Unnumbered Information (UI) or S response frames are transmitted or accepted. The Secondary station capability, or response capability of a Combined station, is limited to 1) accepting one of the mode-setting commands, 2) transmitting a DM or RIM response frame at each respond opportunity and 3) responding to an XID command.

A Secondary/Combined station in LDS, as a minimum capability, must respond DM (Disconnected Mode) to any valid command frame received with the P bit set to "1". A RIM (Request Initialization Mode) response may be transmitted instead of DM; the conditions which cause a Secondary/Combined station to transmit RIM are system defined.

A mode-setting, XID or UP command may be accepted and responded to at the first respond opportunity if the station is capable of accepting and actioning the command. Any other frame received, including a mode setting, XID or UP command that is not accepted, is discarded except for the response requirement described in the paragraph above.

A Secondary or Combined station is system defined as to the condition(s) that cause it to assume one of the two predetermined modes (ADM or NDM).

Examples of possible system-defined conditions (in addition to receiving a DISC command) which may cause a Secondary/Combined station to enter LDS are:

1. the Secondary/Combined station power is turned on

2. the Secondary/Combined station has a temporary loss of power

3. the Secondary/Combined station link level logic is manually reset

4. the Secondary/Combined station is manually switched from a local (home) condition to a connected-to-the-link condition.

While in LDS a Secondary/Combined station may not establish a Frame Reject exception condition.

6.3.1 Modes Within LDS

While in LDS a Secondary/Combined station communicates under the constraints of one of the following two modes.

6.3.1.1 Normal Disconnected Mode (NDM)

NDM is a disconnected mode in which the Secondary station is logically disconnected from the data link and follows Normal Respond Opportunity protocol. See Section 6.2.1.

6.3.1.2 Asynchronous Disconnected Mode (ADM)

ADM is a disconnected mode in which the Secondary station, or response capability of a Combined station, is logically disconnected from the data link and follows Asynchronous Respond Opportunity protocol. See Section 6.2.2.

6.4 Initialization State (IS)

While in IS the Secondary/Combined station may be initialized or regenerated by the remote Primary station or Combined station and communicates under the constraints of the following mode.

6.4.1 Initialization Mode (IM)

A Secondary/Combined station enters the IM upon sending a UA response, under a system-defined respond opportunity, in reply to the receipt of a Set Initialization Mode (SIM) command. The Secondary/Combined station may request SIM by sending a Request Initialization Mode (RIM) response. While in IM the stations may exchange information in any manner specified for that Secondary/Combined station (e.g., unformatted and unchecked bit streams, UI frames, or I frames); however, in a multipoint configuration care shall be taken to prevent interference with other stations on the link. IM is ended when the Secondary/Combined station receives, actions, and acknowledges a set-mode command (i.e., SNRM, SARM, SABM, SNRME, SARME, SABME, or DISC).

6.5 Information Transfer State (ITS)

While in ITS a station is fully operational and capable of transmitting and receiving I, S, and U format frames.

6.5.1 Modes Within ITS

While in ITS a Secondary/Combined station communicates under the constraints of one of the following modes. The particular mode utilized is determined by the Primary/Combined station with an appropriate set-mode command and is entered when the Secondary/Combined station receives, actions, and acknowledges that set-mode command.

6.5.1.1 Normal Response Mode (NRM)

NRM is a Secondary station information transfer mode in which the Secondary station utilizes Normal Respond Opportunity on an unbalanced link configuration. See Sections 2.2.1 and 6.2.1. This mode is selected by a SNRM or SNRME command.

6.5.1.2 Asynchronous Response Mode (ARM)

ARM is a Secondary station information transfer mode in which the Secondary station utilizes Asynchronous Respond Opportunity on an unbalanced link configuration. See Sections 2.2.1 and 6.2.2. This mode is selected by a SARM or SARME command.

6.5.1.3 Asynchronous Balanced Mode (ABM)

ABM is a Combined station information transfer mode in which the Combined stations utilize Asynchronous Respond Opportunity on a balanced link configuration. See Sections 2.2.2 and 6.2.2. This mode is selected by a SABM or SABME command. A Combined station may transmit command frames at any time; therefore, the ABM definition only describes and applies to the response frame transmitting and command frame receiving capability of the Combined stations.

6.5.2 Checkpointing

As the P and F bits are always exchanged as a pair (for every P there is one F, and the next P must not be issued until the previous P has been matched with an F or until the response timer expires), the N(R) contained in a frame with a P or F bit set to "1" can be used to detect I frame sequence errors. This capability can provide early detection of frame sequence errors and indicate the I frame sequence number to begin retransmission. This capability is referred to as checkpointing.

While in ITS the Primary/Combined station shall examine the N(R) contained in any received I or S frame with the F bit set to "1". See Section 8.2.1 for additional qualifying conditions. Appropriate error recovery procedures shall be initiated if this N(R) does not acknowledge all I frames transmitted by the Primary/Combined station prior to and including the last command frame sent with the P bit set to "1". See Section 8.2.1 for additional qualifying conditions.

Similarly, while in ITS the Secondary station shall examine the N(R) contained in any received I or S frame with the P bit set to

"1". Appropriate error recovery procedure shall be initiated if this N(R) does not acknowledge all I frames transmitted by the Secondary station prior to and including the last response frame with the F bit set to "1". See Section 8.2.1 for additional qualifying conditions.

In all cases the N(R) of a correctly received I or S frame shall confirm previously transmitted I frames through N(R)-1.

7.0 COMMANDS AND RESPONSES

This standard defines the link control operation in terms of the actions and internal modes of the Secondary/Combined station. The actual link management procedure (i.e., sequence of commands and related responses) is application and link configuration dependent. Consequently, specific Primary/Combined station command sequences are not defined but left to the designer of the Primary/Combined station link control.

Sections 7.1 through 7.3 contain the definition of the set of commands and responses (listed below) for each of the transmission formats.

<u>Information Transfer Format Commands</u>
I - Information

<u>Information Transfer Format Respons</u>
I - Information

<u>Supervisory Format Commands</u>
RR - Receive Ready
RNR - Receive Not Ready
REJ - Reject
SREJ - Selective Reject

<u>Supervisory Format Responses</u>
RR - Receive Ready
RNR - Receive Not Ready
REJ - Reject
SREJ - Selective Reject

Unnumbered Format Commands

Mode-Setting Commands

SNRM - Set Normal Response Mode
SARM - Set Asynchronous Response Mode
SABM - Set Asynchronous Balanced Mode
SNRME - Set Normal Response Mode Extended
SARME - Set Asynchronous Response Mode Extended
SABME - Set Asynchronous Balanced Mode Extended
SIM - Set Initialization Mode
DISC - Disconnect

Information Transfer Commands

UI - Unnumbered Information
UP - Unnumbered Poll

Recovery Commands

RSET - Reset

Miscellaneous Commands

XID - Exchange Identification

Non-Reserved Commands

4 Encodings

Unnumbered Format Responses

Mode-Setting Responses

UA - Unnumbered Acknowledgement
DM - Disconnected Mode.

RIM - Request Initialization Mode

Information Transfer Responses

UI - Unnumbered Information

Recovery Responses

FRMR - Frame Reject

Miscellaneous Responses

XID - Exchange Identification

RD - Request Disconnect

Non-Reserved Responses

4 Encodings

7.1 Information Transfer Format (I) Command/Response

The function of the Information (I) command/response is to efficiently transfer sequentially numbered frames containing an optional information field.

The encoding of the I command/response control field is:

```
                         I Format Command/Response
                 |<----------Control Field---------->|
                 |                                   |
                 |                                   |
                 |                                   |
                 |                                   |
                 |                                   |
    First Bit Transmitted
                  |
                  V

   Control Field Bits:  1    2    3    4    5    6    7    8
                      ----------------------------------------
                      | 0 |     N(S)      |P/F |    N(R)      |
                      ----------------------------------------
                        |         |           |         |
                        |         |           |         |
                        |         |           |         V
                        |         |           |
                        V         |           |   Receive Sequence
                                  |           |   Number Modulo 8
                 Information      |           V
                 Transfer Format  |
                                  |      Command: Poll
                                  |      Response: Final
                                  V

                       Send Sequence
                       Number Modulo 8
```

For extended control field format see Section 5.2.2.

The I frame control field contains two sequence numbers: N(S), Send Sequence Number, which indicates the sequence number associated with the I frame; N(R), Receive Sequence Number, which indicates the sequence number of the next expected I frame (i.e., I frames numbered up to and including N(R)-1 are accepted.)

An I frame with P/F bit set to "1" may report the end of a station busy condition as specified in Section 8.1.3.

See Sections 6.1, 6.5.2 and 8.2.1 for description of P/F bit operation.

7.2 Supervisory Format (S) Commands/Responses

Supervisory (S) commands/responses are used to perform basic supervisory link control functions such as I frame acknowledgement, polling, temporary interruption of information (I/UI) transfer, and error recovery.

Frames with the S format do not contain an information field. Therefore, a station does not increment its Send Variable (S) upon the transmission of an S format frame nor does it increment its Receive Variable (R) upon accepting an S format frame.

The encoding of the S command/response control field is:

```
                  Supervisory Format
              |<----Control Field--------------->|
              |                                  |
              |                                  |
First Bit Transmitted
                 |
                 |
                 |
                 V

Control Field Bits:  1   2   3   4   5   6   7   8

                 ------------------------------------
                 | 1   0  |  S   |P/F |     N(R)    |
                 ------------------------------------
                     |       |      |         |
                     |       |      |         |
                     |       |      |         |
                     |       |      |         |
                     V       |      V         V
                             |
               Supervisory   |   Command    Receive
                 Format      |    Poll      Sequence
                             |              Number
                             |              Modulo 8
                             |
                             |
                             |   Response
                             |    Final
                             |
                             |
                             V
```

Commands

RR - Receive Reasy
RNR - Receive Not Ready
REJ - Reject
SREJ - Selective Reject

Responses

00 RR - Receive Ready
10 RNR - Receive Not Ready
01 REJ - Reject
11 SREJ - Selective Reject

For extended control field format see Section 5.2.2.

An S frame contains an N(R), Receive Sequence Number, which indicates the sequence number of the next expected I frame (i.e., all received I frames numbered up to and including N(R)-1 are accepted). See Sections 6.1, 6.5.2 and 8.2.1 for description of the P/F bit operation.

7.2.1 Receive Ready (RR) Command/Response

Receive Ready (RR) is used by a station to: 1) indicate it is ready to receive an I frame and 2) acknowledge I frames numbered up to and including N(R)-1.

The Primary/Combined station may use the RR command with the P bit set to "1" to solicit responses from (poll) a Secondary/Combined.

An RR frame is one way to report the end of a station busy condition. See Section 8.1.3.

7.2.2 Receive Not Ready (RNR) Command/Response

Receive Not Ready (RNR) is used by a station to indicate a "busy" condition; i.e., the temporary inability to accept additional incoming information (I or UI) frames. I frames numbered up to and including N(R)-1 are acknowledged. I frame N(R) and any subsequent I frames received, if any, are not acknowledged; the acceptance status of these frames will be indicated in subsequent exchanges.

The Primary/Combined station may also use the RNR command with the P bit set to "1" to obtain the receive status of a Secondary/Combined station. The Secondary/Combined station response will be a frame with the F bit set to "1". See Section 8.1, Busy Condition, for further details on RNR usage.

7.2.3 Reject (REJ) Command/Response

Reject (REJ) is used by a station to request retransmission of I frames starting with the frame numbered N(R). I 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 transmitted (i.e., actioned) until the first REJ exception condition has been cleared at the sender.

The REJ exception condition is cleared (reset) upon acceptance of an I frame with an N(S) number equal to the N(R) of the REJ command/response or after a timeout has occurred.

An REJ is one way to report the end of a station busy condition. See Section 8.1.3.

See Section 8.2 for sequence error recovery protocols.

7.2.4 Selective Reject (SREJ) Command/Response

Selective Reject (SREJ) is used by a station to request retransmission of the single I frame numbered N(R). I frames up to and including N(R)-1 are acknowledged.

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

After a station transmits a SREJ it may not transmit SREJ (except for a SREJ with P or F bit set to "1" and with N(R) equal to the N(R) of the first SREJ; see Section 8.2.3) or REJ for an additional sequence error until the first SREJ error condition has been cleared or a response/command timeout has occurred. (To do so would acknowledge as correctly received all I frames up to and including 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 an SREJ. Additional I frames pending initial transmission may be transmitted following the retransmission of the specific I frame requested by the SREJ.

An SREJ is one way to report the end of a station busy condition. See Section 8.1.3.

See Section 8.2 for sequence error recovery protocols.

7.3 Unnumbered Format (U) Commands/Responses

Unnumbered (U) commands and responses are used to extend the number of link supervisory functions. U frames do not increment the Send Variable (S) at the transmitting station or increment the Receive Variable (R) at the receiving station. Five "modifier" bits are defined which allow up to 32 additional command functions and 32 additional response functions.

The encoding of the U command/response control field is:

```
                 |                                        |
                 |<------Unnumbered Format------->|
                 |        Control Field                   |
                 |                                        |
First Bit        |                                        |
Transmitted------+                                        |
                  |
                  |
                  V
Control
Field Bits:       1    2    3     4    5     6    7    8
                 |-----------------------------------------|
                 | 1    1 | M     M| P/F | M    M    M|
                 |-----------------------------------------|
                    |        |         |          |
                    V        L---------|----------|
                                       |          V
     Unnumbered Format                 |
                                       V      5 "Modifier" Bits

                                  Command: Poll
                                  Response: Final
```

For extended control field format see Section 5.2.2.

See Sections 6.1, 6.5.2 and 8.2.1 for description of the P/F bit operation.

7.4 Unnumbered Format Commands

Unnumbered format commands are grouped according to the function performed:

- Mode-setting commands: SNRM, SARM, SABM, SNRME, SARME, SABME, SIM, DISC
- Information transfer commands: UI, UP
- Recovery commands: RSET
- Miscellaneous commands: XID
- Non-reserved commands: 4 encodings

The following U format commands are defined; other commands may be defined in the future if required. All bit encodings not defined are reserved for future standard assignment.

First Bit Transmitted

Control Field Bits

1	2	3	4	5	6	7	8	
1	1	0	0	P	0	0	1	SNRM Command
1	1	1	1	P	0	0	0	SARM Command
1	1	1	1	P	1	0	0	SABM Command
1	1	1	1	P	0	1	1	SNRME Command
1	1	1	1	P	0	1	0	SARME Command
1	1	1	1	P	1	1	0	SABME Command
1	1	1	0	P	0	0	0	SIM Command
1	1	0	0	P	0	1	0	DISC Command
1	1	0	0	P	0	0	0	UI Command
1	1	0	0	P	1	0	0	UP Command
1	1	1	1	P	0	0	1	RSET Command
1	1	1	1	P	1	0	1	XID Command
1	1	0	1	P	0	0	0	Non-Reserved Command
1	1	0	1	P	0	0	1	Non-Reserved Command
1	1	0	1	P	0	1	0	Non-Reserved Command
1	1	0	1	P	0	1	1	Non-Reserved Command

For extended control field format see Section 5.2.2.

See Sections 6.1, 6.5.2 and 8.2.1 for description of the P bit operation.

7.4.1 Mode-Setting Commands

Mode-setting commands are transmitted by the Primary/Combined station to reset or change the mode of the addressed Secondary/Combined station. Once established a mode remains in effect at a Secondary station until the next mode-setting command is accepted, and at a Combined station until the next mode-setting command is either accepted, or transmitted and acknowledged.

The SNRM, SARM, SABM, SNRME, SARME, SABME, SIM, and DISC commands require the Secondary/Combined station to acknowledge acceptance by responding with a single Unnumbered Acknowledgement (UA) frame at the first respond opportunity. The transmission of a UA response following the receipt of one of these commands takes precedence over any other responses which may be pending at the Secondary/Combined station. If more than one of these U commands is received by a Secondary/Combined station prior to a respond opportunity, a single transmitted UA response refers to the first such command received; i.e., any additional I, S or U commands subsequently received are monitored only to detect the next respond opportunity.

In the case of TWA operation, following the receipt of one of these U commands, a Secondary/Combined station is restricted to transmitting a single UA response frame. In the case of TWS operation a Secondary/Combined station which is transmitting concurrent to the receipt of one of these U commands will initiate transmission of a single UA response frame at the first respond opportunity. The Secondary/Combined station may continue transmission following return of the UA response as appropriate to its respond opportunity.

In the case of the operational mode-setting command (SARM, SNRM, SABM, SARME, SNRME, SABME) the respond opportunity at the Secondary station is determined by the command received (i.e., the mode to which the Secondary/Combined station is directed dictates when the response is transmitted):

1. Upon receipt of a SNRM or SNRME command with the P bit set to "1", the Secondary station responds with a single UA frame with the F bit set to "1"; if the SNRM or SNRME P bit is set to "0", the Secondary station waits until a command frame with the P bit set to "1" is received and then responds with a single UA frame with the F bit set to "1", or until a UP command (with the P bit set to "0") is received and then responds with a single UA frame with the F bit set to "0".

2. Upon receipt of a SARM or SARME command, with or without the P bit set to "1", the Secondary station will transmit a single UA frame:

   a. upon detection of an Idle Link State in TWA operation, or

   b. at the earliest respond opportunity in TWS operation.

   The UA frame will have the F bit set to "1" if the command has the P bit set to "1".

3. Upon receipt of a SABM or SABME command, with or without the P bit set to "1", the Combined station will transmit a single UA frame:

   a. upon detection of an Idle Link state in TWA operation, or

   b. at the earliest respond opportunity in TWS operation.

The UA frame will have the F bit set to "1" if the command has the P bit set to "1".

In the case of the non-operational mode-setting commands (SIM or DISC) the Secondary/Combined station will respond with a single UA frame at its system-defined respond opportunity; i.e., a given Secondary/Combined station is system defined to always use the normal respond opportunity or the asynchronous respond opportunity for the UA response.

If the Secondary/Combined station can not accept a mode-setting command, it will, at its first respond opportunity, transmit one of the responses, DM, FRMR, RD or RIM, as appropriate, indicating non-acceptance of the command.

NOTE: The protocol defined here requires that the Primary/Combined station restrict the transmission of U commands which require UA responses so that only one such command is outstanding (not acknowledged) to any given Secondary/Combined station at any given time. This eliminates the requirement for the Secondary/Combined station to queue responses and prevents any ambiguity relative to the meaning of the UA response.

7.4.1.1 Set Normal Response Mode (SNRM) Command

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

Upon acceptance of this command the Secondary station Send and Receive Variables are set to zero. The Secondary station confirms acceptance of SNRM by transmission of a UA in the unextended control field format.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SNRM is one way to report the end of a Primary station busy condition. See Section 8.1.3.

7.4.1.2 Set Asynchronous Response Mode (SARM) Command

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

Upon acceptance of this command the Secondary station Send and Receive Variables are set to zero. The Secondary station confirms acceptance of SARM by the transmission of a UA response in the unextended control field format.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SARM is one way to report the end of a Primary station busy condition. See Section 8.1.3.

7.4.1.3 Set Asynchronous Balanced Mode (SABM) Command

The SABM command is used to place the addressed Combined station in ABM where all control fields are one octet in length. No information field is permitted with the SABM command.

Upon acceptance of this command the Combined station Send and Receive Variables are set to zero. The Combined station confirms acceptance of SABM by the transmission of a UA response in the unextended control field format.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SABM is one way to report the end of a Combined station busy condition. See Section 8.1.3.

7.4.1.4 Set Normal Response Mode Extended (SNRME) Command

The SNRME command is used to place the addressed Secondary station in NRM where all control fields will be two octets in length as defined in Section 5.2.2. No information field is permitted with the SNRME command.

Upon acceptance of this command the Secondary station Send and Receive Variables are set to zero. The Secondary station confirms acceptance of SNRME by transmission of a UA response in the extended control field format.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SARME is one way to report the end of a Primary busy condition. See Section 8.1.3.

7.4.1.5 Set Asynchronous Response Mode Extended (SARME) Command

The SARME command is used to place the addressed Secondary station in ARM where all control fields will be two octets in length as defined in Section 5.2.2. No information field is permitted with the SARME command.

Upon acceptance of this command the Secondary station Send and Receive Variables are set to zero. The Secondary station confirms acceptance of SARME by transmission of a UA response in the extended control field format.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SARME is one way to report the end of a Primary busy condition. See Section 8.1.3.

7.4.1.6 Set Asynchronous Balanced Mode Extended (SABME) Command

The SABME command is used to place the addressed Combined station in ABM where all control fields will be two octets in length as defined in Section 5.2.2. No information field is permitted with the SABME command.

Upon acceptance of this command the Combined station Send and Receive Variables are set to zero. The Combined station confirms acceptance of SABME by transmission of a UA response in the extended control field format.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Transmission of SABME is one way to report the end of a Combined station busy condition. See Section 8.1.3.

7.4.1.7 Set Initialization Mode (SIM) Command

The SIM command is used to cause the addressed Secondary/Combined station to initiate a station-specified procedure(s) to initialize its link level control functions (e.g., accept a new program or update operational parameters). No information field is permitted with the SIM command.

The Secondary/Combined station confirms acceptance of SIM by transmission of a UA response. The respond opportunity and the control field format of the UA response are system defined.

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

7.4.1.8 Disconnect (DISC) Command

The DISC command is used to perform a logical disconnect; i.e., inform the addressed Secondary/Combined station that the transmitting Primary/Combined station is suspending operation with that Secondary/Combined station. In switched networks, this logical disconnect function at the data link level may serve to initiate a physical disconnect operation at the physical interface level; i.e., to go "on-hook". No information field is permitted with the DISC command.

