CCSDS Historical Document

Consultative Committee for Space Data Systems

RECOMMENDATION FOR SPACE
DATA SYSTEM STANDARDS

PROXIMITY-1 SPACE LINK PROTOCOL—

PHYSICAL LAYER

CCSDS 211.1-B-2

BLUE BOOK

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This Recommendation is published and maintained by:

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DOCUMENT CONTROL

Document	Title and Issue	Date	Status
CCSDS 211.0-B-1	Proximity-1 Space Link Protocol	October 2002	Superseded
CCSDS 211.1-B-1	Proximity-1 Space Link Protocol—Physical Layer	April 2003	Superseded
CCSDS 211.1-B-2	Proximity-1 Space Link Protocol—Physical Layer	May 2004	Current issue

Note

This document contains the Physical layer specification originally published as part of CCSDS 211.0-B-1, *Proximity-1 Space Link Protocol*.

CONTENTS

1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide a Recommendation for Space Data System Standards in the area of Proximity space links. Proximity space links are defined to be short-range, bi-directional, fixed or mobile radio links, generally used to communicate among probes, landers, rovers, orbiting constellations, and orbiting relays. These links are characterized by short time delays, moderate (not weak) signals, and short, independent sessions.

1.2 SCOPE

This Recommendation defines the Proximity-1 Space Link Protocol Physical Layer. The specification for the channel connection process, provision for frequency bands and assignments, hailing channel, polarization, modulation, data rates, and performance requirements are defined in this document. Currently, the Physical Layer only defines operations at UHF frequencies for the Mars environment. The Coding layer is defined in the separate CCSDS recommendation entitled, *Proximity-1 Space Link Protocol—Coding and Synchronization Sublayer*; see reference [3]. The Data Link layer is defined in the separate CCSDS recommendation entitled, *Proximity-1 Space Link Protocol—Data Link Layer*; see reference [4]. This Recommendation does not specify a) individual implementations or products, b) implementation of service interfaces within real systems, c) the methods or technologies required to perform the procedures, or d) the management activities required to configure and control the protocol.

1.3 APPLICABILITY

This Recommendation applies to the creation of Agency standards and to future data communications over space links between CCSDS Agencies in cross-support situations. It applies also to internal Agency links where no cross-support is required. It includes specification of the services and protocols for inter-Agency cross support. It is neither a specification of, nor a design for, systems that may be implemented for existing or future missions.

The Recommendation specified in this document is to be invoked through the normal standards programs of each CCSDS Agency and is applicable to those missions for which cross support based on capabilities described in this Recommendation is anticipated. Where mandatory capabilities are clearly indicated in sections of the Recommendation, they must be implemented when this document is used as a basis for cross support. Where options are allowed or implied, implementation of these options is subject to specific bilateral cross support agreements between the Agencies involved.

1.4 RATIONALE

The CCSDS believes it is important to document the rationale underlying the recommendations chosen, so that future evaluations of proposed changes or improvements will not lose sight of previous decisions. Concept and rationale behind the decisions that formed the basis for Proximity-1 will be documented in the CCSDS Proximity-1 Space Link Green Book, which is under development.

1.5 CONVENTIONS AND DEFINITIONS

1.5.1 DEFINITIONS

1.5.1.1 Definitions from the Open Systems Interconnection (OSI) Basic Reference Model

This Recommendation makes use of a number of terms defined in reference [1]. The use of those terms in this Recommendation shall be understood in a generic sense, i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are as follows:

a) connection;

b) Data Link layer;

c) entity;

d) physical layer;

e) protocol control information;

f) Protocol Data Unit (PDU);

g) real system;

h) segmenting;

i) service;

j) Service Access Point (SAP);

k) SAP address;

l) Service Data Unit (SDU).