The Secondary/Combined station confirms acceptance of DISC by the transmission of a UA response. The respond opportunity and the control field format of the UA response is system defined. A Secondary/Combined station in ADM or NDM will transmit a DM response upon receiving a DISC command. The respond opportunity and control field format after receipt of DISC is system defined for any given Secondary station. The respond opportunities are defined in Section 6.2.

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

7.4.2 Unnumbered Information Transfer Commands

Unnumbered information transfer commands are used to exchange frames containing information.

7.4.2.1 Unnumbered Information (UI) Command

The UI command is used to transfer an information field to a Secondary/Combined station or group of Secondary stations without impacting the Send and Receive Variables. The information field is optionally present with the UI command. Reception of the UI frame is not sequence number verified; therefore, the frame may be lost if a link exception occurs during transmission of the UI, or duplicated if an exception occurs during any reply to the UI. Examples of UI frame information are higher level status, operation interruption, temporal data (e.g., time-of-day), or link initialization parameters.

See Appendix B, 7.4.2.1 for additional explanatory information.

7.4.2.2 Unnumbered Poll (UP) Command

The UP command is used to solicit response frames from a single Secondary/Combined station (Individual Poll) or from a group of Secondary stations (Group Poll), by establishing a logical operational condition that exists at each addressed station for one respond opportunity. (In the case of a Group Poll, the mechanism employed to control (schedule) the response transmissions (to avoid simultaneous transmissions) is considered to exist and is not defined in this standard.) Secondary stations receiving UP with a group address will respond in the same manner as when addressed using an individual address. The response frame(s) will contain the sending Secondary/Combined station individual address, plus N(S) and N(R) numbers as required by the particular responses. (The continuity of each Secondary/Combined station N(S) will be maintained.) The UP command does not acknowledge receipt of any response frames that may have been previously transmitted by the Secondary/Combined station. No information field is permitted with the UP command.

A Secondary/Combined station which receives a UP with the P bit set to "1" will respond (at its respond opportunity and consistent with its mode of operation) with a frame which has the F bit set to "1".

A Secondary/Combined station which receives a UP with the P bit set to "0" may or may not respond; responses will have the F bit set to "0" in all response frames. A Secondary/Combined station will respond to a received UP which has the P bit set to "0" when 1) it has an I/UI frame(s) to send, 2) it has accepted but not acknowledged an I frame(s), 3) it has experienced an exception condition or change of status that has not been reported, 4) it has a status to be reported (e.g., DM, FRMR, or optionally an appropriate frame to report a no traffic condition).

7.4.3 Unnumbered Recovery Commands

7.4.3.1 Reset (RSET) Command

The RSET command is transmitted by a Combined station to reset the Receive State Variable (R) and applicable FRMR conditions in the addressed Combined station. No information field is permitted with the RSET command.

Upon acceptance of this command the station Receive State Variable (R) is set to zero. The Combined station confirms acceptance of RSET by transmission of the UA response while remaining in the previously established operational mode. If the UA is received correctly, the initiating Combined station resets its Send State Variable (S). Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged.

The RSET command will clear all frame rejection conditions except for an invalid N(R) condition in the addressed Combined station. The RSET command may be sent by a Combined station which detects an invalid N(R) instead of reporting such a frame rejection condition via a FRMR response.

7.4.4 Miscellaneous Commands

7.4.4.1 Exchange Identification (XID) Command

The XID command is used to cause the addressed Secondary/Combined station to report its station identification, and optionally to provide the station identification of the transmitting Primary/Combined station to the addressed Secondary/Combined station. An information field is optional with the XID command; if present the information field will be the station ID of the Primary/Combined station. The Primary/Combined station may use the global address if the unique address of the

Secondary/Combined station is not known. A Secondary/Combined station in any mode receiving an XID command will transmit an XID response unless 1) a UA response is pending, 2) a FRMR condition exists, 3) a RIM condition exists, or 4) the XID command cannot be actioned in a disconnected mode.

7.4.5 Non-Reserved Commands

Four non-reserved commands are specified to permit the implementer to define special system-dependent functions that do not have general applicability. Such special system-dependent functions are beyond the scope of this standard.

7.5 Unnumbered Format Responses

Unnumbered format responses are grouped according to the function performed:

- Responses to mode-setting and status requests: UA,DM,RIM
- Information transfer responses: UI
- Recovery responses: FRMR
- Miscellaneous responses: XID, RD
- Non-reserved responses: 4 encodings

First Bit Transmitted

Control Field Bits

1	2	3	4	5	6	7	8	
1	1	0	0	F	1	1	0	UA Response
1	1	1	1	F	0	0	0	DM Response
1	1	1	0	F	0	0	0	RIM Response
1	1	0	0	F	0	0	0	UI Response
1	1	1	0	F	0	0	1	FRMR Response
1	1	1	1	F	1	0	1	XID Response
1	1	0	0	F	0	1	0	RD Response
1	1	0	1	F	0	0	0	Non-Reserved Response
1	1	0	1	F	0	0	1	Non-Reserved Response
1	1	0	1	F	0	1	0	Non-Reserved Response
1	1	0	1	F	0	1	1	Non-Reserved Response

For extended control field format see Section 5.2.2.

See Sections 6.1, 6.5.2 and 8.2.1 for description of the F bit operation.

7.5.1 Responses to Mode-Setting and Status Requests

The UA, DM and RIM responses are used by the Secondary/Combined station to request transmission of, or to respond to, the mode-setting commands of the Primary/Combined station; DM and RIM are additionally used to indicate Secondary/Combined station status.

7.5.1.1 Unnumbered Acknowledgement (UA) Response

The UA response is used to acknowledge the receipt and acceptance of the SNRM, SARM, SABM, SNRME, SARME, SABME, SIM, DISC, and RSET Unnumbered commands defined in Sections 7.4.1 and 7.4.3. The UA response is transmitted in the basic or the extended control field format as directed by the received Unnumbered command. No information field is permitted with the UA response.

A UA response is one way to report the end of a station busy condition. See Section 8.1.3.

7.5.1.2 Disconnected Mode (DM) Response

The DM response is used to report that the Secondary/Combined station is in the logically disconnected state; i.e., the Secondary/Combined station is, per system definition, in NDM or ADM. See Section 6.3.

The DM response is sent by a Secondary/Combined station in NDM or ADM to request the remote Primary/Combined station to issue a mode-setting command, or, if sent in response to the reception of a mode-setting command, to inform the inform the addressed Primary/Combined station that the transmitting Secondary/Combined station is still in NDM/ADM and cannot action the mode-setting command. On a switched network where the call is initiated by a Secondary/Combined station DM is sent to request a mode-setting command. On a non-switched line a Secondary/Combined station in ADM may send the DM response at any respond opportunity. No information field is permitted with the DM response.

A Secondary/Combined station in NDM or ADM will monitor received commands (other than those that reset the disconnected mode) only to detect a respond opportunity in order to (re)transmit DM (or RIM if initialization is required); i.e., no I/UI transmissions are exchanged until the disconnected mode is reset by the acceptance of SNRM, SARM, SABM, SNRME, SARME, SABME, OR SIM.

See Appendix C, Example 5.5.

7.5.1.3 Request Initialization Mode (RIM) Response

The RIM response is used to request the SIM command. A Secondary/Combined station which has established a RIM condition will monitor any subsequently received commands (other than SIM or DISC) only to detect a respond opportunity to (re)transmit RIM; i.e., no command transmissions are accepted until the RIM condition is reset by the receipt of SIM or DISC. No information field is permitted with the RIM response.

7.5.2 Unnumbered Information Transfer Responses

Unnumbered information transfer responses are used to exchange frames containing information.

7.5.2.1 Unnumbered Information (UI) Response

The UI response is used to transfer an information field to a Primary/Combined station without impacting the Send and Receive Variables. The information field is optionally present with the UI response. Reception of the UI frame is not sequence-number verified; therefore, the frame may be lost if a link exception condition occurs during transmission of the UI, or duplicated if an exception occurs during any reply to the UI. Examples of UI frame information are higher level status, operation interruption, temporal data, and link initialization parameters.

7.5.3 Unnumbered Recovery Responses

Unnumbered recovery responses are used to facilitate the link-level exception condition recovery protocol.

7.5.3.1 Frame Reject (FRMR) Response

The FRMR response is used to report an error condition not recoverable by retransmission of the identical frame; i.e., one of the following conditions resulted from the receipt of an error-free frame from the Primary/Combined station:

1. the receipt of a control field that is invalid or not implemented.

2. the receipt of an I/UI frame with an information field which exceeded the maximum established length.

3. the receipt of an invalid N(R) number from the remote Primary/Combined station.

AD-A067 647 WESTERN UNION TELEGRAPH CO MCLEAN VA GOVERNMENT SYS--ETC F/G 17/2
AUTODIN II MODE VI (ADCCP) LINE CONTROL PROCEDURES--ETC(U)
MAY 78

UNCLASSIFIED SBIE-AD-E100 108 N/L

2 OF 2
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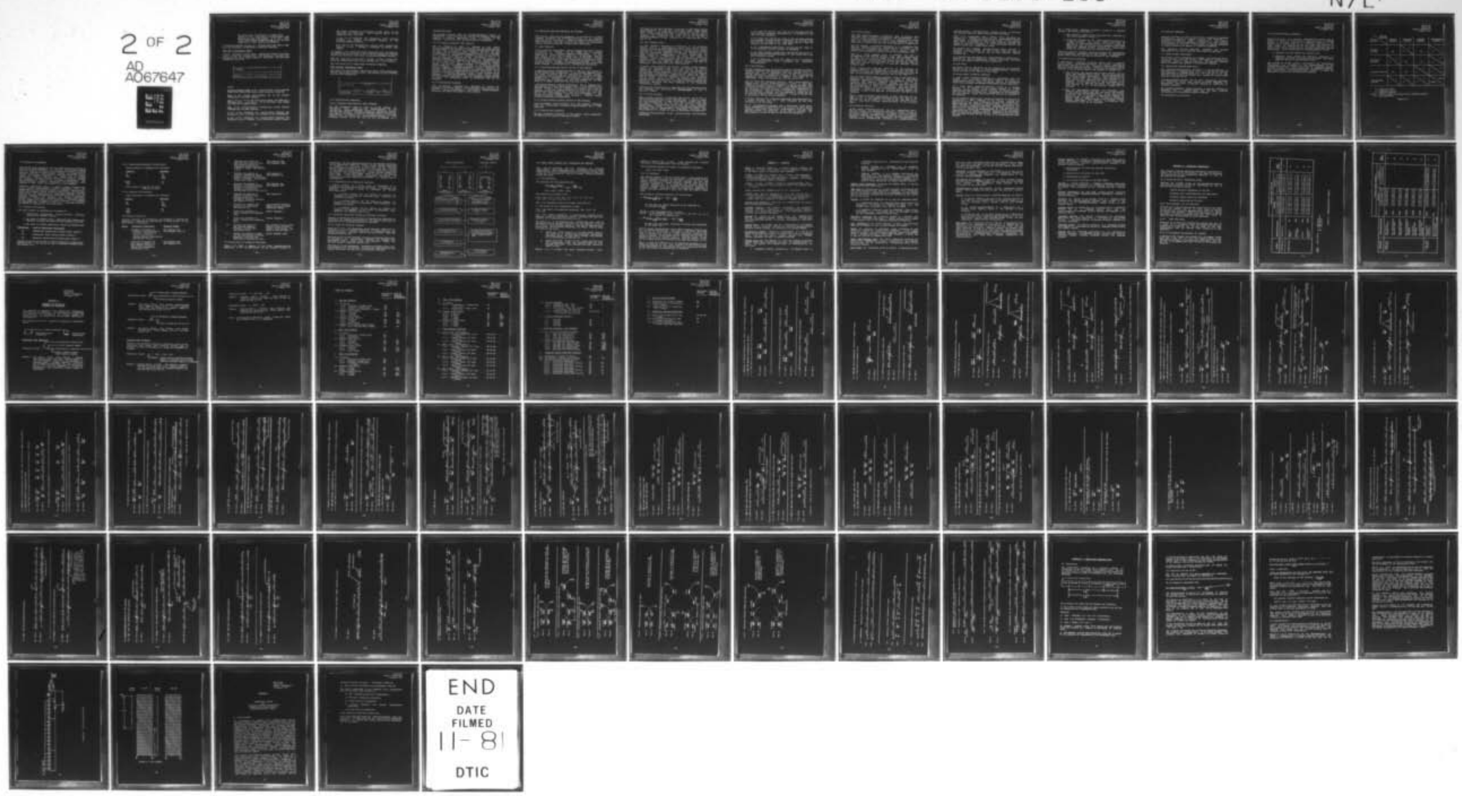
A067647



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An invalid N(R) is defined as a number which points to an I frame which has previously been transmitted <u>and</u> acknowledged, or to an I frame which has not been transmitted <u>and</u> is not the next sequential I frame pending transmission.

A Secondary/Combined station in a disconnected mode (NDM or ADM) will not establish a Frame Reject exception condition.

<u>FRMR Basic Information Field</u>

A basic information field, which immediately follows the basic control field, is returned with this response to provide the reason for the Frame Reject response. The format for the basic information field is:

```
|                                                                      |
|                                                                      |
|<-------------------Basic Information Fields------------------------> |
|r----First Bit                                                        |
|V    Transmitted                                                      |
|                                                                      |
|1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20|

r----------------------------------------------------------------------+
|Rejected                 |   |        |      |           |           |
|Basic Control Field      | 0 |   N(S) | C(R) | N(R)      | W  X  Y  Z|
L----------------------------------------------------------------------+
```

where:

<u>Rejected Control Field</u> is the control field of the received frame which caused the frame reject exception condition.

<u>N(S)</u> is the current Send Variable (S) at the station transmitting the FRMR response.

<u>C/R</u> is set to "1" if the frame which caused the FRMR was a response frame, or is set to "0" if the frame that caused the FRMR was a command frame.

<u>N(R)</u> is the current Receive Variable (R) at the station transmitting the FRMR response.

<u>W</u> set to "1" indicates the control field received and returned in bits 1 through 8 was invalid or not implemented.

<u>X</u> 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 frame. Bit W must be set to "1" in conjunction with this bit.

X set to "1" indicates the information field received exceeded the maximum established capacity of the Secondary/Combined station.

Z if set to "1" indicates the control field received and returned in bits 1 through 8 contained an invalid N(R) number.

If required, the information field associated with the FRMR may be padded with zero bits so as to end on any convenient, mutually agreed upon character, byte, word or machine-dependent boundary.

FRMR may have bits W,X,Y, and Z all set to zero; however the cause for frame reject shall be as defined in 1, 2 and 3 above.

See also Section 8.4, Frame Reject Exception Condition.

FRMR Extended Information Field

The format for the extended information field, which immediately follows the extended control field (see Section 5.2.2), returned with the FRMR response is:

```
|                                                                    |
|                                                                    |
|<-------------------------Extended Information-------------------->|
|                             Field Bits                             |
|First Bit Transmitted                                               |
| |                                                                  |
| V                                                                  |
|                                                                    |
 1               16  17 18         24  25 26         32 33        36
 --------------------------------------------------------------------
| Rejected Extended  |  0 |          N(S) |C/R|    N(R)     |  WXYZ  |
|   Control Field    |    |               |   |             |        |
 --------------------------------------------------------------------
```

7.5.4 Miscellaneous Responses

7.5.4.1 Exchange Identification (XID) Response

The XID response is used to reply to an XID command. An information field containing the identification of the transmitting Secondary/Combined station is optionally present with the XID response. A Secondary/Combined station receiving an XID command will action the XID in any mode unless 1) a set mode response (UA) is pending, 2) a FRMR condition exists, 3) a RIM condition exists, or 4) the XID can not be actioned in a disconnected mode.

On switched networks when the Secondary/Combined station is constrained to send first, it may use the XID response, which may contain an optional information field, to request an XID exchange. See Section 10.0, Switched Network Conventions.

7.5.4.2 Request Disconnect (RD) Response

The RD response is used to indicate to the remote Primary/Combined station that the transmitting Secondary/Combined station wishes to be placed in a logically disconnected mode (NDM or ADM) by receiving a DISC command. RD may be sent asynchronously if the Secondary/Combined station is in ARM/ABM, or if in NRM as a response to a command with the P bit set to "1" or a UP with the P bit set to "0". See Section 7.4.2.2. A Secondary/Combined station which has sent an RD response and receives any non-DISC frame(s) must accept the command frame(s) if it is able to do so. If the Secondary/Combined station accepts the non-DISC command frame(s), it follows the normal ADCCP elements of procedures to respond to the Primary/Combined station commands. Secondary/Combined station acceptance of non-DISC frames after having issued an RD response cancels the RD response. If the Secondary/Combined station still wants to be placed in disconnected mode (NDM or ADM), it must re-issue the RD response. A Secondary/Combined station which cannot accept non-DISC command frames due to internal problems may respond with RD again. No information field is permitted with the RD response.

7.5.5 Non-Reserved Responses

Four non-reserved responses are specified to permit the implementer to define special system-dependent functions that do not have general applicability. Such special system-dependent functions are beyond the scope of this standard.

8.0 EXCEPTION CONDITION REPORTING AND RECOVERY

This section specifies the procedures to be observed 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.

8.1 Busy Condition

A busy condition occurs when a station temporarily cannot receive or continue to receive I or UI frames due to internal constraints; e.g., receive buffering limitations. The busy condition is reported by transmission of an RNR frame with the N(R) number of the next I frame that is expected. Traffic pending transmission at the busy station 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. See Section 8.1.3, Clearing Busy Condition.

8.1.1 Secondary/Combined Station Receipt of RNR Command

A Secondary station transmitting TWS in NRM will upon receipt of an RNR command cease transmission at the earliest possible time. The frame in process may be completed or aborted; however, transmission must be terminated with the F bit to set to "1" (see Example 5.2.1, Appendix C). The Secondary station 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/Combined station transmitting TWS in ARM/ABM will, upon receipt of an RNR, cease transmitting I or UI frames at the earliest possible time by completing or aborting the frame in process. If the RNR command frame had the P bit set to "1" the Secondary/Combined station must transmit a frame with the F bit set to "1". See Examples 5.4.1 and 5.4.3 in Appendix C. The Secondary/Combined station must perform a time-out before resuming asynchronous transmission.

8.1.2 Primary/Combined Station Receipt of RNR Response

Primary/Combined station receipt of an RNR response indicates that the transmitting Secondary/Combined station has a busy condition.

8.1.3 Clearing Busy Condition

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, SREJ, SARM, SARME, SNRM, SNRME, SABM, SABME, or UA frame (with or without the P/F bit set to "1"). A busy condition is also cleared when a Primary station transmits an I frame with the P bit set to "1", or when a Secondary/Combined station transmits an I frame with the F bit set to "1".

8.2 N(S) Sequence Error

An N(S) sequence exception is established in the receiving station when an I frame received error free (no FCS error) contains an N(S) sequence number that is not equal to the Receive Variable (R) at the receiving station. The receiving station does not acknowledge (increment its Receive Variable (R)) the frame causing the sequence error, or any I frames which may follow, until an I frame with the correct N(S) number is received. Unless SREJ is to be used to recover from a given sequence error, the information field of all I frames received whose N(S) does not equal the Receive Variable (R) will be discarded. See Section 8.2.3 for SREJ recovery.

A station which receives one or more I frames having sequence errors, but otherwise error free, will accept the control information contained in the N(R) field and the P/F bit to perform link control functions; e.g., to receive acknowledgement of previously transmitted I frames (via the N(R)), to cause a Secondary/Combined station to respond (P bit set to "1"), and in NRM to detect that the Secondary station will terminate transmission (F bit set to "1"). The retransmitted frame may contain an N(R) and/or P/F bit information that are updated and, therefore, different from that contained in the originally transmitted I frames.

Following the occurrence of a sequence error the following means are available for initiating the retransmission of lost or errored I frames.

8.2.1 P/F Bit Recovery

When a station receives a frame with the P/F bit set to "1", it initiates retransmission of all unacknowledged I frames if there are any unacknowledged I frames with sequence numbers less than the Send Variable (S) at the time the last P/F frame was transmitted. Retransmission starts with the lowest numbered unacknowledged I frame. I frames are retransmitted sequentially. New frames may be transmitted if they become available. Such retransmission of I frames is known as checkpoint retransmission.

Checkpoint retransmission is not initiated under the following conditions:

1. If a REJ with the P/F bit equal to "0" has been received and actioned, checkpoint retransmission is inhibited on the next P/F frame received.

2. If a SREJ with the P/F bit equal to "0" has been received and actioned, retransmission is inhibited on the next frame with the P/F bit equal to "1" when this frame is a SREJ and contains the same N(R) as the first SREJ.

3. If a Unnumbered format frame with the P/F bit equal to "1" is received, P/F bit recovery is inhibited.

4. If, after sending a frame with the P/F bit set to "1", a station receives an acknowledgement to that frame before the next checkpoint occurs.

5. If an SREJ with the P/F bit equal to "1" is received, SREJ retransmission takes precedence over checkpoint retransmission.

8.2.2 REJ Recovery

The REJ command/response is primarily used to initiate an earlier exception recovery (retransmission) following the detection of a sequence error than is possible by P/F bit recovery; e.g., in two-way simultaneous information transfer if REJ is immediately transmitted upon detection of a sequence error there is no requirement to wait for a frame with P/F bit set to "1".

Only one "sent REJ" exception condition, from a given station to another given station, is established at a time. A "sent REJ" exception is cleared when the requested I frame is received, when a time-out function expires, or when a P/F checkpoint cycle that was initiated concurrent with or following the transmission of REJ is completed. When the station perceives by time-out or by the checkpointing mechanism that the requested I frame will not be received, because either the requested I frame or the REJ was in error/lost, the REJ may be repeated.

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

If (1) retransmission beginning with a particular frame occurs due to checkpointing (Sections 6.5.2 and 8.2.1), and (2) a REJ is received which would also start retransmission with the same particular frame (as identified by the N(R) in the REJ), the retransmission resulting from the REJ shall be inhibited.

8.2.3 SREJ Recovery

The SREJ command/response is primarily used to initiate more efficient error recovery by requesting the retransmission of a single I frame following the detection of a sequence error rather than the retransmission of the I frame requested plus all additional I frames which may have been subsequently transmitted.

Note: 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)).

When an I frame sequence error is detected, the SREJ is transmitted at the earliest possible time. When a station sends an SREJ with the P/F bit equal to "0" and the "sent SREJ" condition is not cleared when the station is ready to issue the next frame with the P/F bit equal to "1", the station sends an SREJ with the P/F bit equal to "1" with the same N(R) as the original SREJ.

Since a frame sent with P/F equal "1" has the potential of causing checkpoint retransmission, a station will not send an SREJ with the same N(R) (same value and same numbering cycle) as that of the previously sent frame with the P/F bit equal to 1.

Only one "sent SREJ" exception condition from a given station to another given station is established at a time. A "sent SREJ" exception condition is cleared when the requested I frame is received, when time-out function expires, or when a P/F checkpoint cycle that was initiated concurrent with or following the transmission of SREJ is completed. When the station perceives by timeout or by the checkpointing mechanism that the requested I frame will not be received, because either the requested I frame or the SREJ was in error/lost, the SREJ may be repeated.

When a station receives and actions an SREJ with the P/F bit equal to "0", it will disable actioning of the next SREJ if the SREJ has the P/F bit equal to "1" and has the same N(R) (i.e., has the same value and same numbering cycle) as the original SREJ.

8.2.4 Time-out Recovery

In the event a receiving 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 and, therefore, will not transmit SREJ/REJ. The station which transmitted the unacknowledged I frame(s) shall, following the completion of a system-specified time-out period, take appropriate recovery action to determine the sequence number at which retransmission must begin.

NOTE: It is recommended that a station which has timed out waiting for a response not retransmit all unacknowledged frames immediately. A Secondary station in ARM should, in this time-out case, either retransmit its last single frame or transmit new frames if they are available. A Primary/Combined station may enquire status with a supervisory frame.

To account for possible retransmissions after time-out, a receiving station should not set a SREJ condition when it receives an I frame with an N(S) one less than its Receive Variable (R).

If a station does retransmit all unacknowledged I frames after a time-out, it must be prepared to receive a following REJ frame with an N(R) greater than its Send Variable (S).

8.3 FCS Error

Any frame with an FCS error is not accepted by the receiving station and is discarded. At the Secondary/Combined station no action is taken as the result of that frame.

8.4 Frame Reject Exception Condition

A frame reject exception condition is established upon the receipt of an error-free frame which contains an invalid or unimplemented control field, an invalid N(R) or an information field which exceeded the maximum established storage capability.

If a frame reject exception condition occurs in a Primary station, or is reported to the Primary station by a FRMR response, recovery action will be taken by the Primary station. This recovery action includes the transmission of an implemented set mode command. Higher level functions may also be included in the recovery.

At the Secondary station this exception condition is reported by transmitting a FRMR response to the Primary station for appropriate action. Once a Secondary station has established a FRMR exception any additional commands (other than those that reset the FRMR exception condition) subsequently received are examined only with regard to the state of the N(R) and the P bit; i.e., only to update the acknowledgement of I frames previously transmitted and to detect a respond opportunity to retransmit FRMR. No additional transmissions are accepted or actioned until the condition is reset by the receipt of an implemented set mode command.

If a frame reject exception condition occurs in a Combined station, the station will either:

1. take recovery action without reporting the condition to the remote Combined station, or

2. report the condition to the remote Combined station with a FRMR response. The remote station will then be expected to take recovery action; if, after waiting an appropriate time, no recovery action appears to have been taken, the Combined station reporting the frame reject exception condition may take recovery action.

Recovery action for Balanced operation includes the transmission of an implemented mode-setting or RSET command, as appropriate. Higher level functions may also be involved in the recovery.

8.5 Mode-Setting Contention

A mode-setting contention situation exists when a Combined station issues a mode-setting command and, before receiving an appropriate response (UA or DM), receives a mode-setting command from the remote Combined station. Contention situations shall be resolved in the following manner (see Appendix C, Example 8.5):

1. When the send and receive mode-setting commands are the same, each Combined station shall send an UA response at the earliest respond opportunity. Each Combined station shall either enter the indicated mode immediately or defer entering the indicated mode until receiving an UA response. In the latter case, if the UA response is not received, (1) the mode may be entered when the response timer expires, or (2) the mode-setting command may be reissued.

2. When the mode-setting commands are different, each Combined station shall enter ADM and issue a DM response at the earliest respond opportunity. In the case of DISC contention with a different mode-setting command no further action is required. In the case of contention between SABM and SABME commands, the Combined station sending SABME shall have priority in attempting link establishment after the DM responses.

9.0 TIME-OUT FUNCTIONS

Time-out functions are used to detect that a required or expected acknowledging action or response has not been received to a previously transmitted frame. Expiration of the time-out function shall initiate appropriate action, e.g., error recovery or reissuance of the P-bit. The duration of time-out functions is system dependent and subject to bilateral agreement.

The following time-out functions represent the minimum requirements, and do not preclude other time-out functions.

9.1 Normal Respond Opportunity

The Primary station transmitting a command with the P bit set to "1" or UP with P bit set to "0", anticipates a response and, therefore, starts a time-out function. The time-out function shall be stopped upon receipt of the expected response.

9.2 Asynchronous Respond Opportunity

The Primary/Combined station provides a time-out function to determine that a response frame with F bit set to "1" has not been received to a command frame with the P bit set to "1". The time-out function shall be stopped upon receipt of a valid frame with the F bit set to "1".

A Primary/Combined station with no P bit outstanding, and which has transmitted one or more frames for which responses are anticipated, must start a time-out function to detect the no response condition.

The Secondary/Combined station provides a time-out function to determine that a command frame has not been received acknowledging an unsolicited response frame(s).

See Sections 6.2.2 and 8.2.4.

10.0 SWITCHED NETWORK CONVENTIONS

Stations connected to a switched communications network may be capable of operation as one station type only (e.g., a Primary station, a Secondary station, or a Combined station); or the station may be configurable as (one at a time) more than one of these types. The capabilities of the called station must be known at the calling station and the calling station must operate accordingly. If the called station is configurable it will:

1. implement the XID command and response, and

2. determine which station type (Primary, Secondary, or Combined) to invoke by recognition of either the remote station address or identification (XID).

The calling or called station will initate the transmission interchange first depending on the characteristics of the transmission network. When initiated by the Secondary station, it sends a single unsolicited Supervisory or Unnumbered response. When initiated by the Primary/Combined station, it sends any appropriate command with an appropriate address.

CALLED STATION \ CALLING STATION	PRIMARY STATION	SECONDARY STATION	COMBINED STATION	CONFIGURABLE STATION
PRIMARY STATION	NA	S P	NA	S P
SECONDARY STATION	P S	NA	NA	P S
COMBINED STATION	NA	NA	C C	C C
CONFIGURABLE STATION	P S	S P	C C	P/S/C P/S/C

P = Primary Station
S = Secondary Station
C = Combined Station
P/S/C = Primary and/or Secondary and/or Combined Station
NA = Not Applicable

FIGURE 10-1

11.0 CLASSES OF PROCEDURES

All classes of procedures use the two frame formats as defined in Section 3.0 FRAME STRUCTURE. In addition, all procedures assume that the links include Primary and Secondary stations or Combined stations. Primary stations transmit commands (in frames with or without information), and Secondary stations receive the command frames and transmit responses (in frames with or without information). Combined stations transmit and receive commands and responses (in frames with or without information). The Primary/Combined station is responsible for determining which commands to send, within the constraints of the standard.

Procedure differences based on overall system consideration (e.g., network configuration, traffic management, etc.) are accommodated by defining three modes of operation - Asynchronous, Normal and Balanced, and by defining three Classes of Procedures that utilize the capabilities of these modes together with the exception recovery characteristics specified within the standard. Optional Functions are defined to provide additional capabilities. Individual classes implement a prescribed subset of the commands and responses defined in Section 7.0, COMMANDS AND RESPONSES, and include P/F recovery as a minimum capability as defined in Sections 6.1, 6.5.2 and 8.2.1.

11.1 Classes of Procedures

The three Classes of Procedures are composed of:

1. Three types of stations: Primary stations, Secondary stations and Combined stations

2. Two types of configurations: Unbalanced (for Primary and Secondary stations) and Balanced (for Combined stations).

3. Two types of respond opportunity: Normal and Asynchronous

Designation	Class of Procedures Description
UA	Unbalanced, Asynchronous Response Mode, Modulo 8
UN	Unbalanced, Normal Response Mode, Modulo 8
BA	Balanced, Asynchronous Balanced Mode, Modulo 8

Classes UA and UN can be used on either Unbalanced or Symmetrical configurations. Class BA can be used on Balanced configurations. See Section 2.2.

11.1.1 Unbalanced/Symmetrical Configuration

Basic Repertoire of Commands and Responses

Commands	Responses
I	I
RR	RR
RNR	RNR
	FRMR
*SXXM	UA
DISC	DM

*SXXM Command is SARM for UA Class
SNRM for UN Class

11.1.2 Balanced Configuration

Basic Repertoire of Commands and Responses

Commands	Responses
I	I
RR	RR
RNR	RNR
	FRMR
SABM	UA
DISC	DM
RSET	

11.2 Optional Functions

Optional functions are achieved by the addition or deletion of commands and responses or capabilities to those present in any basic Class of Procedures.

Option	Functional Description	Required Change
1	Provides the ability to: - exchange identification of stations. See Sections 7.4.4.1 and 7.5.4.1. - request logical disconnection. See Section 7.5.4.2.	Add command: XID Add response: XID, RD
2	Provides the ability for more timely reporting of N(S) sequence errors to improve TWS performance. See Section 7.2.3.	Add command: REJ Add response: REJ

3	Provides the ability for more efficient recovery from N(S) sequence errors by requesting retransmission of a single I frame. See Section 7.2.4.	Add command: SREJ Add response: SREJ
4	Provides the ability to exchange information fields without impacting the Send and Receive Variables. See Sections 7.4.2.1 and 7.5.2.1.	Add command: UI Add response: UI
5	Provides the ability to ability to initialize remote stations and the ability to request initialization. See Sections 7.4.1.7 and 7.5.1.3.	Add command: SIM Add response: RIM
6	Provides the ability to perform unnumbered group polling as well as unnumbered individual polling. See Section 7.4.2.2.	Add command: UP
7	Provides for greater than single octet addressing. See Section 4.3.	Use extended addressing format in lieu of basic addressing format.
8	Limits the procedure to allow I frames to be commands only.	Delete response: I
9	Limits the procedure to allow I frames to be responses only.	Delete command: I
10	Provides the ability to use extended sequence numbering (modulo 128). See Section 5.2.2.	Use extended control field format in lieu of basic control field format. Use SXXME in lieu of SXXM.
11	Removes the ability to reset the Send and Receive variables associated with only one direction of information flow.	Delete command: RSET

11.3 Consistency of Classes of Procedures

Figure 11-1 gives a summary of the basic command/response repertoire of the two Unbalanced and one Balanced Classes of

Procedures, and the commands/responses of the Optional Functions. In the Unbalanced classes the Primary station command repertoire is listed on the left side of each class and the Secondary station response repertoire is listed on the right side. As seen in the figure, the basic repertoire of all Classes of Procedures is identical with the exception of a unique set-mode command for each class, and the RSET command which is used in the Balanced Class only. This repertoire consistency facilitates the inclusion of multiple Classes of Procedures in a station that is configurable.

11.4 Implementation of Classes of Procedure

A station conforms to a given Class of Procedures if it implements the basic repertoire of that class. To implement (see Appendix A definition) a Class of Procedures (or Optional Functions) means:

1. A Primary station has the ability to receive all responses in the Class of Procedures basic repertoire (or Optional Functions).

2. A Secondary station has the ability to receive all commands in the Class of Procedures basic repertoire (or Optional Functions).

3. A Combined station has the ability to receive all commands and responses in the Class of Procedures basic repertoire (or Optional Functions).

11.5 Method of Indicating Classes and Optional Functions

Classes of Procedures and the Optional Functions are indicated by specifying the mnemonic designation for the desired Class and the number(s) of the accompanying Optional Functions.

11.5.1 Class and Option(s) Examples

Class UN,1,2,6 is the Unbalanced, Normal Response Mode Class of Procedures with the Optional Functions for identification and request disconnect (XID,RD), improved TWS performance (REJ) and unnumbered polling (UP).

Class BA,2,3,10 is the Balanced, Asynchronous Balanced Mode Class of Procedures with the Optional Functions for improved TWS performance (REJ), single frame retransmission (SREJ) and extended sequence numbering (modulo 128).

Class UA,1,5 is the Unbalanced, Asynchronous Response Mode Class of Procedures with the Optional Functions for identification and request disconnect (XID,RD) and initialization (SIM,RIM).

```
        UNBALANCED BASIC REPERTOIRE                         BALANCED BASIC REPERTOIRE
                    |                                                   |
    ----------------------------------------------            -------------------------

               UA                        UN                                BA
    ----------------------   ----------------------   ------------------------------
    | PRI          SEC   |   | PRI          SEC   |   |                            |
    | STA          STA   |   | STA          STA   |   |   COMBINED STATION         |
    | ---          ---   |   | ---          ---   |   |   ----------------         |
    | CMD          RESP  |   | CMD          RESP  |   |   CMD              RESP    |
    | ---          ----  |   | ---          ----  |   |   ---              ----    |
    | I            I     |   | I            I     |   |   I                I       |
    | RR           RR    |   | RR           RR    |   |   RR               RR      |
    | RNR          RNR   |   | RNR          RNR   |   |   RNR              RNR     |
    |                    |   |                    |   |                            |
    | SARM         UA    |   | SNRM         UA    |   |   SABM             UA      |
    | DISC         DM    |   | DISC         DM    |   |   DISC             DM      |
    |              FRMR  |   |              FRMR  |   |   RSET             FRMR    |
    |                    |   |                    |   |                            |
    |     Modulo 8       |   |     Modulo 8       |   |      Modulo 8              |
    | Sequence Numbering |   | Sequence Numbering |   |   Sequence numbering       |
    ----------------------   ----------------------   ------------------------------
              v                        v                           v
              ----------------------------------------------------------
          Optional Functions           |           Optional Functions
    Command                  Response  |    Command                      Response
    -------------------------------    |    ---------------------------------
    |For Identification and Request Disc.| |For Multiple Octet Addressing     |
    |-----------------------------------|<---+--->|-----------------------------|
    |1. XID <---------Add---------> XID |  |    | 7. Use extended in lieu of    |
    |                               RD  |  |    |  basic addressing format      |
    -------------------------------------  |    ---------------------------------

    -------------------------------------  |    ---------------------------------
    |  For Improved TWS Performance     |  |    |  For Command I Frames Only    |
    |  ----------------------------     |<---+--->|  -------------------------  |
    |2. REJ <---------Add --------> REJ |  |    |   8. Delete    ----> I        |
    -------------------------------------  |    ---------------------------------

    -------------------------------------  |    ---------------------------------
    |  For Single Frame Retransmission  |  |    | For Response I Frames Only    |
    |  -------------------------------  |<---+--->|  -------------------------  |
    |3. SREJ <--------Add --------> SREJ|  |    |   9. I <-----Delete           |
    -------------------------------------  |    ---------------------------------

    -------------------------------------  |    ------------------------------------------
    |   For Unnumbered Information      |  |    |  For Extended Sequence Numbering       |
    |   --------------------------      |  |    |  -------------------------------       |
    |4. UI <---------Add ---------> UI  |<---|    | 10. Use extended control field format |
    -------------------------------------  |--->|     in lieu of basic control field     |
                                           |    |     format.  Use SXXME in lieu of      |
                                           |    |     SXXM.                              |
                                           |    ------------------------------------------
    -------------------------------------  |
    |      For Initialization           |  |
    |      ------------------           |  |
    |5. SIM <- --------Add---------> RIM|<---|
    -------------------------------------  |
                                           |    ---------------------------------
                                           |--->|     For Mode Reset Only       |
    -------------------------------------  |    |     -------------------       |
    |    For Unnumbered Polling         |  |    |11. RSET  <---------Delete     |
    |    ----------------------         |<---|    ---------------------------------
    |6. UP <---------Add                |
    -------------------------------------
```

12.0 FRAME CHECK SEQUENCE (FCS) GENERATION AND CHECKING

This section specifies the FCS generation and checking requirements. These 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.

12.1 FCS Generation

The equations for FCS generation are:

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

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

The arithmetic 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.,

k = 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 (see Section 3.7).

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):

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

12.2 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 sequence 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. $$X^{\gamma}\left[\frac{M^*(X) + X^{K}L(X)}{P(X)}\right] = Q(X) + \frac{R(X)}{P(X)}$$

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

When $\gamma = 0$ the remainderis $L(x)$ (16 ones).
When $\gamma = 16$ the remainder is $X^{12} + X^{11} + X^{10} + X^{8} + X^{3} + X^{2} + X + 1$ (X^{15} through X^{0} respectively).

2. $$X^{\gamma}\left[\frac{M^*(X) + (X^{K}+1)\ L(X)}{P(X)}\right] = Q(X) + \frac{R(X)}{P(X)}$$

   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 $X^{K} L(x)$ 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 portion 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 A - GLOSSARY

ABORT: A function invoked by a sending 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 station upon accepting a correctly received FRAME for processing. A station "ACCEPTS" a COMMAND/RESPONSE when the COMMAND/RESPONSE encoded in the CONTROL FIELD of the RECEIVED FRAME is ACTIONED.

ACTION: A station "ACTIONS" a RECEIVED COMMAND/RESPONSE when it performs (or executes) the functions encoded in the CONTROL FIELD of the FRAME.

ADCCP: Advanced Data Communication Control Procedures.

ADDRESS FIELD (A): The sequence of eight (or any multiple of eight if extended) bits immediately following the opening FLAG of a FRAME identifying the SECONDARY/COMBINED STATION sending a RESPONSE FRAME (or designated to receive a COMMAND FRAME).

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

COMBINED STATION: That STATION responsible for performing Balanced LINK LEVEL operations. A COMBINED STATION generates COMMANDS and interprets RESPONSES, and interprets received COMMANDS and generates RESPONSES.

COMMAND: The content of the CONTROL FIELD, of a COMMAND FRAME sent by the PRIMARY/COMBINED STATION instructing the addressed SECONDARY/COMBINED STATION to perform some specific LINK LEVEL function.

COMMAND FRAME: All FRAMES that are transmitted by the PRIMARY STATION (or by a COMBINED STATION that have the remote/receiving COMBINED STATION address) are referred to as COMMAND FRAMES.

CONFIGURABLE STATION: A STATION is CONFIGURABLE if it has as the result of mode-setting action, the capability to be, at different times, more than one type of logical station; i.e., PRIMARY STATION, SECONDARY STATION, or COMBINED STATION.

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

1. SECONDARY STATION, designated by the ADDRESS FIELD, as

a COMMAND instructing the performance of some specific function.

2. PRIMARY STATION, as a RESPONSE from the SECONDARY STATION, designated by the ADDRESS FIELD, to one or more COMMANDS.

3. COMBINED STATION, 1) as a COMMAND instructing the performance of some specific function, if the ADDRESS FIELD designates the receiving COMBINED STATION, 2) as a RESPONSE to one or more transmitted COMMANDS if the ADDRESS FIELD designates the remote COMBINED STATION.

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

DATA LINK: An assembly of two or more terminal installations and the interconnecting line operating according to a particular method that permits information to be exchanged; in this context the term "terminal installation" does not include the data source and the data sink.

DISCARD: A STATION may "DISCARD" all or part of a RECEIVED FRAME:

1. A "DISCARDED" FRAME is a RECEIVED FRAME whose control and information fields are not examined or used; i.e., the STATION takes no ACTION on any part of the FRAME.

2. A "RECEIVED" FRAME may have its INFORMATION FIELD (I/UI) "DISCARDED", i.e., the CONTROL FIELD of the FRAME is used but the INFORMATION FIELD is thrown away.

EXCEPTION CONDITION: The condition assumed by a STATION upon receipt of a CONTROL FIELD 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 opening and closing of a FRAME.

FRAME: The sequence of contiguous bits, bracketed by and including opening and closing 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 closing FLAG SEQUENCE of a FRAME, containing the bit sequence that provides for the detection of transmission errors by the receiving STATION.

HIGH LEVEL: The conceptual level of control or processing logic existing in the hierarchical structure of a 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.

<u>IMPLEMENT</u>: A COMMAND/RESPONSE is IMPLEMENTED if it is part of the receiving STATION'S repertoire; i.e., the receiving STATION is capable of decoding and ACTIONING the CONTROL FIELD in the RECEIVED COMMAND/RESPONSE.

<u>INFORMATION FIELD (INFO)</u>: The sequence of bits, ocurring 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.

<u>INTERFRAME TIME FILL</u>: The sequence of bits transmitted between FRAMES. This standard does not provide for time fill within a FRAME.

<u>INVALID</u>: There are three reasons a RECEIVED FRAME may be INVALID:

1. An INVALID FRAME is one that is not properly bounded by two FLAGS (thus an ABORTED FRAME is an INVALID FRAME) or one that is too short (e.g., shorter than 32 bits between FLAGS).

2. An INVALID COMMAND/RESPONSE is a FRAME which has a CONTROL FIELD encoding which is not defined in this standard.

3. An INVALID N(R) is one which points to an I FRAME which has previously been transmitted <u>and</u> acknowledged, or to an I FRAME which has not been transmitted <u>and</u> is not the next sequential I FRAME pending transmission.