1.5.1.2 Terms Defined in This Recommendation

For the purposes of this Recommendation, the following definitions also apply. Many other terms that pertain to specific items are defined in the appropriate sections.

asynchronous channel: a data channel where the symbol data are modulated onto the channel only for the period of the message. The message must be preceded by an acquisition sequence to achieve symbol synchronization. Bit synchronization must be reacquired on every message. A hailing channel is an example of an asynchronous channel.

asynchronous data link: a data link consisting of a sequence of variable-length Proximity Link Transmission Units (PLTUs), which are not necessarily concatenated. Two types of asynchronous data links are:

1) Asynchronous Data Link over an Asynchronous Channel

   Hailing provides an example of an asynchronous data link over an asynchronous channel. An important issue is resynchronization between successive hails. Idle is provided for the reacquisition process.

2) Asynchronous Data Link over a Synchronous Channel

   Data service provides an example of an asynchronous data link over a synchronous channel. Once the link is established via hailing, communication transitions to a synchronous channel and maintains the link in this configuration until the session is interrupted or ends. If the physical layer does not receive data from the data link layer, it provides idle to maintain a synchronous channel.

caller and responder: A **caller transceiver** is the initiator of the link establishment process and manager of negotiation (if required) of the session. A **responder transceiver** typically receives link establishment parameters from the caller. The caller initiates communication between itself and a responder on a pre-arranged communications channel with predefined controlling parameters. As necessary, the caller and responder may negotiate the controlling parameters for the session (at some level between fully controlled and completely adaptive).

forward link: that portion of a Proximity space link in which the caller transmits and the responder receives (typically a command link).

hailing: the persistent activity used to establish a Proximity link by a caller to a responder in either full or half duplex. It does not apply to simplex operations.

hailing channel: the forward and return frequency pairs that a caller and responder use to establish physical link communications.

physical channel: The RF channel upon which the stream of bits is transferred over a space link in a single direction.

PLTU: The Proximity Link Transmission Unit is the data unit composed of the Attached Synchronization Marker, the Version-3 Transfer Frame, and the attached Cyclic Redundancy Check (CRC)-32.

Proximity link: short-range, bi-directional, fixed or mobile radio links, generally used to communicate among probes, landers, rovers, orbiting constellations, and orbiting relays. These links are characterized by short time delays, moderate (not weak) signals, and short, independent sessions.

return link: that portion of a Proximity space link in which the responder transmits and the caller receives (typically a telemetry link).

session: a continuous dialog between two communicating Proximity link transceivers. It consists of three distinct operational phases: session establishment, data services, and session termination.

space link: a communications link between transmitting and receiving entities, at least one of which is in space.

synchronous channel: a data channel where the symbol data are continuously modulated onto the channel at a fixed data rate. If the data link fails to provide frames (data or fill), it is the responsibility of the physical layer to provide the continuous bit stream.

working channel: a forward and return frequency pair used for transferring User data/information frames (U-frames) and Protocol/supervisory frames (P-frames) during the data service and session termination phases.

1.5.2 NOMENCLATURE

The following conventions apply throughout this Recommendation:

a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;

b) the word ‘should’ implies an optional, but desirable, specification;

c) the word ‘may’ implies an optional specification;

d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

1.5.3 CONVENTIONS

In this document, the following convention is used to identify each bit in an *N*-bit field. The first bit in the field to be transmitted (i.e., the most left justified when drawing a figure) is defined to be ‘Bit 0’; the following bit is defined to be ‘Bit 1’ and so on up to ‘Bit *N*-1’. When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., ‘Bit 0’, as shown in figure 1-1.

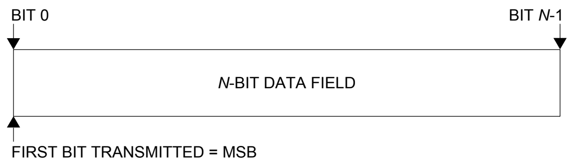

Figure 1-1: Bit Numbering Convention

In accordance with standard data-communications practice, data fields are often grouped into 8-bit 'words' that conform to the above convention. Throughout this Recommendation, such an 8-bit word is called an 'octet'.

The numbering for octets within a data structure begins with zero. Octet zero is the first octet to be transmitted.

By CCSDS convention, all 'spare' bits shall be permanently set to value 'zero'.