<u>LINK LEVEL</u>: The conceptual level of control or processing logic existing in the hierarchical structure of a 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, transmission and interpretation, and FRAME CHECK SEQUENCE computation and interpretation.

<u>PRIMARY STATION</u>: That STATION responsible for Unbalanced control of the DATA LINK. The PRIMARY STATION generates COMMANDS and interprets RESPONSES. Specific responsibilities assigned to the PRIMARY STATION include:

1. Initialization of (data and control) information interchange

2. Organization and control of data flow

3. Retransmission control

4. All recovery functions at the LINK LEVEL

<u>RECEIVE</u>: A STATION "RECEIVES" a COMMAND or RESPONSE FRAME when the incoming bit configuration is bounded by two FLAGS, contains an ADDRESS FIELD recognized by that STATION, and has a correct FCS.

<u>RESPOND OPPORTUNITY</u>: The LINK LEVEL logical control condition during which a given SECONDARY/COMBINED STATION may transmit a RESPONSE FRAME(s).

<u>RESPONSE</u>: The content of the CONTROL FIELD of a RESPONSE FRAME advising the PRIMARY/COMBINED STATION with respect to the processing by the SECONDARY/COMBINED STATION of one or more COMMAND FRAMES.

<u>RESPONSE FRAME</u>: All FRAMES that may be transmitted by a SECONDARY STATION (or by a COMBINED STATION that have the local/transmitting COMBINED STATION address) are referred to as RESPONSE FRAMES.

<u>SECONDARY STATION</u>: That STATION responsible for performing Unbalanced LINK LEVEL operations, as instructed by the PRIMARY STATION. A SECONDARY STATION interprets received COMMANDS and generates RESPONSES.

<u>SECONDARY STATUS</u>: The current condition of a SECONDARY STATION with respect to processing the series of COMMANDS received from the PRIMARY STATION.

<u>STATION</u>: The word "STATION" unqualified (i.e., not preceeded by PRIMARY, SECONDARY, or COMBINED) applies to all three types of STATIONS: PRIMARY STATION, SECONDARY STATION and COMBINED STATION.

APPENDIX B - ADDITIONAL INFORMATION

This appendix provides additional explanatory information to assist in the use of the standard. For ease of reference, the organization of this appendix is identical to that of the body of the standard.

B.3.4 Frame Structure, Information Field

Although the maximum length of the information field is theoretically unlimited it will be constrained by one or more of the following factors:

1. Error detection capability of the FCS
2. Channel error characteristics and data rates
3. Station buffer sizes and strategies
4. Logical properties of the data

B.3.1 Flag Sequence, and 3.8 Time Fill

Although this standard permits the closing flag of one frame to be the opening flag of the next frame, it must be recognized that in certain implementations this may result in crisis time problems. Under those conditions, it may be necessary to transmit interframe time fill. The amount of time fill must be determined by prior agreement.

B.3.9 IDLE Link State

Detection of an IDLE link condition may require the use of a timer or an alternate clock to determine receipt of a continuous one condition for 15 bit times if the link configuration does not provide clock signals in an IDLE condition.

B.7.4.2.1 Unnumbered Information, UI, Command

A Secondary must respond upon receipt of a UI command frame with the P bit set to "1"; the response shall be any appropriate frame(s), one of which will have the P bit set to "1". A UI command with the P bit set to "0" solicits no response.

FORMAT	COMMAND/RESPONSE		CONTROL FIELD ENCODING: COMMAND (bits 1 2 3 4 / 5 / 6 7 8)	CONTROL FIELD ENCODING: RESPONSE (bits 1 2 3 4 / 5 / 6 7 8)	INFO FIELD
Information	Information	I	0 N(S) P N(R)	0 N(S) F N(R)	0
Supervisory	Receive Ready	RR	1 0 0 0 P N(R)	1 0 0 0 F N(R)	N
	Receive Not Ready	RNR	1 0 1 0 P N(R)	1 0 1 0 F N(R)	N
	Reject	REJ	1 0 0 1 P N(R)	1 0 0 1 F N(R)	N
	Selective Reject	SREJ	1 0 1 1 P N(R)	1 0 1 1 F N(R)	N

NOTE: Info Field: 0 - Optional
N - Not Allowed
R - Required

TABLE B1 COMMAND/RESPONSE SUMMARY

FUNCTION	COMMAND/RESPONSE	CONTROL FIELD ENCODING				INFO FIELD
		COMMAND		RESPONSE		
			1 2 3 4 5 6 7 8		1 2 3 4 5 6 7 8	
Mode Set Commands	Set Normal Response Mode	SNRM	1 1 0 0 P 0 0 1			N
	Set Asynchronous Response Mode	SARM	1 1 1 1 P 0 0 0			N
	Set Asynchronous Balanced Mode	SABM	1 1 1 1 P 1 0 0			N
	Set Asynchronous Response Mode Extended	SARME	1 1 1 1 P 0 1 0			N
	Set Normal Response Mode Extended	SNRME	1 1 1 1 P 0 1 1			N
	Set Asynchronous Balanced Mode Extended	SABME	1 1 1 1 P 1 1 0			N
Mode Set/ Request	Disconnect/ Request Disconnect	DISC	1 1 0 0 P 0 1 0	RD	1 1 0 0 F 0 1 0	N
	Set Initialization Mode/ Request Initialization Mode	SIM	1 1 1 0 P 0 0 0	RIM	1 1 1 0 F 0 0 0	N

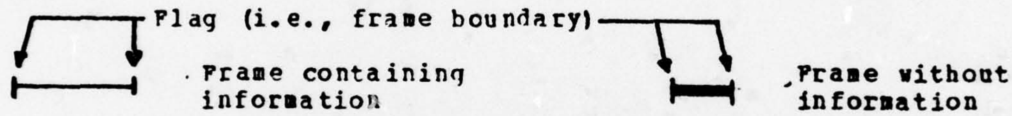
TABLE B1 (continued)

APPENDIX C

EXAMPLES OF THE USE OF COMMANDS AND RESPONSES

The examples in Appendix C are offered for illustrative purposes only and should not be interpreted as establishing any protocol; the exchange of the various command and response frames is limited only by the rules specified in the standard.

The notation used in the Appendix C diagrams is illustrated below:



UNBALANCED MODE OPERATION

Information Format Frame

Send Sequence Number

Information Frame: I N(S),N(R) P/F ←Poll or Final Bit set to "1"

Receive Sequence Number (next expected frame).

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 acknkowledged) 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
Supervisory Frame:  XXX N(R),P/F  Poll or Final bit set to "1"
                            Receive Sequence Number
```

Example: Pri xmits: RR2,P. 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".

```
                           Unnumbered command/response
Unnumbered Frame:   YYYY , P/F
                             Poll or Final Bit set to "1"
```

Example: Pri xmits: SNRM,P. This denotes a Set Normal Response Mode (SNRM) command with the Poll bit set to "1".

BALANCED MODE OPERATION

Balanced Mode operation notation is identical to that of the Unbalanced Mode except that a station address must be indicated in order to designate the frame as a command of a response.

```
Information Frame:  A , I  N(S) ,  N(R)  P/F
                    Address:  remote station address indicates
                              frame is a command; local station
                              address indicates frame is a response
```

Example: Combined xmits: A,I2,6P. This denotes a command Information Format frame with sequence number 2, the next expected frame is sequence number 6 and the Poll bit is set to "1".

Supervisory Frame: A , XXX N(R) , P/F

Example: Combined xmits: B,RR2,F. This denotes a response Receive Ready (RR) with N(R) = 2 and the Final bit set to "1".

Unnumbered Frame: A , YYYY , P/F

Example: Combined xmits: A,SABM,P. This denotes a Set Asynchronous Balanced Mode (SABM) command with the Poll bit set to "1".

NOTE: Retransmitted Information Format frames are shown with a double line: i.e., .

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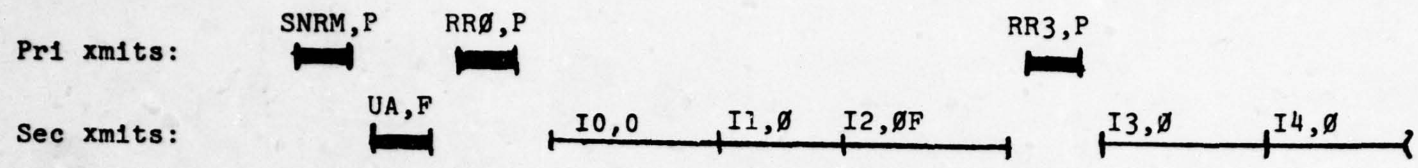
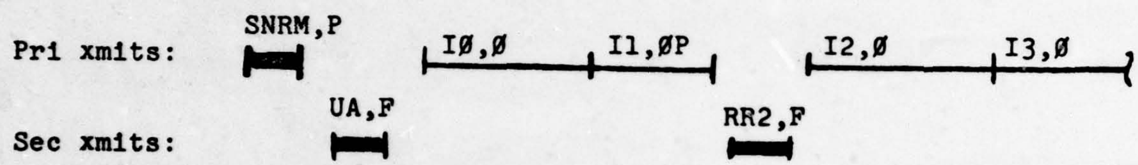
1. Examples of Normal Response Mode (NRM) 2 Way Alternate (TWA) Transmission

1.1 NRM TWA Without Transmission Errors

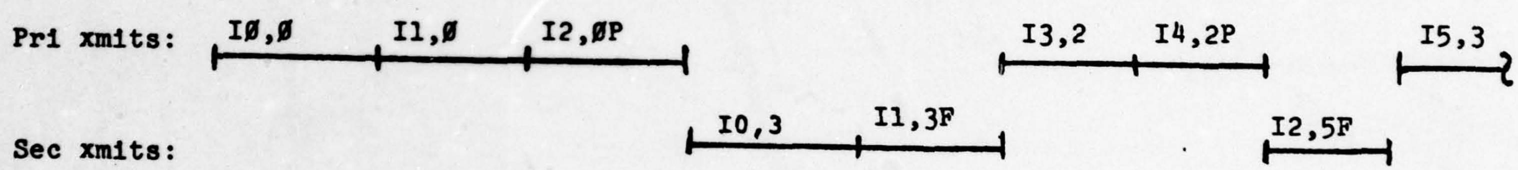
1.1.1 NRM Start-up procedure and Secondary-only information transfer



1.1.2 NRM Start-up procedure and Primary-only information transfer



1.1.3 NRM information transfer by Primary and Secondary



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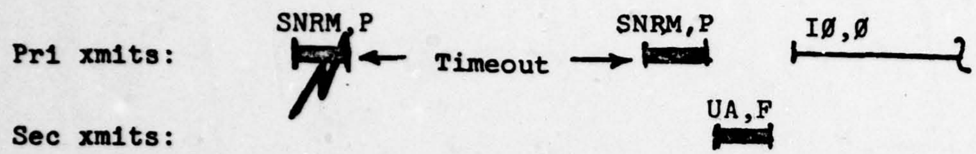
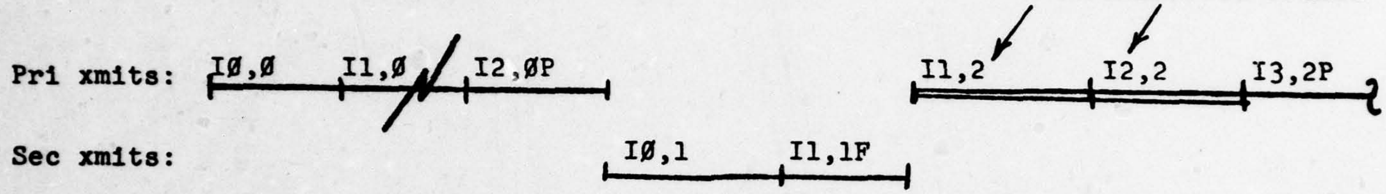
1.2 **NRM TWA with transmission errors in command frames**

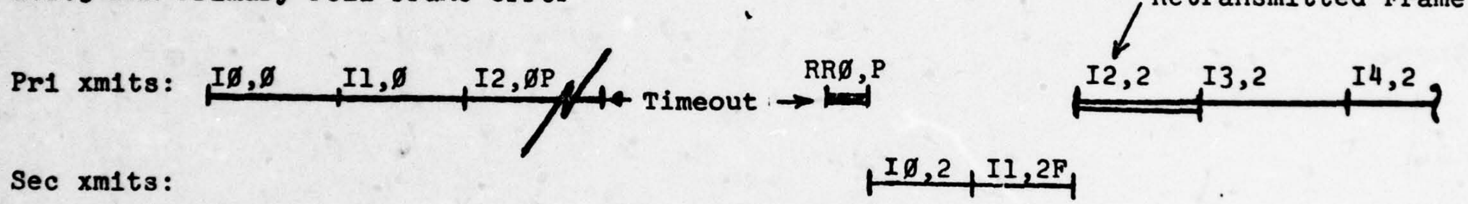
1.2.1 NRM Start-up command error



1.2.2 NRM Primary information frame error



1.2.3 NRM Primary Poll frame error



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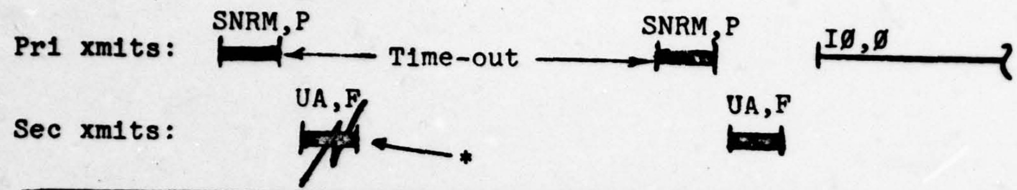
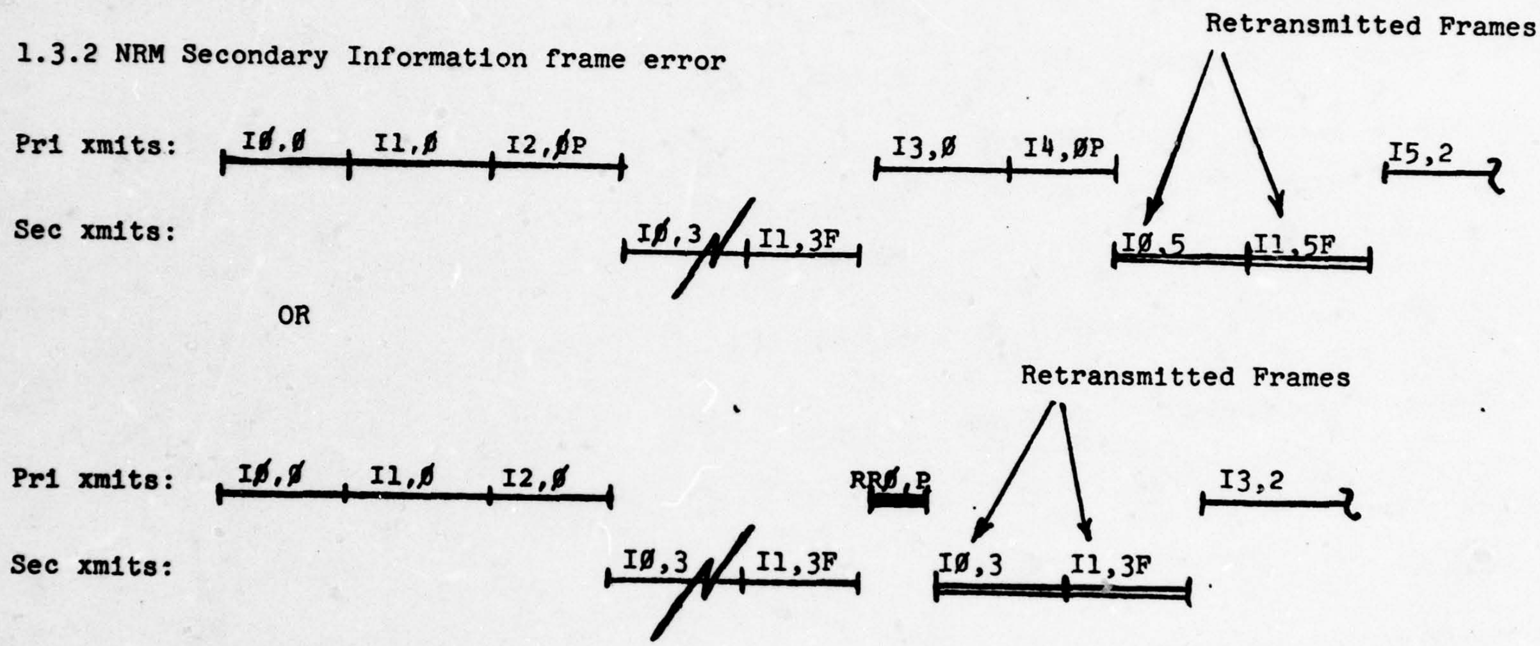
1.3 NRM TWA with transmission errors in response frames

1.3.1 NRM Start-up response error

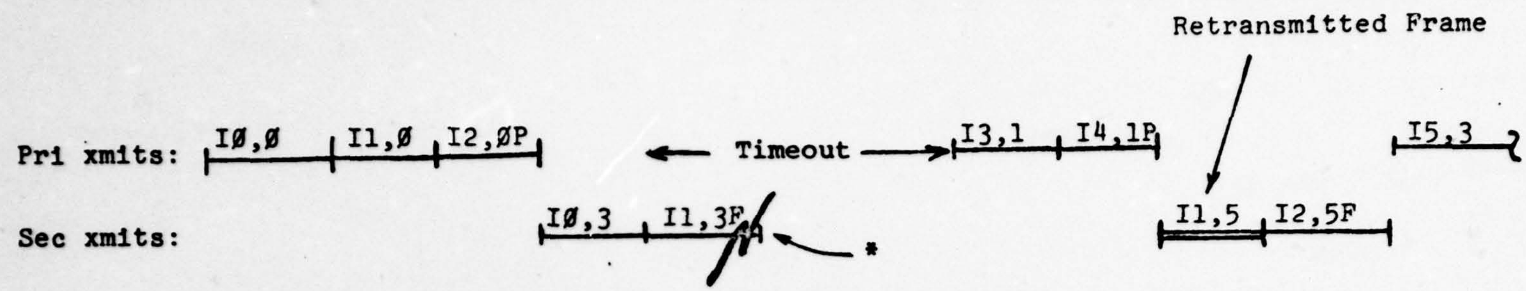


1.3.2 NRM Secondary Information frame error

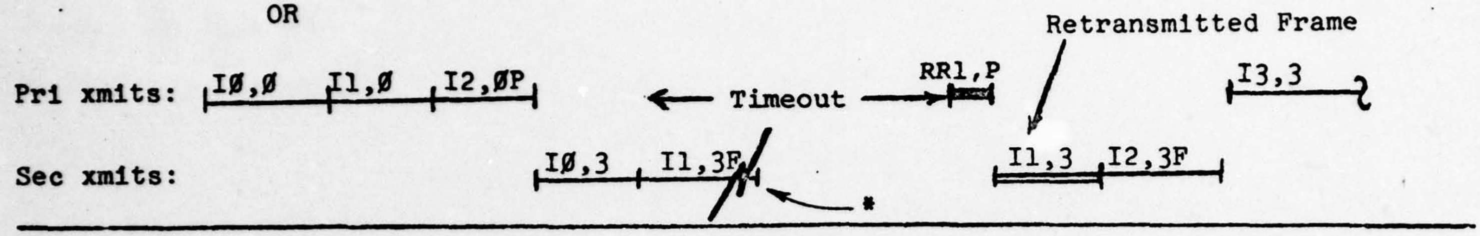


* Idle Link State detection may be used in place of Timeout to initiate Primary transmission

1.3.3 NRM Secondary "Final" frame error

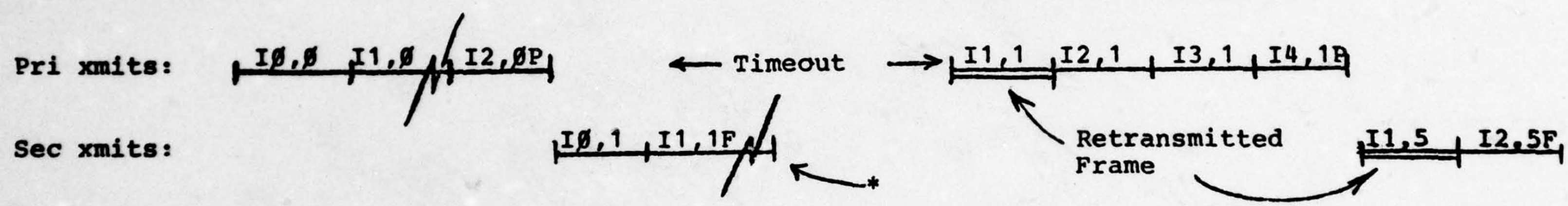


OR



1.4 NRM TWA Command and Response Frame Errors

1.4.1 NRM TWA Primary I and Secondary "Final" I Frame Errors



* Idle Link State detection may be used in place of Timeout to initiate Primary Transmission.

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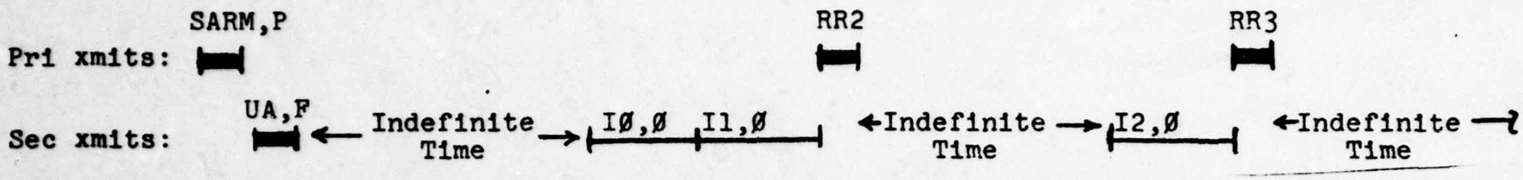
2. **Examples of Asynchronous Response Mode (ARM) 2-Way Alternate (TWA) Transmission**

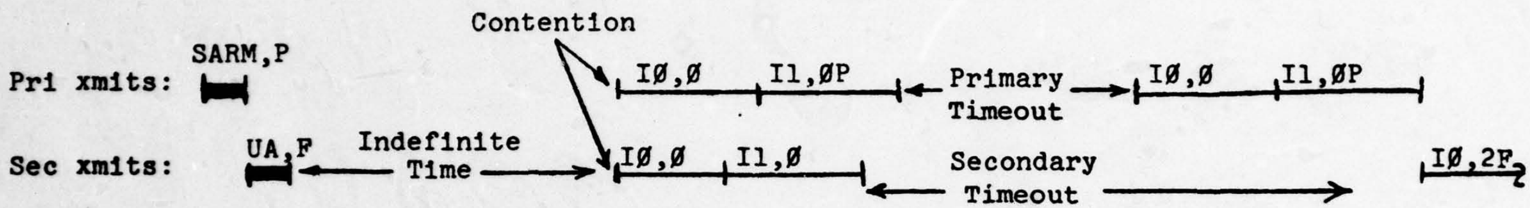
NOTE: All turnarounds in ARM TWA are by means of Idle Link State detection.

2.1 ARM TWA Without Transmission Error

2.1.1 ARM Start-up procedure and Secondary only information transfer

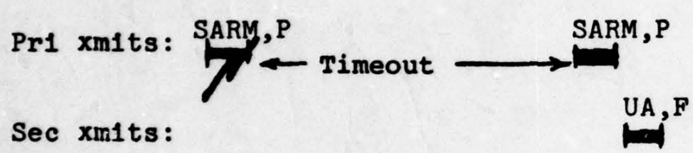


2.1.2 ARM Primary and Secondary information transfer with contention situation



2.2 **ARM TWA With Transmission Errors in Command Frames**

2.2.1 ARM Start-up command error



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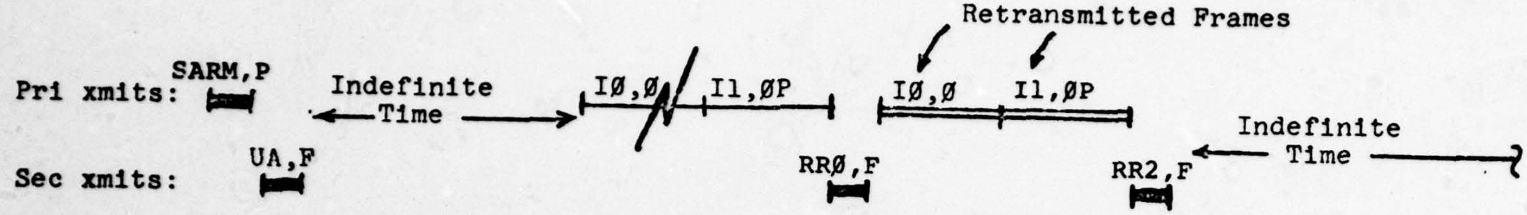
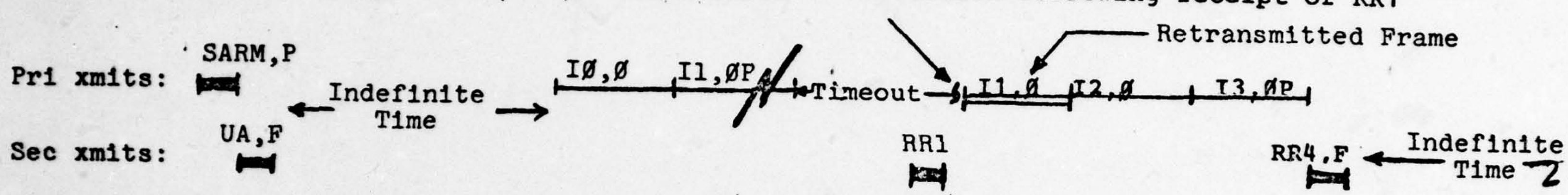
2.2.2 ARM Primary information frame error

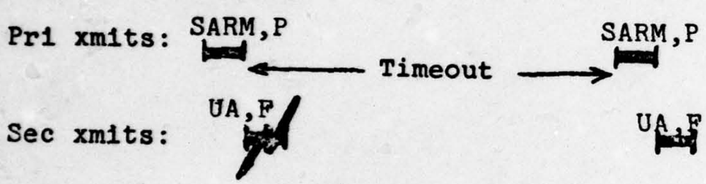


2.2.3 ARM Primary "Poll" information frame error

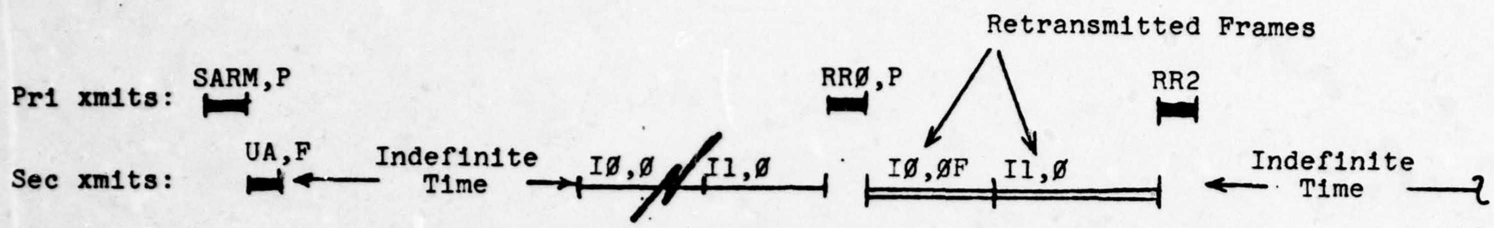


2.3 ARM TWA With Transmission Errors in Response Frames

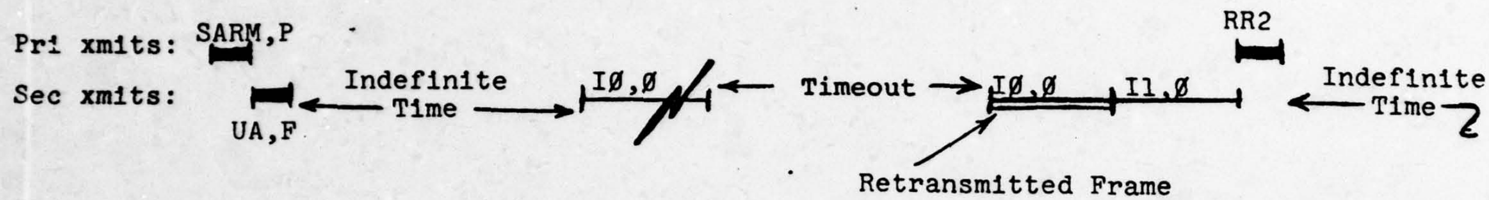
2.3.1 ARM Start-up



2.3.2 ARM Secondary information frame error



2.3.3 ARM Secondary information frame error - no reply received



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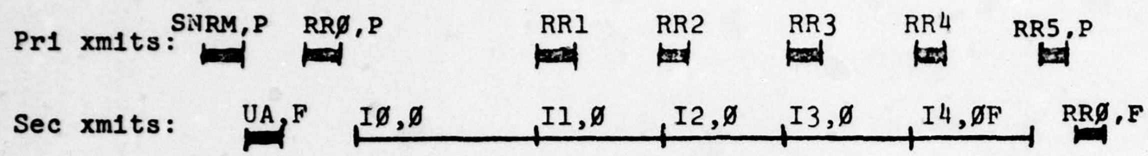
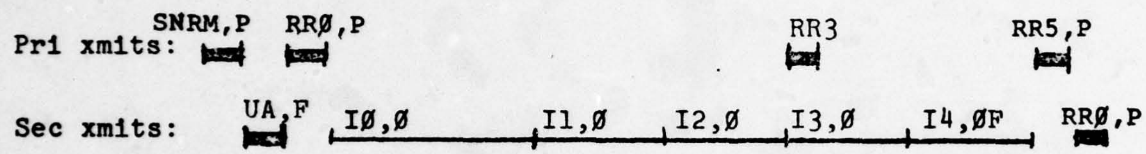
3. Examples of Normal Response Mode (NRM) 2-Way Simultaneous (TWS) Transmission

3.1 NRM TWS Without Transmission Errors

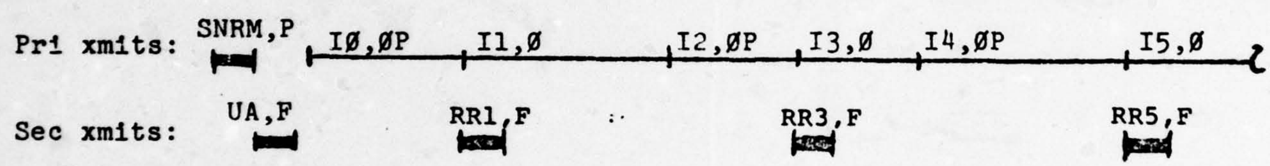
3.1.1 NRM Start-up procedure and Secondary only information transfer



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



3.I.2 NRM Start-up procedure and Primary only information transfer



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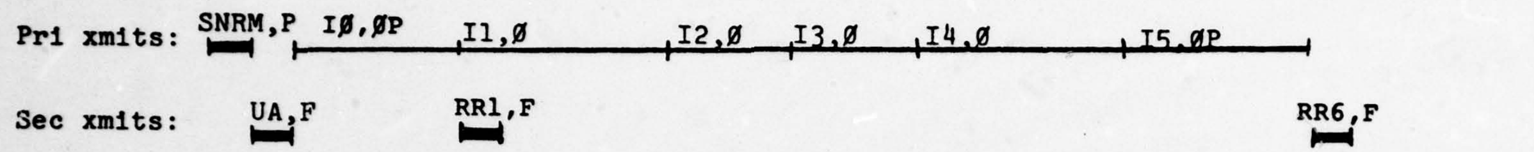
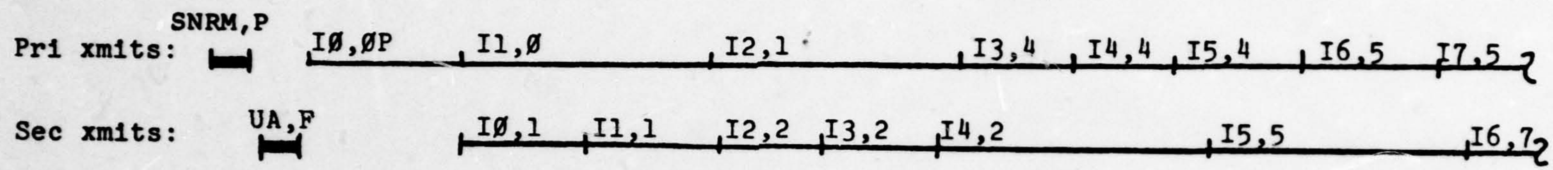
OR (where Primary sets Poll bit to "1" to solicit acknowledgement for several frames)

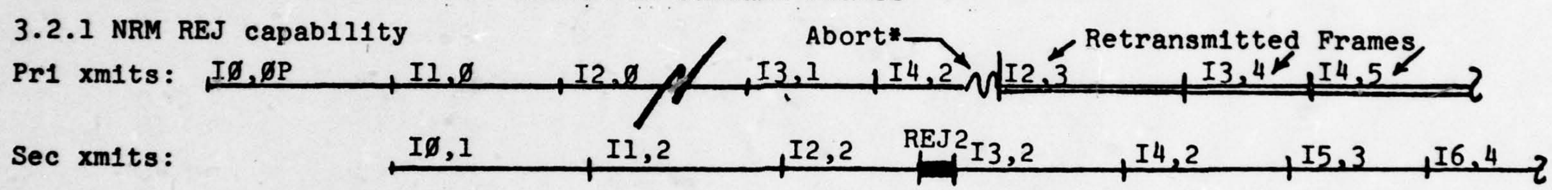


3.1.3 NRM Start-up procedure and Primary/Secondary information transfer



3.2 NRM TWS With Transmission Errors in Command Frames

3.2.1 NRM REJ capability



* Optional: Frame may be completed or aborted

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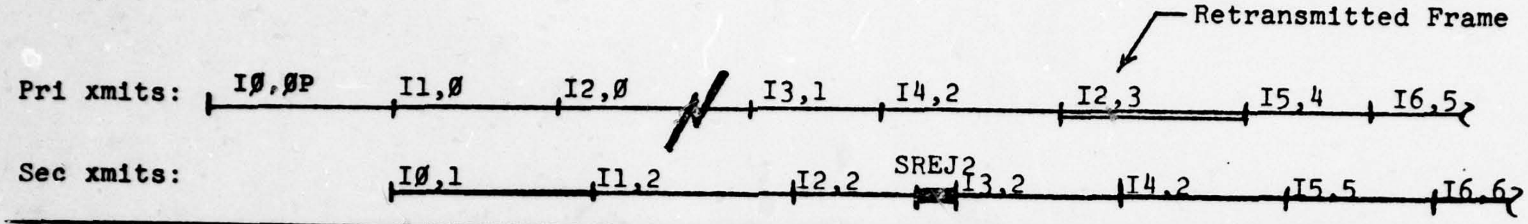
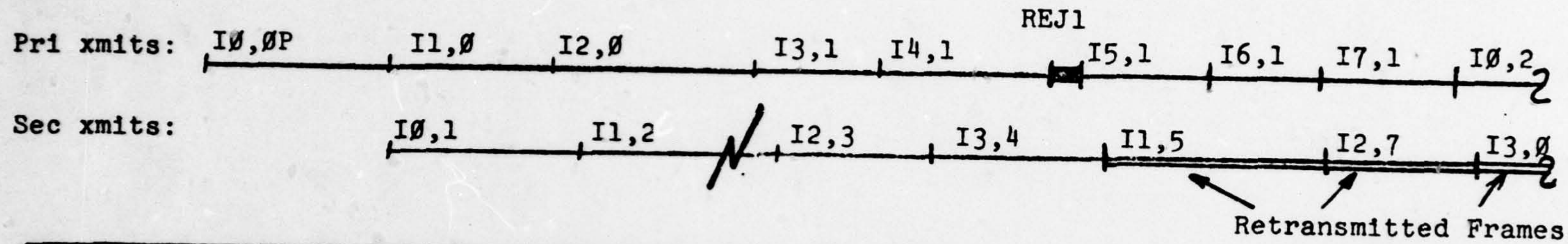
3.2.2 NRM SREJ capability

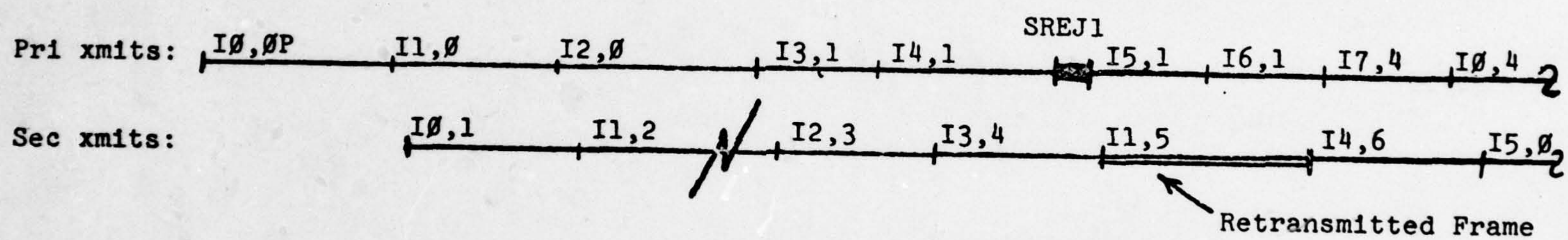


3.3 NRM TWS With Transmission Errors in Response Frames

3.3.1 NRM REJ capability



3.3.2 NRM SREJ capability



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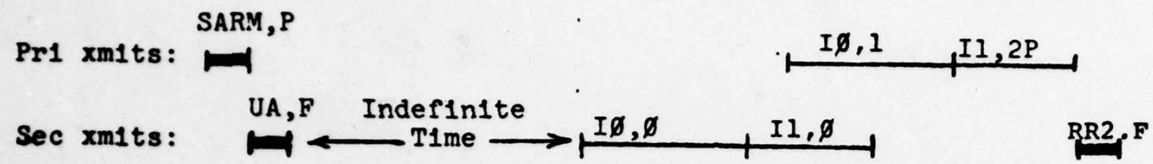
4. Examples of Asynchronous Response Mode (ARM) 2-Way Simultaneous (TWS) Transmission

4.1 **ARM TWS Without Transmission Errors**

4.1.1 ARM Start-up procedure and intermittent Secondary or Primary information transfer



4.1.2 ARM Start-up procedure and continuous Primary Secondary information transfer

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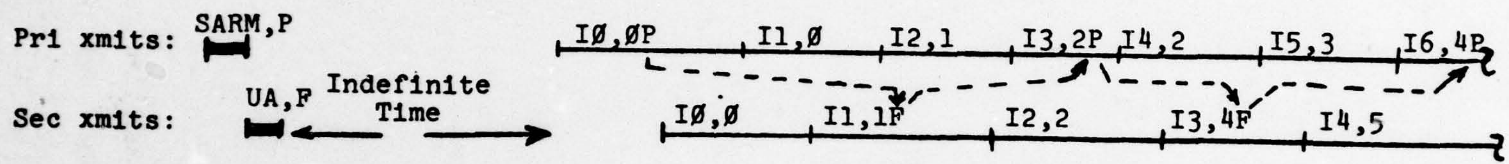
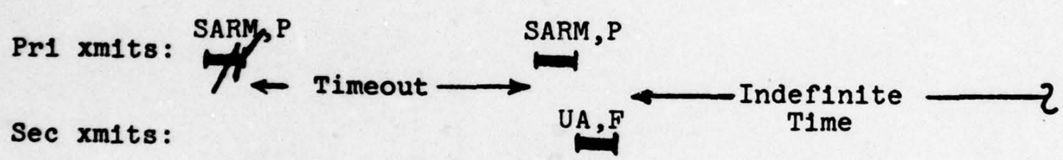
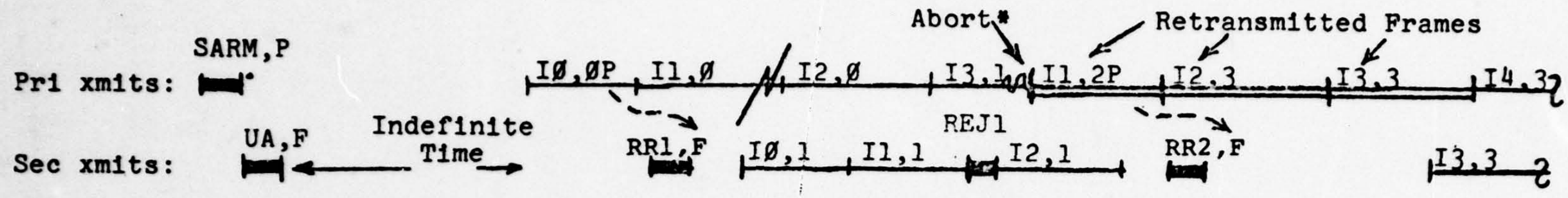


4.2 **ARM TWS With Transmission Errors in Command Frames**

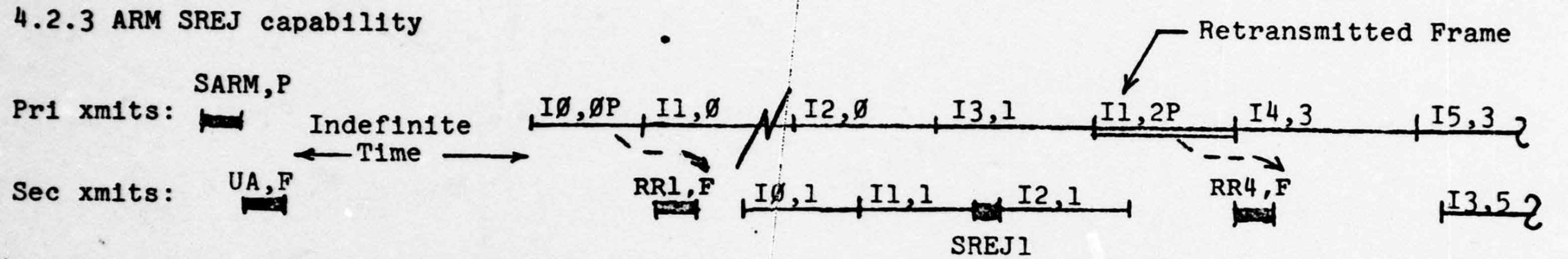
4.2.1 ARM Start-up command error



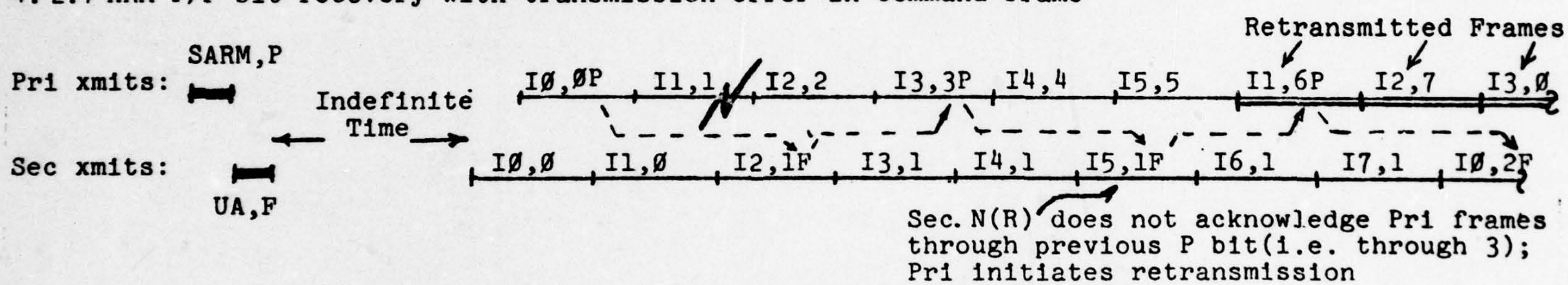
4.2.2 ARM REJ capability



4.2.3 ARM SREJ capability



4.2.4 ARM P/F bit recovery with transmission error in command frame



* Optional: Frame may be completed or aborted

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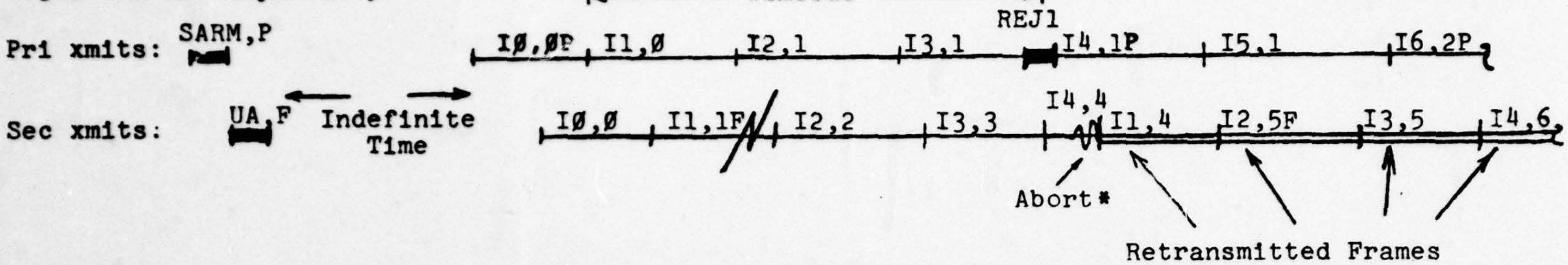