Throughout this Recommendation, directive, parameter, variable, and signal names are presented with all upper-case characters; data-field and MIB-parameter names are presented with initial capitalization; values and state names are presented with predominantly lower-case characters, and are italicized.

1.6 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommendation are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommendations.

[1] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. International Standard, ISO/IEC 7498-1. 2nd ed. Geneva: ISO, 1994.

[2] *TM Synchronization and Channel Coding*. Recommendation for Space Data System Standards, CCSDS 131.0-B-1. Blue Book. Issue 1. CCSDS, September 2003.

[3] *Proximity-1 Space Link Protocol—Coding and Synchronization Sublayer*. Recommendation for Space Data System Standards, CCSDS 211.2-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, April 2003.

[4] *Proximity-1 Space Link Protocol—Data Link Layer*. Recommendation for Space Data System Standards, CCSDS 211.0-B-2. Blue Book. Issue 3. St. Hubert, Canada: CCSDS, May 2004.

2 OVERVIEW

Proximity-1 is a bi-directional Space Link layer protocol to be used by space missions. It consists of a Physical Layer (the subject of this document), a Coding and Synchronization (C&S) sublayer (reference [3]) and a Data Link Layer (reference [4]). This protocol has been designed to meet the requirements of space missions for efficient transfer of space data over various types and characteristics of Proximity space links. On the send side, the Data Link layer is responsible for providing data to be transmitted by the Coding and Synchronization sublayer and Physical layer. The operation of the transmitter is state-driven. On the receive side, the Data Link layer accepts the serial data output from the receiver (Physical Layer) and verified by the Coding and Synchronization sublayer and processes the protocol data units received. It accepts directives both from the local vehicle controller and across the Proximity link to control its operations. Once the receiver is turned on, its operation is modeless. It accepts and processes all valid local and remote directives and received service data units.

The layered model consists of two layers (Physical and Data Link) and has five component sublayers within the Data Link layer, as follows:

a) Physical Layer

   1) On the send side:

      i) provides an Output Bit Clock to the Coding & Synchronization sublayer in order to receive the Output Bit Stream;

      ii) provides status, i.e., Carrier_Acquired and Bit_In_Lock_Status signals to the Media Access Control Sub-layer.

   2) On the receive side: Provides the Received Bit Clock/Data to the Coding & Synchronization sublayer.

b) Coding and Synchronization Sublayer. The Coding and Synchronization sublayer includes PLTU delimiting and verification procedures. In addition, this sublayer performs as follows:

   1) On the send side:

      i) includes pre-pending Version-3 frames with the required Attached Synchronization Marker (ASM);

      ii) includes addition of CRC-32 to PLTUs.

   2) On both the send and receive sides: Captures the value of the clock used for time correlation process.

c) Frame Sublayer. The Frame sublayer includes frame validation procedures, such as transfer frame header checks, and supervisory data processing for supervisory frames. In addition, this sublayer performs as follows:

1) On the send side:

   i) encapsulates the Input/Output (I/O) Sublayer–provided User Data into Version-3 frames;

   ii) prioritizes and multiplexes the frames for output via the C&S sublayer to the Physical layer for transmission across the link.

2) On the receive side:

   i) accepts delimited and verified frames from the C&S sublayer;

   ii) delivers supervisory protocol data units (reports, directives) to the Medium Access Control (MAC) sublayer;

   iii) passes the user data to the Data Services sublayer;

   iv) performs a subset of validation checks to ensure that the received data should be further processed.

d) Medium Access Control Sublayer. The Medium Access Control (MAC) sublayer defines how a session is established, maintained (and how characteristics are modified, e.g., data rate changes), and terminated for point-to-point communications between Proximity entities. This sublayer builds upon the Physical and Data Link layer functionality. The MAC controls the operational state of the Data Link and Physical layers. It accepts and processes Supervisory Protocol Data Units (SPDUs) and provides the various control signals that dictate the operational state. In addition, this sublayer:

1) decodes the directives from the local vehicle's controller (e.g., spacecraft control computer);

2) decodes the directives received via the remote transceiver (extracting and processing SPDUs from the Frame Data Field);

3) stores and distributes the Management Information Base (MIB) parameters (implementation-specific) and status variables;

4) maintains and distributes the state control variables (MODE, TRANSMIT, DUPLEX, see figure 2-1);

5) provides status information to the local vehicle controller.

e) Data Services Sublayer. The Data Services sublayer defines the Frame Acceptance and Reporting Mechanism for Proximity links (FARM-P) (receive side) and the Frame Operations Procedures for Proximity links (FOP-P) (send side) associated with the Expedited and Sequence Controlled data services including how the FOP-P and FARM-P (COP-P) operate in the Sequence Controlled service.

f) Input/Output (I/O) Sublayer. The Input/Output interface sublayer provides the interface between the transceiver and the on-board data system and their applications. In addition, this sublayer performs as follows:

   1) On the receive side:

      i) accepts received U-frames;

      ii) extracts the SDUs from U-frames;

      iii) provides required packet aggregation services;

      iv) routes SDUs to data service users via the specified Port ID.

   2) On the send side: accepts local user-provided SDUs and associated routing and control information (SCID, PCID, Source-or-Destination ID, QOS, Port ID) and:

      i) aggregates these SDUs as required to form U-frame data fields;

      ii) provides required packet segmentation services;

      iii) delivers these U-frame data fields to the Data Services sublayer;

      iv) delivers acknowledgements to spacecraft vehicle controller for SDUs delivered via Sequence Controlled service.

The interactions of the Proximity-1 layers and associated data and control flows are shown in figure 2-1.