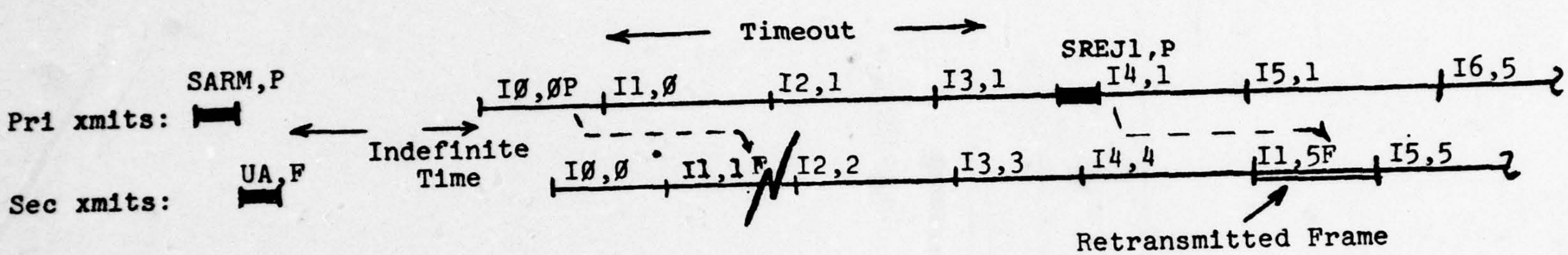
4.3 ARM TWS With Transmission Errors In Response Frames

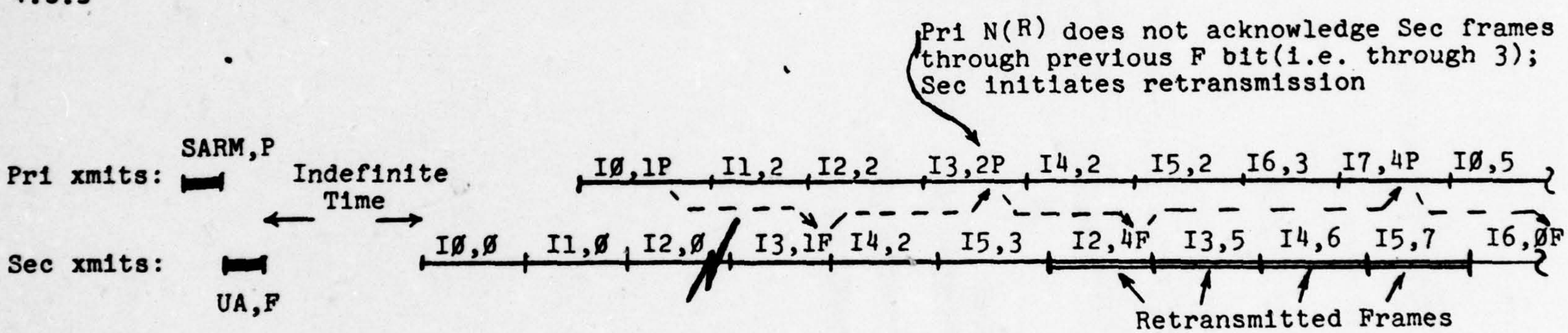
4.3.1 ARM REJ capability



4.3.2 ARM SREJ capability



4.3.3 ARM P/F bit recovery with transmission error in response frame

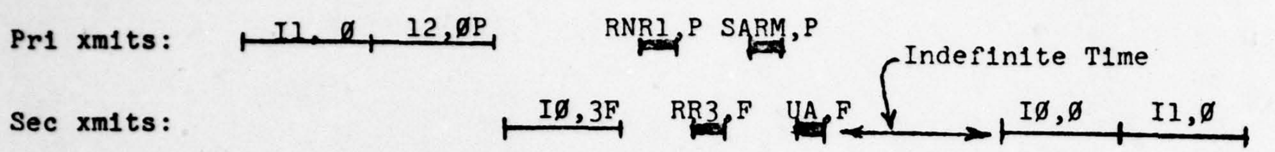


*Optional: Frame may be completed or aborted.

5.0 Examples of Changing Control Mode

5.1 NRM to ARM 2-Way Alternate (TWA)

5.1.1 TWA NRM to ARM Mode Change



5.1.2 NRM to ARM Mode Change TWA

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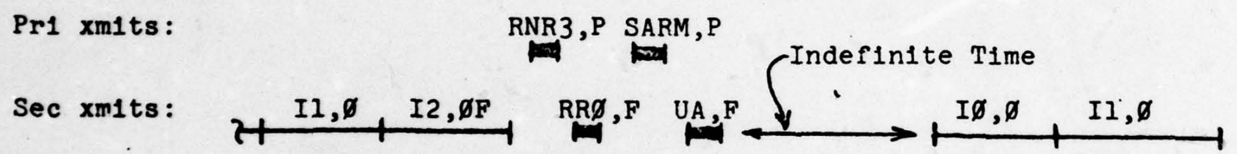
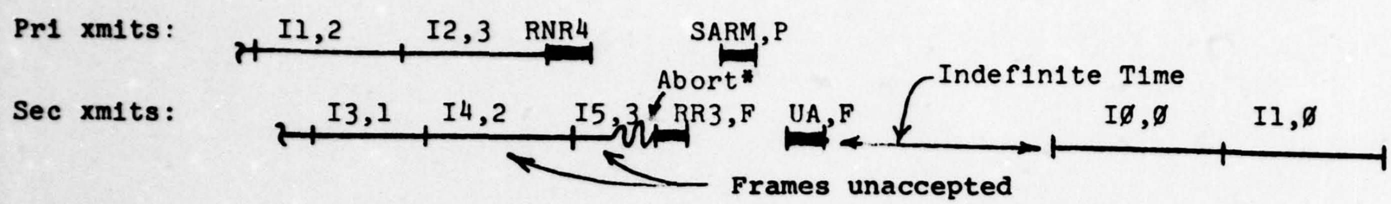
5.1.3 NRM to ARM Mode Change TWA

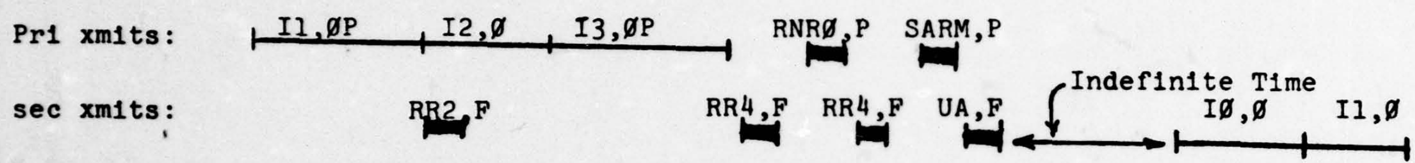


5.2 NRM to ARM 2-Way Simultaneous (TWS)

5.2.1 NRM to ARM Mode Change TWS (Immediate Change)



5.2.2 NRM to ARM Mode Change TWS (Orderly Change while Pri xmits)



5.2.3 NRM to ARM Mode Change TWS (Orderly change while Sec xmits)

* Optional: Frame may be completed or aborted

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5.3 2-Way Alternate (TWA) ARM to NRM Change

5.3.1 TWA ARM to NRM Mode Change

Pri xmits: I1,Ø I2,ØP RNR1,P SNRM,P IØ,Ø I1,Ø

Sec xmits: IØ,3F RR3,F UA,F

5.3.2 TWA ARM to NRM Mode Change

Pri xmits: I1,Ø I2,ØP RNRØ,P SNRM,P IØ,Ø I1,Ø

Sec xmits: RR3,F RR3,F UA,F

5.3.3 TWA ARM to NRM Mode Change

Pri xmits: RNR3,P SNRM,P IØ,Ø I1,Ø

Sec xmits: I1,Ø I2,Ø RRØ,F UA,F

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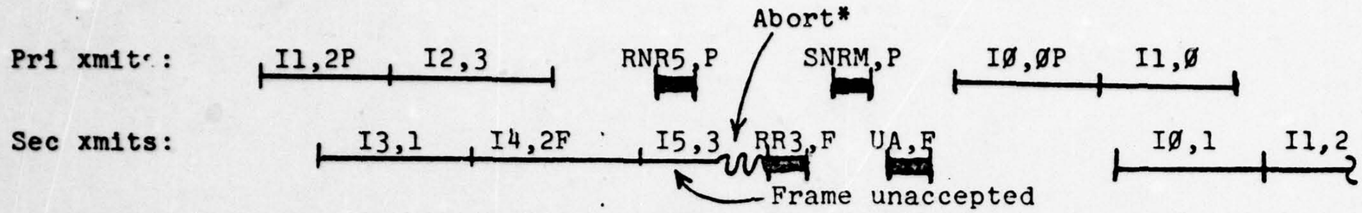
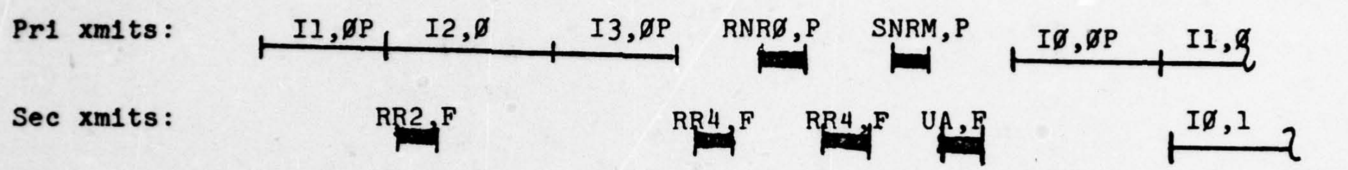
5.4 2-Way Simultaneous (TWS) ARM to NRM Change

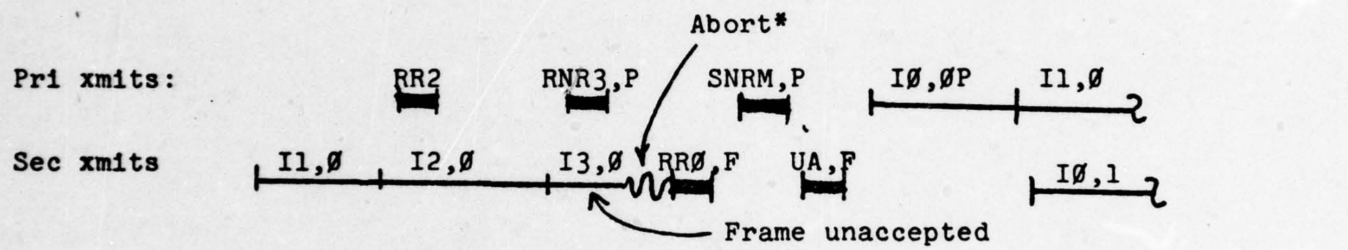
5.4.1 TWS ARM to NRM Mode Change (Immediate Change)



5.4.2 TWS ARM to NRM Mode Change (Orderly Change while Pri xmits)



5.4.3 TWS ARM to NRM Mode Change (Orderly change while Sec xmits)



*Optional: Frame may be completed or aborted.

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5.5 Normal Disconnected Mode (NDM) Examples

5.5.1 **TWA NDM (or ADM) to ARM Change**

Pri xmits: SARM,P   IØ,Ø   I1,ØP

Sec xmits: UA,F   IØ,2

5.5.2 **TWA Secondary in NDM (or ADM) to NRM Change**
(Sec. indicates it is unable to change to NRM)

Pri xmits: SNRM,P

Sec xmits: DM,F

5.5.3 **TWA Secondary in ADM**
(Sec. indicates it is disconnected and Primary sends set mode command)

Pri xmits: (Poll) SARM,P

Sec xmits: DM,F   UA,F

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5.5.4 TWA Secondary in NDM (or ADM)
(Sec indicates it is disconnected, and Primary refuses to send set mode command)

Pri xmits: (Poll) DISC,P

Sec xmits: DM,F DM,F

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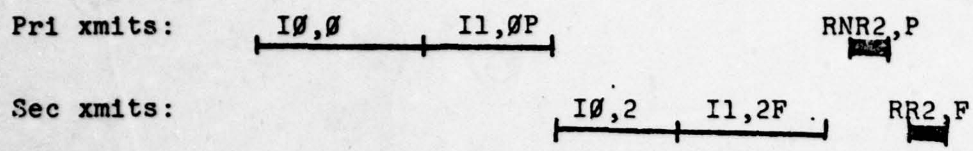
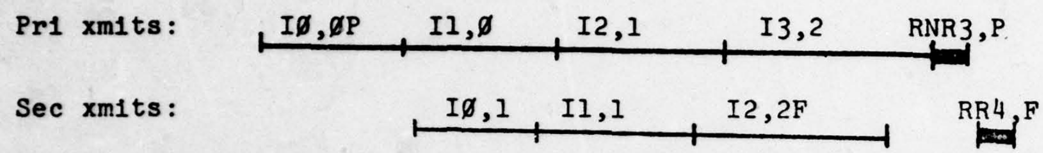
6.0 Examples of End of Operation (General Closing Procedure)

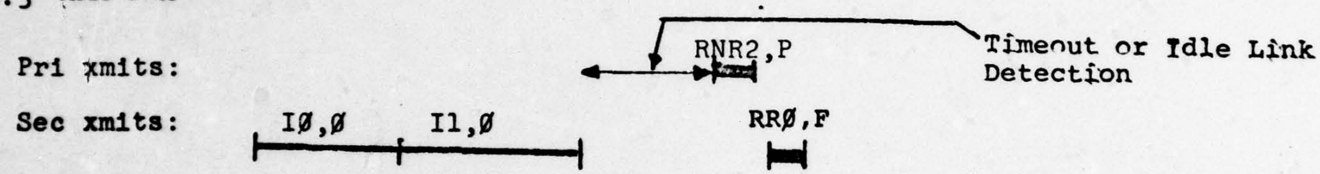
6.1 NRM TWA



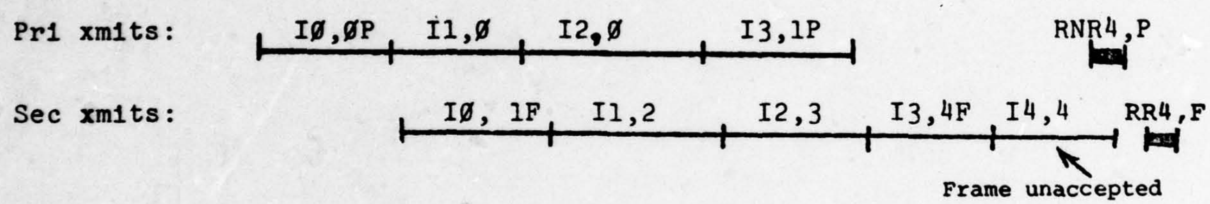
6.2 NRM TWS



6.3 ARM TWA



6.4 ARM TWS



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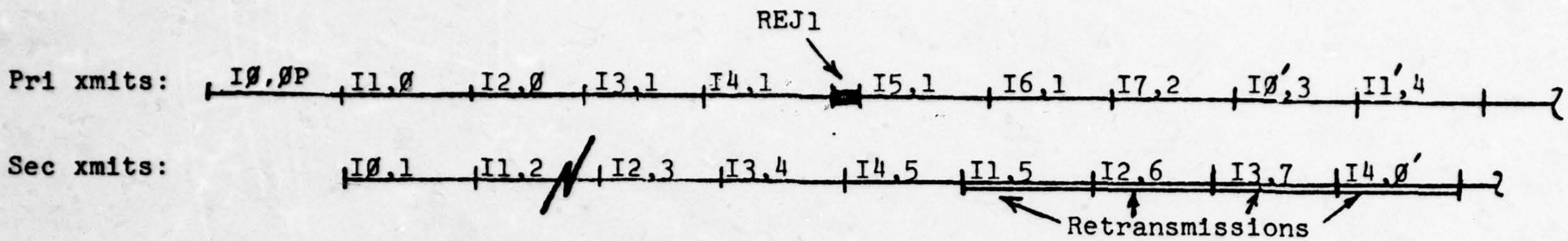
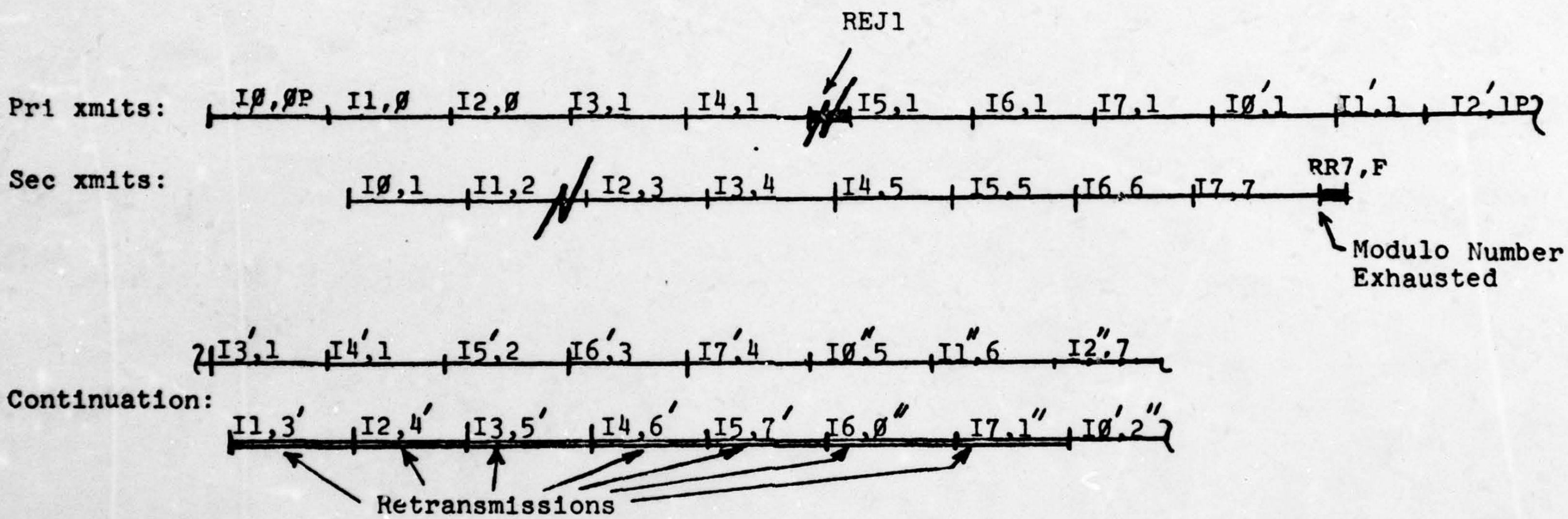
7. Examples of Exception Recovery Procedures

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

7.1.1 NRM - TWS with Information Frame Exception



7.1.2 Example 7.1.1 above except REJ is not received correctly.



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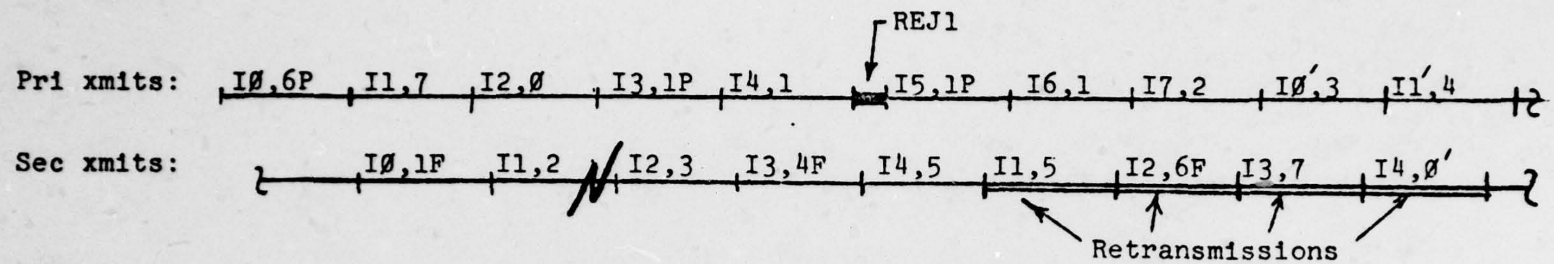
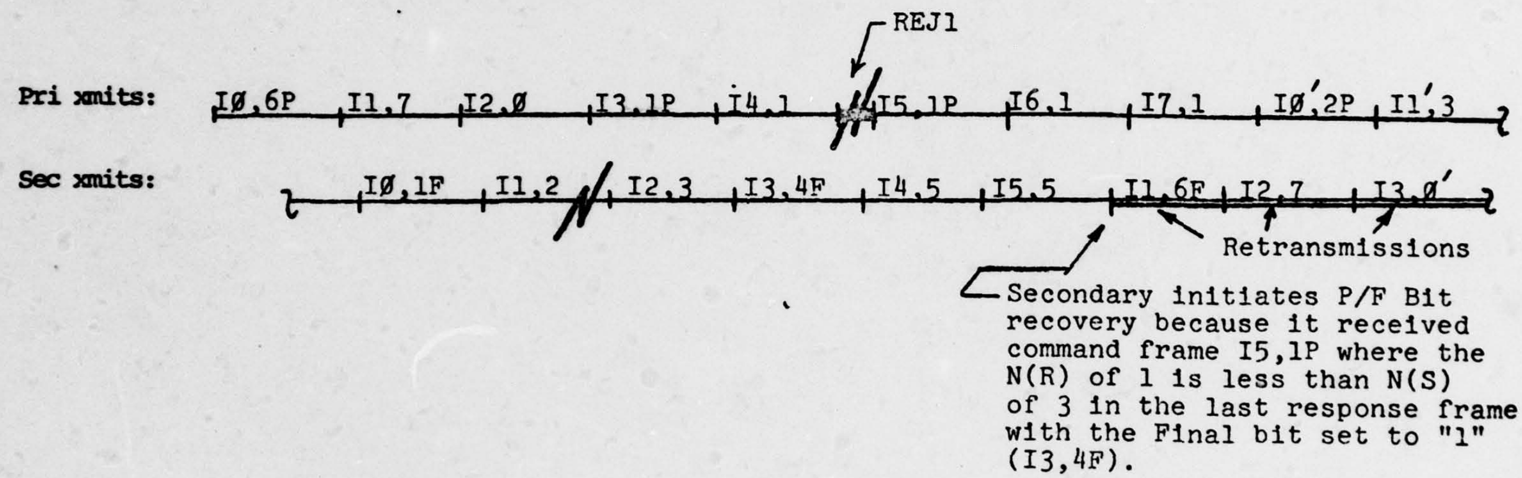
7.1.3 ARM - TWS with Information Frame Exception



7.1.4 Example 7.1.3 above except REJ is not received correctly



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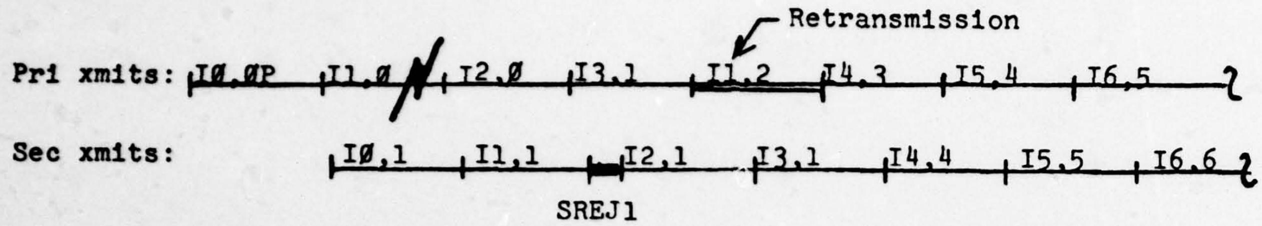
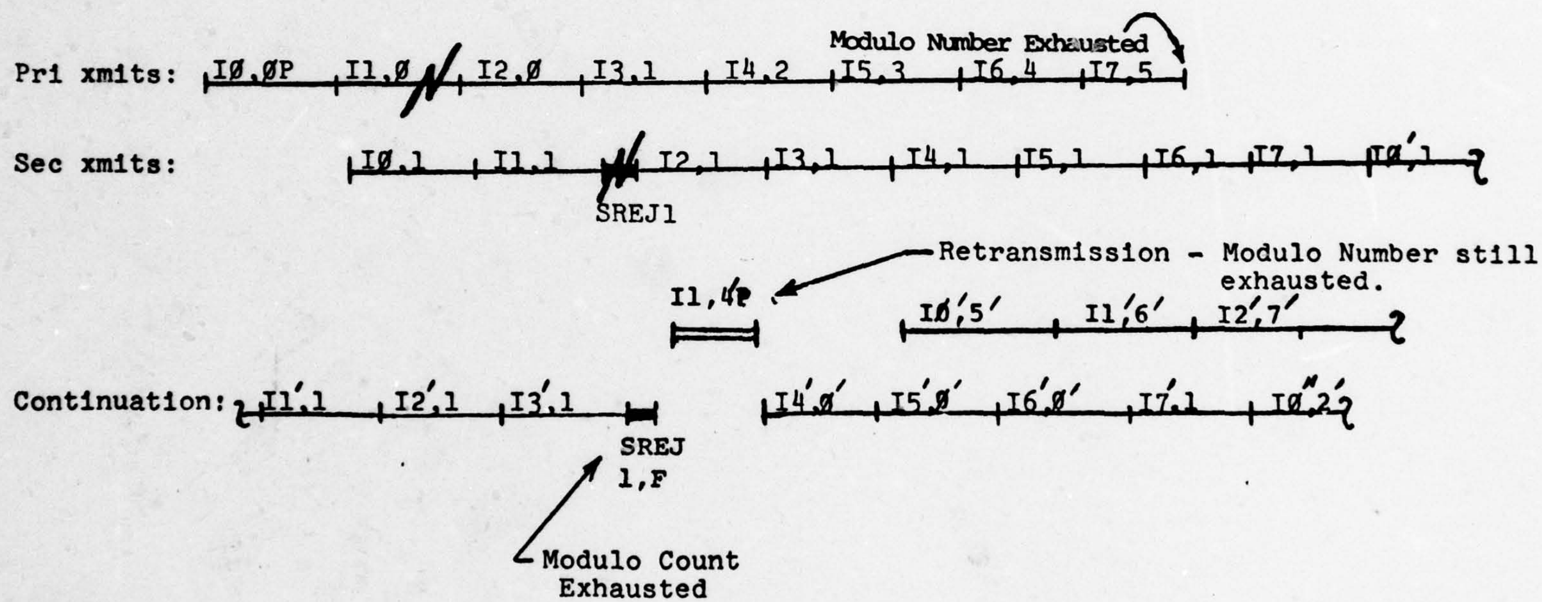
7.2 SREJ/REJ Exception Recovery for TWS Operation

7.2.1 NRM - TWS with Information Frame Exception



7.2.2 Example 7.2.1 above except SREJ is not received correctly



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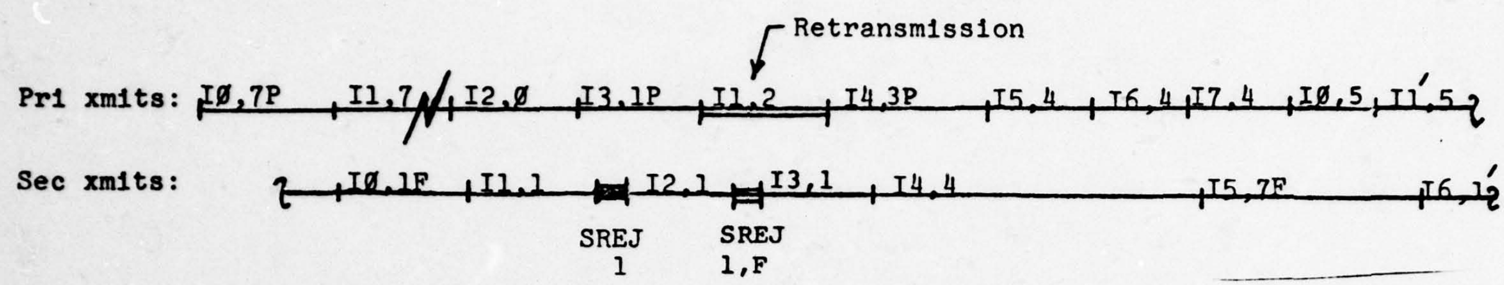
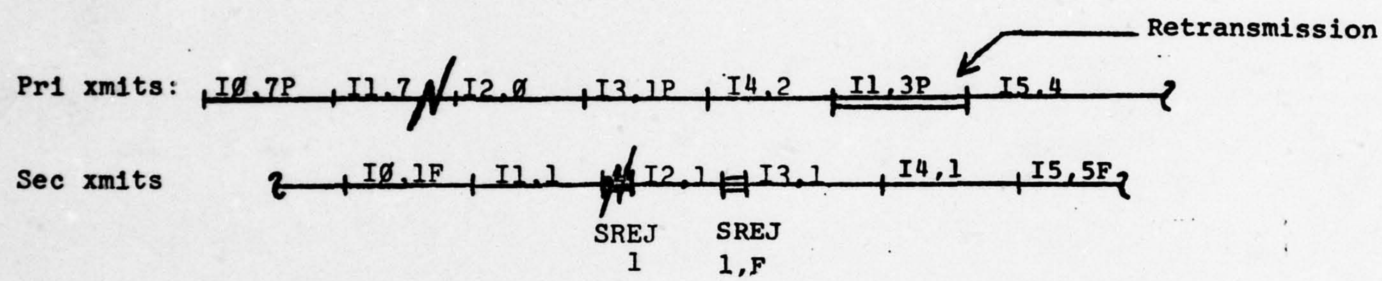
7.2.3 ARM - TWS with I Frame Exception Condition



7.2.4 Example 7.2.3 above except SREJ is received in error



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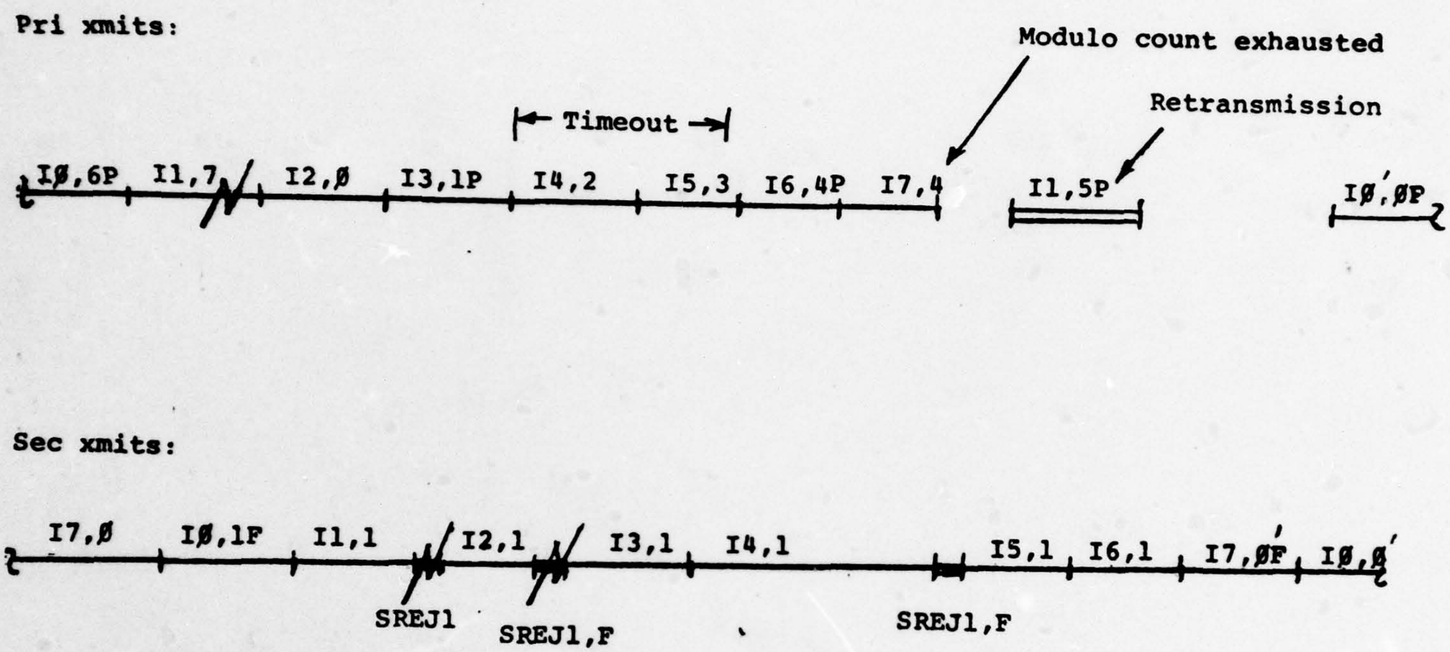
7.2.5 Example 7.2.4 above except two SREJ1 frames received in error.



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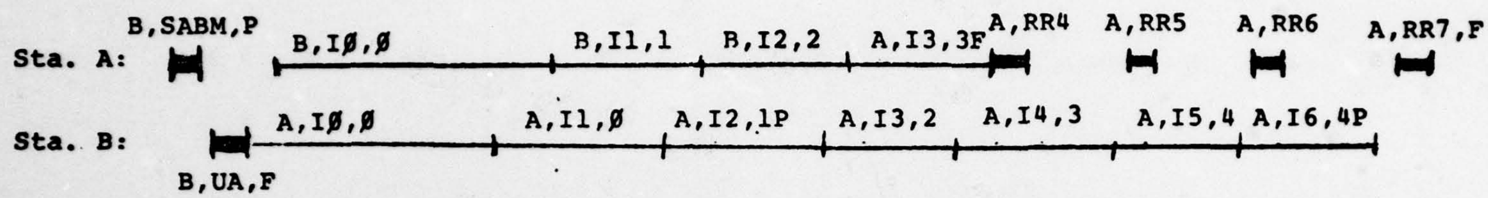
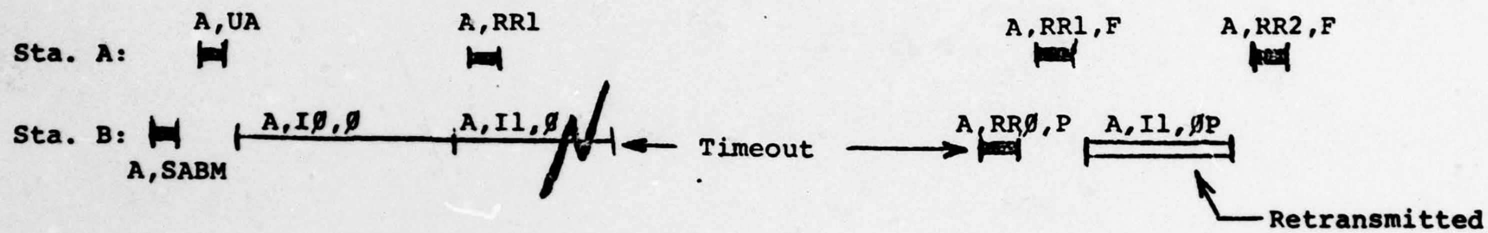
8.0 Examples of Balanced Control Operation

8.1 Continuous Information Frames



8.2 Discontinuous Information Frames (with error)



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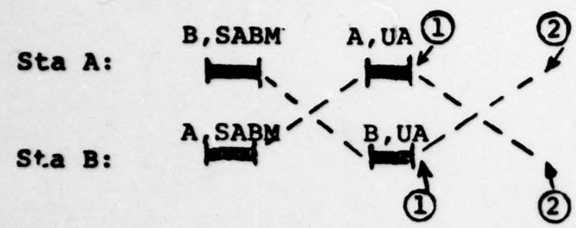
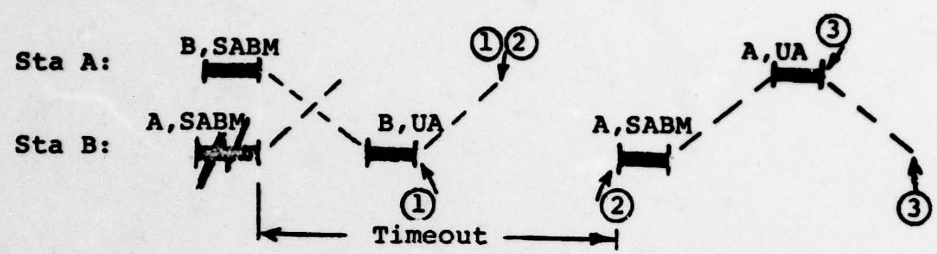
8.3 Simultaneous Mode-Setting Actions (Contention)

8.3.1 Contention Between SABM and SABM



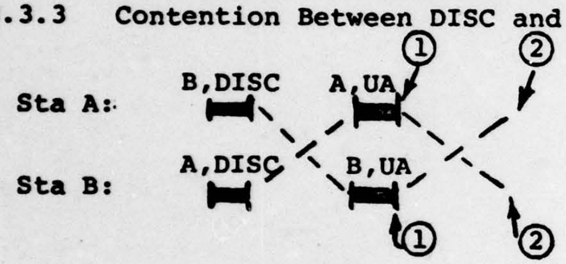
Procedure may be completed at either 1 or 2 with link available for information transfer.

8.3.2 Contention Between SABM and SABM (Errors)



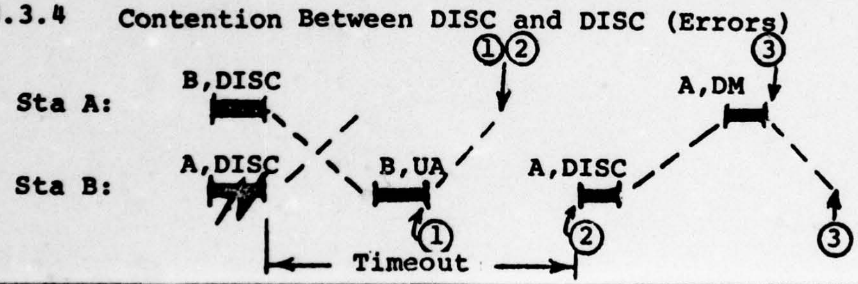
Procedure may be completed at either 1, 2 or 3 with link available for information transfer.

8.3.3 Contention Between DISC and DISC



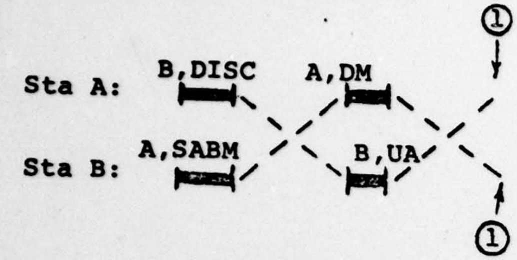
Procedure may be completed at either 1 or 2 with link in Disconnected Mode.

8.3.4 Contention Between DISC and DISC (Errors)



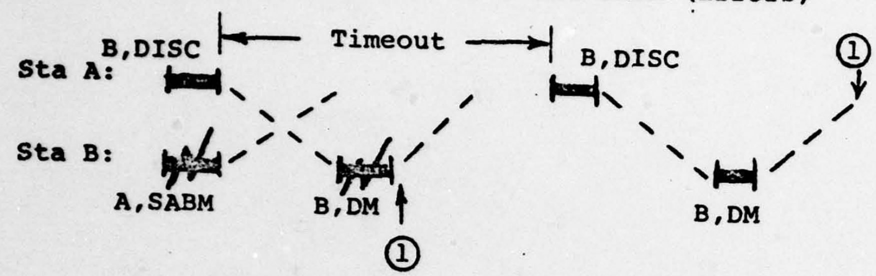
Procedure may be completed at either 1, 2 or 3 with link in Disconnected Mode.

8.3.5 Contention Between DISC and SABM

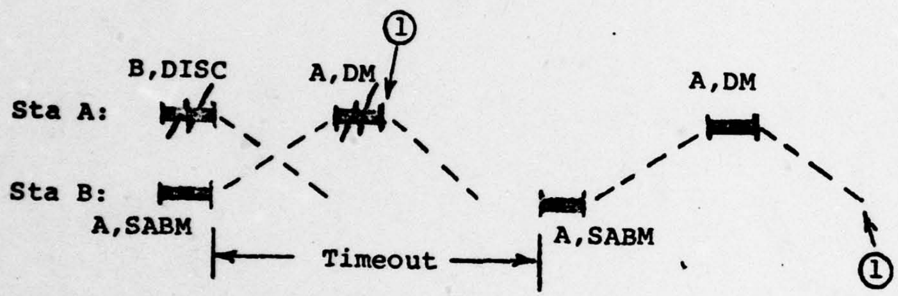


Procedure is completed at 1 with link in Disconnected Mode.

8.3.6 Contention Between DISC and SABM (Errors)

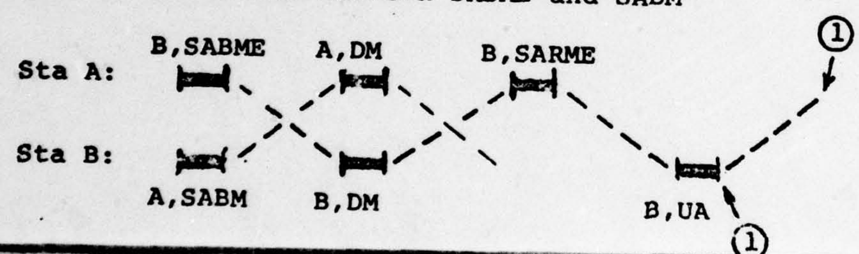


Procedure is completed at 1 with link in Disconnected Mode.



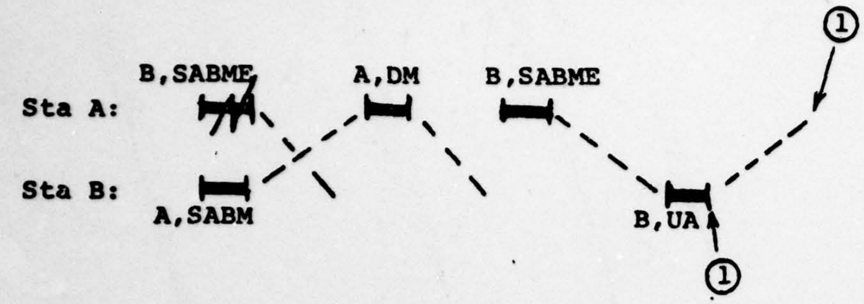
Procedure is completed at 1 with link in Disconnected Mode.

8.3.7 Contention Between SABME and SABM

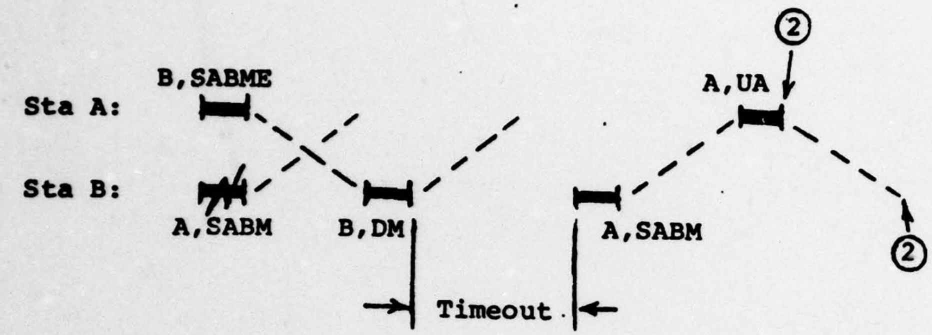


Procedure is completed at 1 with link available for information transfer in extended mode.

8.3.8 Contention Between SABME and SABM (Errors)



Procedure is completed at 1 with link available for information transfer in extended mode.



Procedure is completed at 2 with link available for information transfer in unextended mode.

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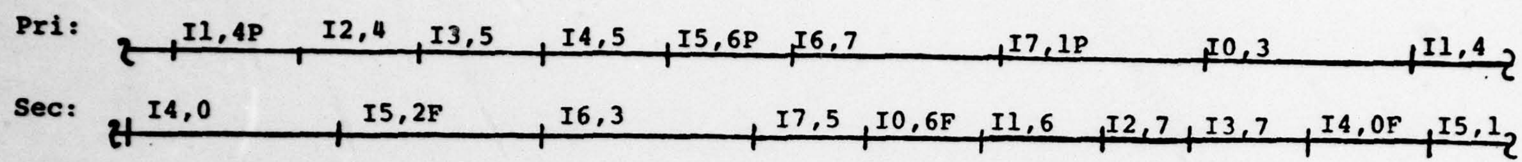
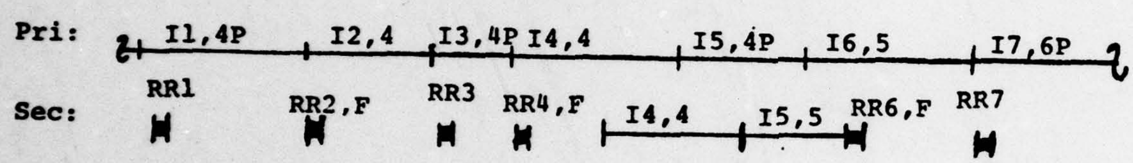
9.0 Primarv-Secondarv ARM Two-Wav Simultaneous Point-to-Point Operation

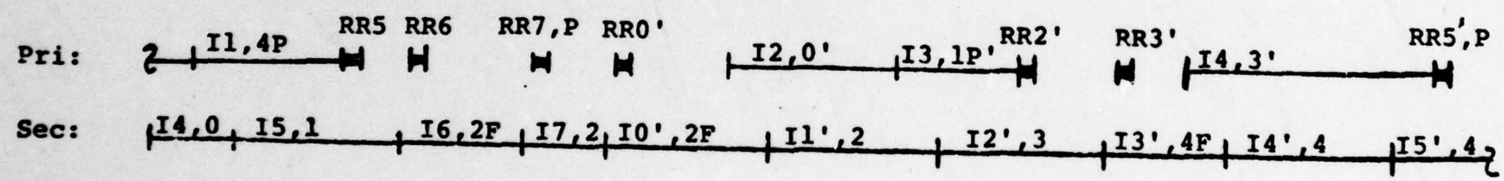
9.1 Continuous Information Frames from Primary and Secondary



9.2 Continuous Primary Information Frames



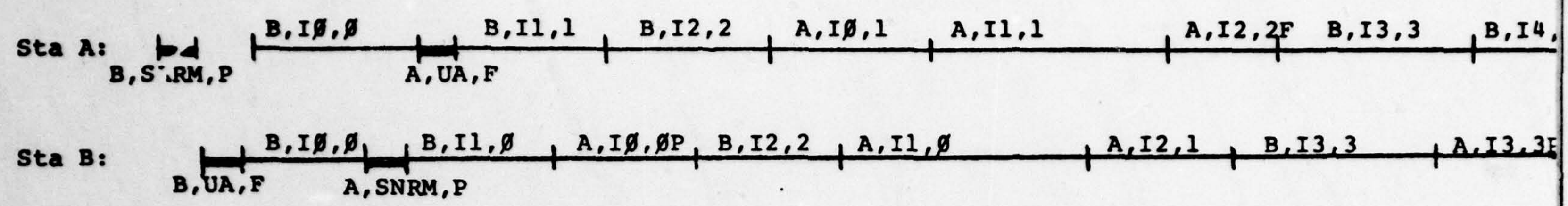
9.3 Continuous Secondary Information Frames



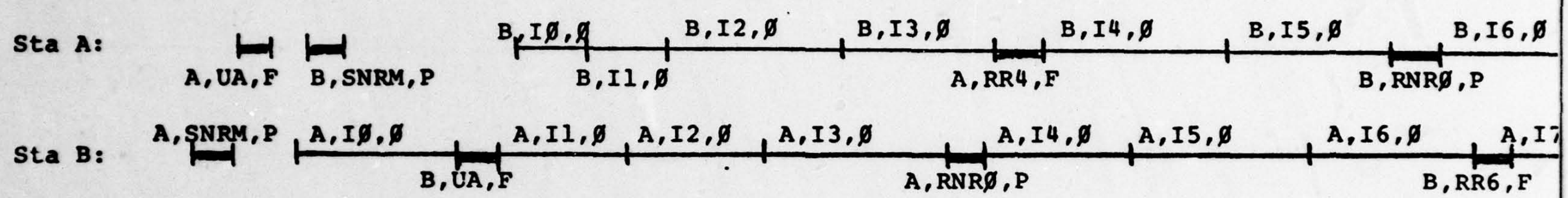
C37

10.0 Symmetrical (Back-to-Back) Primary-Secondary Point-to-Point TWS Operation
Reference Figure 2-3 Configuration

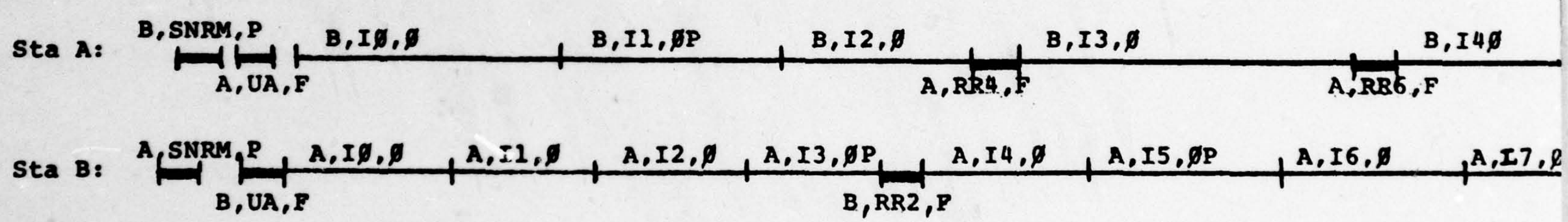
10.1 Secondary B in ARM - Secondary A in NRM Operation



10.2 Use of RNR to restrict Information frames from Secondary Operation



10.3 Secondaries do not transmit Information frames (Optional Function 8) Operation



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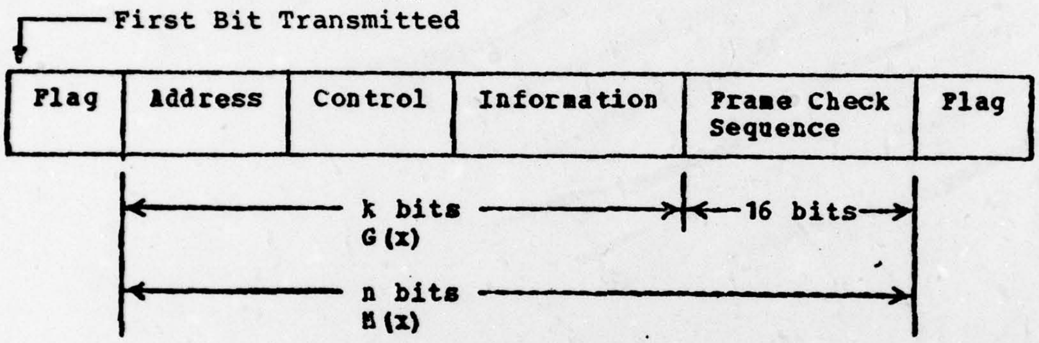
APPENDIX D - FRAME CHECK SEQUENCE (FCS)

D1. Description

The transmission integrity of a received message is determined by use of a Frame Check Sequence (FCS). The FCS is generated by a transmitter, inspected by the receiver and positioned within a frame in accordance with the following diagrams:



The procedure for using the FCS assumes the following:

1. The k bits of data which are being checked by the FCS can be represented by a polynomial G(x).

Examples:

a. $G(x) = 10100100 = X^7 + X^5 + X^2 = X^2(X^5+X^3+1)$

b. $G(x) = 00\text{--}010100100 = X^7+X^5+X^2 = X^2(X^5+X^3+1)$

c. $G(x) = 101001 = X^5 + X^3 + 1$

In general, leading zeros don't change G(x) and trailing zeros add a factor of X where n is the number of trailing zeros.

2. The Address, Control and Information field (if it exists in the message) are represented by the polynomial G(x).

3. For the purpose of generating the FCS, the first bit following the opening flag is the coefficient of the highest degree term of $G(x)$ regardless of the actual representation of the Address, Control and Information fields.

4. There exists a generator polynomial $P(x)$ of degree 16, having the form $P(x) = X^{16}+X^{12}+X^{5}+1$

D.2 Generation and use of FCS

The FCS is defined as a one's complement of a remainder, $R(x)$, obtained from the modulo two division of

$$X^{16}\,G(x)+X^{k}(X^{15}+X^{14}+X^{13}+X^{12}+X^{11}+X^{10}+X^{9}+X^{8}+X^{7}+X^{6}+X^{5}+X^{4}+X^{3}+X^{2}+X^{1}+1)$$

by the generator polynomial $P(x)$.

$$\frac{X^{16}\,G(x)+X^{k}(X^{15}+X^{14}----+X+1)}{P(x)} = Q(x) + \frac{R(x)}{P(x)} \longleftarrow \overline{FCS}$$

The multiplication of $G(x)$ by X^{16} corresponds to shifting the message $G(x)$, 16 places and thus providing the space of 16 bits for the FCS.

The addition of $X^{k}(X^{15}+X^{14}----------+X+1)$ to $X^{16}\,G(x)$ is equivalent to inverting the first 16 bits of $G(x)$. It can also be accomplished in a shift register implementation by presetting the register to all "ones" initially. This term is present to detect erroneous addition or deletion of zero bits at the leading end of $M(x)$ due to erroneous flag shifts.

The complementing of $R(x)$, by the transmitter, at the completion of the division insures that the transmitted sequence $M(x)$ has a property which permits the receiver to detect addition or deletion of trailing zeros which may appear as a result of errors.

At the transmitter the FCS is added to the $X^{16}\,G(x)$ and results in the total message $M(x)$ of length k+16, where $M(x) = X^{16}\,G(x) + FCS$.

The receiver can employ one of several detection processes, two of which are discussed here. In the first process, the incoming $M(x)$ (assuming no errors; i.e. $M^{*}(x) = M(x)$) is multiplied by X^{16}, added to X^{k+16} $(X^{15} + X^{14}$ - - - - - - - + $X + 1)$ and divided by $P(X)$.

$$\frac{X^{16} [X^{16} G(X) + FCS] + X^{k+16} (X^{15} + X^{14} - - - + X + 1)}{P(x)} =$$

$Qr(x) + Rr(x)/P(x)$

Since the transmission is error free, the remainder $Rr(x)$ will be "0001110100001111" (X^{15} through X^{0}).

$Rr(X)$ is the remainder of the division: $\frac{X^{16} L(x)}{P(x)}$

where $L(x) = X^{15} + X^{14} - - - - + X + 1$. This can be shown by establishing that all other terms of the numerator of the receiver division are divisible by $P(x)$. This will be done below.

Note that $FCS = \overline{R(x)} = L(x)+R(x)$. (Adding $L(x)$ to a polynomial of its same length is equivalent to a bit by bit inversion of the polynomial.)

The receiver division numerator can be rearranged to:

$X^{16}[X^{16} G(x) + X^{k} L(x) + R(x)] + X^{16} L(x)$.

It can be seen that the first term is divisible by $P(x)$ by inspecting the transmitter generation equation, thus the $X^{16}L(x)$ term is the only contributor to $Rr(x)$.

The second process differs from the first in that another term $(X^{16}L(x))$ is added to the numerator of the generation equation. This causes a remainder of zero to be generated if $M^*(x)$ is received error free.

D.3 Implementation

A shift register FCS implementation is described in detail here. It utilizes "ones presetting" at both the sender and the receiver and the receiver does not invert the FCS. The receiver thus checks for the non-zero residual $Rr(x)$ to indicate an error free transmission.

Figure D.1 is an illustration of the implementation. It shows a configuration of storage elements and gates. The addition of $X^{k}(X^{15}+X^{14}$-------$+X+1)$ to the X^{16} $G(x)$ can be accomplished by presetting all storage elements to a binary value "1".

The one's complement of R(x) is obtained by the logical bit by bit inversion of the transmitter's R(x).