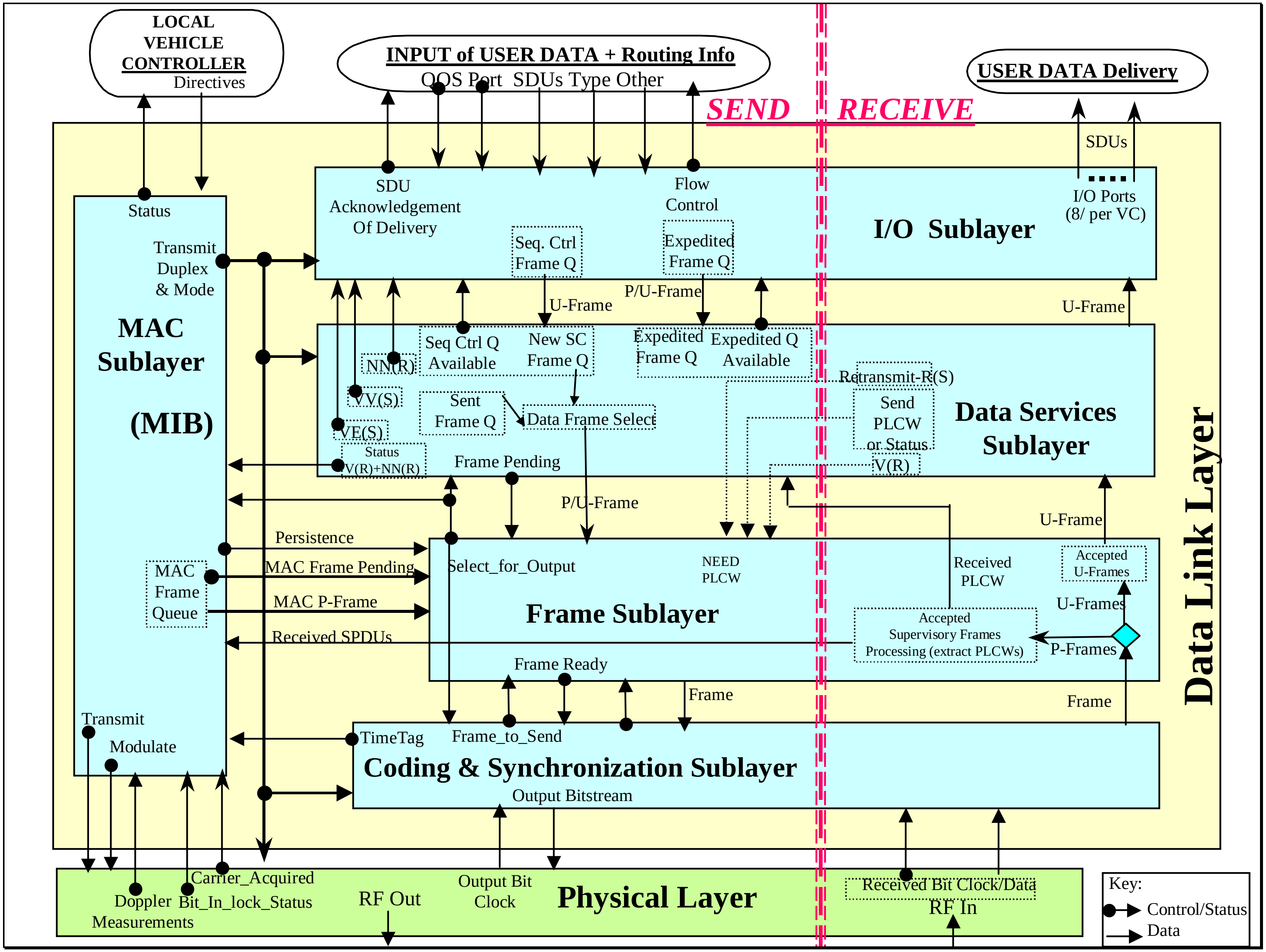

Figure 2-1: Proximity-1 Layered Protocol Model

CCSDS HISTORICAL DOCUMENT

3 GENERAL REQUIREMENTS FOR THE PHYSICAL LAYER

3.1 APPLICABILITY

3.1.1 The Proximity-1 Link system shall be capable of supporting the communication and navigation needs between a variety of network elements, e.g., orbiters, landers, rovers, microprobes, balloons, aerobots, gliders.

NOTE – The categories of network elements (E1, E2,…) are listed in table 3-1.

3.1.2 Landed elements in category E2c (see table 3-1), for which range and range-rate measurements are needed, shall have transmit/receive frequency coherency capability.

Table 3-1: Categories of Radio Equipment Contained on Proximity-1 Link Elements

Category	Description
E1:	Elements with transmit-only capability.
E2:	Elements with transmit and receive capability.
E2n:	E2 elements with non-coherent mode only.
E2c:	E2 elements offering in addition transmit/receive frequency coherency capability.
E2d:	E2 elements with a descoped receiver capable of receiving an FSK modulated carrier. These elements transmit using PSK modulation.
NOTE – E2d radio equipment is intended to be used in microprobes.	

3.2 FUNCTIONAL REQUIREMENTS

3.2.1 DISCUSSION

The prime function of the Physical layer is to establish a communications channel upon which the data can flow. This process includes configuration of the following Physical layer parameters: frequency, polarization, modulation, acquisition and idle sequence, and data rates, such that common operating characteristics exist in both communicating entities.

3.2.2 GENERAL REQUIREMENTS

In order to enable a physical channel connection, the Physical layer shall go through a series of actions to establish a communication channel. The transmitter shall vary its initial modulation to optimize the recipient receiver's ability to acquire the channel.

3.2.3 CHANNEL CONNECTION PROCESSES

3.2.3.1 General Requirements

3.2.3.1.1 The Physical layer shall accept operational control signals from, and provide operational status to the Data Link layer.

NOTE – The MAC sublayer provides the MODE, TRANSMIT and DUPLEX parameters that control the operational state of the receiver and transmitter.

3.2.3.1.2 The Physical layer shall, as required, sequence its modulation from *off* to *carrier_only* to *data_modulation* in order to establish a data channel with a communications partner preceding the transfer of data.

3.2.3.1.3 The receiving portion of the transceiver shall sweep the frequency channel to which it is assigned in order to acquire lock at an assigned frequency channel:

a) the receiver shall first attempt to lock to the carrier;

b) the internal state of the physical channel connection shall be tracked in the CONNECTION variable.

NOTE – During this process, the receiver status is provided to the MAC sublayer of the Data Link layer. This status is provided by two interlayer signals: CARRIER_ACQUIRED and BIT_INLOCK_STATUS.

3.2.3.2 Send Side Signals

3.2.3.2.1 CARRIER_ACQUIRED

The CARRIER_ACQUIRED signal shall notify the MAC sublayer that the receiver has acquired a carrier signal. The CARRIER_ACQUIRED signal shall be set to *true* when the receiver is locked to the received RF signal and *false* when not in lock.

3.2.3.2.2 BIT_INLOCK_STATUS

The BIT_INLOCK_STATUS signal shall be used to notify the MAC sublayer that bit synchronization has been acquired, and the received serial bit stream is being provided to the C&S sublayer by the Physical layer. The BIT_INLOCK_STATUS signal shall be set to *true* when the receiver is confident that its bit detection processes are synchronized to the modulated bit stream and the bits output are of an acceptable quality for processing by the Data Link layer. It shall be set to *false* when the receiver is not in bit lock.

3.2.3.2.3 OUTPUT_BIT_CLOCK

The OUTPUT_BIT_CLOCK is the clock signal provided by the Physical layer to the C&S sublayer to clock out the PLTU whenever a PLTU is ready for transmission.

3.2.3.2.4 RF_OUT

RF_OUT represents all of the possible signal outputs to the communication partner from the Physical layer. These consist of: *off* (no signal), *carrier_only*, *idle_data*, and *pltu_data*.

3.2.3.3 Receive Side Signals

3.2.3.3.1 RECEIVED BIT CLOCK/DATA BITS

The RECEIVED BIT CLOCK/DATA BITS is the clock signal and data provided by the Physical layer to the coding and synchronization sublayer.

3.2.3.3.2 DOPPLER MEASUREMENTS

The DOPPLER MEASUREMENTS are Doppler samples calculated within the transceiver.

3.2.3.3.3 RF_IN

RF_IN represents all of the possible signal inputs into the Physical layer of the communication partner. These consist of: *off* (no signal) *carrier_only*, *idle_data*, and *pltu_data.*

3.2.3.4 Physical Layer Internal Variables

3.2.3.4.1 CONNECTION

3.2.3.4.1.1 The CONNECTION Physical layer variable tracks the internal state of the Physical layer of the given transceiver's physical connection to a communication partner. It takes on the values: *open*, *acquire_carrier*, *acquire_idle*, *tail_idle*, *closed.*

3.2.3.4.1.2 CONNECTION variable values are:

a) *open* - Proximity entities are not connected at the Physical layer; i.e., neither carrier nor bit lock has been achieved;

b) *closed* - a connection between Proximity entities at the Physical layer exists; i.e., carrier and bit lock have been achieved and are maintained;

c) *acquire_carrier* - a carrier-only signal is being transmitted for the purpose of acquisition;

d) *acquire_idle* - the idle sequence is modulated onto the carrier before the hail frame;

e) *tail_idle* - consists of the idle sequence modulated onto the carrier after the hail frame (to ensure processing of the hail frame through the convolutional decoder, if convolutional code was applied; see reference [3]).

3.2.3.4.2 Receiver State

The states of the receiver are: *on*, *off*.

3.2.3.4.3 Transmitter State

The states of the transmitter are: *on (*asynchronous or synchronous channel*)*, *off*.

3.3 IDLE DATA

3.3.1 GENERAL

A specific Pseudo-noise (PN) sequence of data bits defines the bit pattern used for all the functions that Idle data performs for the Proximity link. Idle data is required for data acquisition, the Idle sequence (Idle interjected between PLTUs) and the tail sequence. In all cases, it consists of the repeating PN 352EF853 (in hexadecimal). Idle data can start on any bit within the PN sequence. However the continuum of idle bits shall follow the defined PN sequence (partially or redundantly as required).

NOTE – When the convolutional code is applied, all transmitted bits including the Idle data shall be convolutionally encoded; see reference [3].