Figure D.1 shows the implementation of the FCS generation for transmission. The same hardware can also be used for verification of data integrity upon data reception.

Before transmitting data, the storage elements, X_0-X_{15} are initialized to "ones". The accumulation of the remainder R(x) is begun by enabling the "A" and thereby enabling gates G2 and G3. The data to be transmitted goes out to the receiver via G2 and at the same time the remainder is being calculated with the use of feedback path via G3. Upon completion of transmitting the k bits of data, the "A" is disabled and the stored R(x) is transmitted via G1 and I1 while G2 and G3 are disabled. The I1 provides the necessary inversion of R(x).

At the receiver, before data reception, the storage elements, X_0 - X_{15} are initialized to "ones". The incoming message is then continuously divided by P(x) via G3 ("A" enabled). If the message contained no errors, the storage elements will contain "0001110100001111" (X^{15} through X^0) at the end of the M*(x).

Figure D.2 is an example of the receiver and transmitter states during a transmission of a 19 bit G(x) and a 16 bit FCS.

The implementation of the FCS generation and the division by P(x) as described in this Appendix is used as an example only. Other implementations are possible and may be utilized. This standard only requires that the FCS be generated in accordance with the rules of Sections 3.5 and 12.1 and that the checking process involve division by the polynomial P(x). Furthermore, the order of transmission of M(x) is the coefficient of the highest degree term first and thereafter in decreasing order of powers of x, regardless of the actual representation of fields internal to M(x).

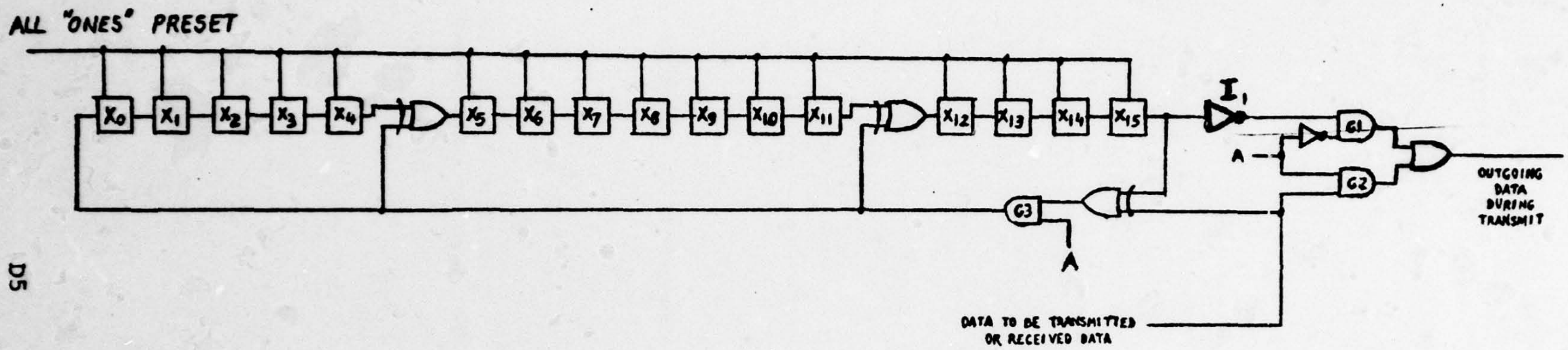


FIGURE D1. FCS IMPLEMENTATION

	INPUT TO TX	TX CRC		INPUT TO RX	RX CRC
MSB		1111111111111111			1111111111111111
	0	1111101111110111		0	1111101111110111
	1	0111110111111011		1	0111110111111011
	1	0011111011111101		1	0011111011111101
	1	0001111101111110		1	0001111101111110
	1	1000101110110111		1	1000101110110111
	0	1100000111010011		0	1100000111010011
	0	1110010011100001		0	1110010011100001
	1	0111001001110000		1	0111001001110000
G(x)	1	1011110100110000		1	1011110100110000
	0	0101111010011000		0	0101111010011000
	0	0010111101001100		0	0010111101001100
	1	1001001110101110		1	1001001110101110
	1	1100110111011111		1	1100110111011111
	0	1110001011100111		0	1110001011100111
	0	1111010101111011		0	1111010101111011
	0	1111111010110101		0	1111111010110101
	1	0111111101011010		1	0111111101011010
	1	1011101110100101		1	1011101110100101
	1	0101110111010010		1	0101110111010010
		0010111011101001		1	1010101011100001
		0001011101110100		0	1101000101111000
		0000101110111010		1	1110110010110100
		0000010111011101		1	1111001001010010
		0000001011101110	F	0	0111100100101001
		0000000101110111		1	0011110010010100
		0000000010111011	C	0	0001111001001010
		0000000001011101		0	0000111100100101
		0000000000101110	S	0	1000001110011010
		0000000000010111		1	1100010111000101
		0000000000001011		0	1110011011101010
		0000000000000101		0	0111001101110101
		0000000000000010		0	1011110110110010
		0000000000000001		1	1101101011010001
		0000000000000000		0	1110100101100000
		0000000000000000		1	1111000010111000
		X^0 … X^{15}			X^0 … X^{15}

FIGURE D.2 FCS EXAMPLE

BSP X3.66
X3S34-589
DRAFT 6 REVISION-2
11 August 1977

APPENDIX E

EXPOSITORY REMARKS
for
American National Standard for
Advanced Data Communication
Control Procedure (ADCCP)

A. BRIEF HISTORY

The development of advanced data communication control procedure standards began in late 1969 during final work on the American National Standard-Procedures for the Use of the Communication Control Characters of American National Standard Code for Information Interchange in Specified Data Communication Links (X3.28 - 1971). At that time, it was recognized that X3.28 lacked certain desirable interactive capabilities that would be impractical to incorporate due to the basic philosophy of the standard. Consequently, several proposals were submitted by members of the Task Group for new and improved procedures. Similar work was proceeding at the same time in ECMA and ISO. One of the most significant proposals was a bit-oriented approach to link control that became widely accepted in a short period of time, both domestically and internationally. Domestically, the resultant control procedures have ben called Advanced Data Communication Control Procedures (ADCCP). Internationally, the development going on in this area is called High-Level Data Link Control (HDLC).

The original bit-oriented proposal and most of the work, both domestically and internationally, was based on a dependent/single sequence number per frame. In late 1971, a proposal was submitted for independent/dual numbering. It was the general concensus at that time, both domestically and internationally, that the net advantages over the disadvantages of the independent/dual numbering approach was not great enough to warrant working on the two procedures in parrallel. Consequently, the American National Standard for ADCCP - Dependent Numbering evolved. Now that the work on dependent/single numbering is complete, the efforts of the Task Group are directed toward this proposed American

National Standard for ADCCP - Independent Numbering.

B. MAIN TECHNICAL ARGUMENTS AND RELATIONSHIP WITH ISC

The basic objectives of the Advanced Data Communicaton Control Procedures are to provide:

a) Full transparency and code independence,

b) Efficient interactive operation,

c) A High level of reliability,

d) Two-way alternate and two-way simultaneous operation,

e) A high level of modularity.

These objectives have been largely met.

During the four-year period of ADCCP development, there has been active liaison with both the ECMA and ISO spheres of interest. As a result each group's activity has influenced that of the other.

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