3.3.2 ACQUISITION SEQUENCE

The Physical layer shall provide the modulation necessary for the partners in a session to acquire and process each other’s transmission. When transmission commences, the transmitter’s modulation shall be sequenced (first carrier only then idle bits) such that the receiving unit can acquire the signal, achieve a reliable symbol stream and pre-condition the Convolutional decoder (when selected—see reference [3]) in preparation for acceptance of the transmitted data units.

3.3.3 IDLE SEQUENCE

During the data services phase, the physical channel operates in a synchronous channel mode where a continuous stream of bits is sent from the transmitter to the receiver. In asynchronous data link operations, the Data Link layer provides PLTUs intermittently for transfer. During the periods when no PLTU is ready for transfer, the Physical layer shall inject the Idle sequence into the channel in order to keep the stream flowing.

3.3.4 TAIL SEQUENCE

Prior to terminating transmission (removing modulation) the transmitter may be required to transmit a series of idle bits (tail sequence) for a fixed period in order for the receiving unit to process the received data unit fully (for convolutional decoding and bit lock assurances).

3.3.5 PHYSICAL CONNECTION PROCESS MIB PARAMETERS

3.3.5.1 Carrier_Only_Duration

Carrier_Only_Duration represents the time that shall be used to radiate an unmodulated carrier at the beginning of a transmission.

3.3.5.2 Acquisition_Idle_Duration

Acquisition_Idle_Duration represents the time that shall be used to radiate the idle sequence pattern at the beginning of a transmission to enable the receiving transceiver to achieve bit synchronization and decoder lock.

3.3.5.3 Tail_Idle_Duration

The Tail_Idle_Duration MIB parameter contains the number of idle bits that need to be sent in the tail process prior to extinguishing the transmitted output signal.

3.4 CONTROLLED COMMUNICATIONS CHANNEL PROPERTIES

NOTES

1 This Recommendation is designed primarily for use in a Proximity link space environment far from Earth. The radio frequencies selected in this Recommendation are designed not to cause interference to radio communication services allocated by the Radio Regulations of the International Telecommunication Union (ITU). Note that particular precautions have to be taken to protect frequency bands allocated to Near Earth Space Research, Deep Space, and Space Research, passive.

2 The frequencies specified near 430 MHz cannot be used for this purpose in the vicinity of the Earth, and particular precautions have to be taken for equipment testing on Earth. However, by layering appropriately, provision is made to change only the physical layer by adding other frequencies (e.g., near 26 GHz) to enable the same protocol to be used in near Earth applications; in the latter case a strict compliance with the frequency allocations in the ITU Radio Regulations is mandatory.

3.4.1 UHF FREQUENCIES

3.4.1.1 General

The UHF frequency allocation consists of 60 MHz between 390 MHz to 450 MHz. The forward frequency band is defined from 435 to 450 MHz. The return band is defined from 390 to 405 MHz. There is a 30 MHz deadband between them.

3.4.1.2 UHF Frequency Channel Assignments

NOTES

1 Hailing is an activity that is used to establish a Proximity link with a remote vehicle. Hailing requires the use of a hailing frequency pair.

2 See annex A of reference [4] for the SET TRANSMITTER PARAMETERS and SET RECEIVER PARAMETERS directives, which are used to configure the channel assignment for the remote vehicle's transmitter and receiver for Channels 0 through 7. See the SET PL EXTENSIONS directive in annex A of reference [4] for Channels 8 through 15, respectively.

3.4.1.3 Hailing Channel

3.4.1.3.1 The hailing channel is enterprise specific. The default configuration of the physical layer parameters (established by the enterprise) defines the hailing channel frequencies that enables two transceivers to communicate initially (via a demand or negotiation process) so that they can establish a configuration for the data services portion of the session.

3.4.1.3.2 The hailing channel (Channel 1) for interoperability at UHF shall be 435.6 MHz in the forward link and 404.4 MHz in the return link (1348/44*33 turnaround ratio).

3.4.1.3.3 If the Proximity link radio equipment supports only a single channel (i.e., a single forward and return frequency pair), then the hailing channel shall be the same as the working channel (see 1.5.1.2).

3.4.1.3.4 If the Proximity link radio equipment supports multiple channels, then the hailing channel shall be distinct from the working channel.

NOTES

1 Hailing is bi-directional; i.e., either element can initiate hailing. Hailing is done at a low data rate and therefore is a low bandwidth activity. Channel 1 has been selected to minimize the use of UHF bandwidth.

2 Hailing is performed between transceivers that are pre-configured. Therefore it is nominally performed on the hailing channel. However if transceivers are compatibly

configured, hailing can occur on an agreed-to channel. The first generation transceivers are fixed frequency and use Channel 0.

3 See the MAC sublayer for further details of hailing in the link establishment process. There are various parameters associated with the Hail activity that are defined in the MIB. See reference [4], annex B for these enterprise-specific parameters.

4 Hailing is accomplished for half and full duplex links using an asynchronous channel and an asynchronous data link.

5 It is recommended that after link establishment through hailing is accomplished, one transitions over to the working channel (if available) as soon as possible.

3.4.1.4 Single Forward and Single Return Frequency Pairs

NOTE – Forward and return link frequencies may be coherently related or non-coherent.

3.4.1.4.1 The following three additional channels (fixed single forward and return frequency pairs) are defined for Proximity-1 operations:

a) Channel 0. In the case where the system requires only one return frequency, associated with the forward 437.1 MHz frequency, the return frequency shall be 401.585625 MHz (147/160 turnaround ratio).

b) Channel 2. In the case where the system requires only one return frequency, associated with the forward 439.2 MHz frequency, the return frequency shall be 397.5 MHz (1325/24*61 turnaround ratio).

c) Channel 3. In the case where the system requires only one return frequency, associated with the forward 444.6 MHz frequency, the return frequency shall be 393.9 MHz (1313/38*39 turnaround ratio).

3.4.1.4.2 Table 3-2 details Proximity-1 channel assignments 0 through 7.

NOTE – Channels 8 through 15 are defined in the SET PL EXTENSIONS directive; see annex a of Reference [4]. The assignment of specific frequencies to these channels is reserved by CCSDS.

Table 3-2: Proximity-1 Channel Assignments 0 through 7 (Frequencies in MHz)

Channel (Ch) Number	Forward (F) Frequency	Return (R)Frequency
0	437.1	401.585625
1	435.6	404.4
2	439.2	397.5
3	444.6	393.9

4	Within 435 to 450	Within 390 to 405
5	Within 435 to 450	Within 390 to 405
6	Within 435 to 450	Within 390 to 405
7	Within 435 to 450	Within 390 to 405

3.4.1.5 Multiple Forward and Multiple Return Frequencies

NOTE – Forward and return link frequencies may be coherently related or non-coherent.

In the case where there is a need for one or multiple return frequencies paired with one or multiple forward frequencies, the forward frequencies shall be selected from the 435 to 450 MHz band in 20 kHz steps and the return frequencies shall be selected from 390 to 405 MHz in 20 kHz steps. These frequency pairs shall be distinct from the frequency pairs defined in Channels 0 through 7. The forward and return frequency components of Channels 8 through 15 are reserved for this purpose.

3.4.2 S-BAND FREQUENCIES

S-Band frequencies are intentionally left unspecified until a user need for them is identified.

NOTE – If such a need arises, users are requested to contact the CCSDS Secretariat at: ccsds@lists.hq.nasa.gov.

3.4.3 X-BAND FREQUENCIES

X-Band frequencies are intentionally left unspecified until a user need for them is identified.

NOTE – If such a need arises, users are requested to contact the CCSDS Secretariat at: ccsds@lists.hq.nasa.gov.

3.4.4 KA-BAND FREQUENCIES

Ka-Band frequencies are intentionally left unspecified until a user need for them is identified.

NOTE – If such a need arises, users are requested to contact the CCSDS Secretariat at: ccsds@lists.hq.nasa.gov.

3.4.5 POLARIZATION

Both forward and return links shall operate with RHCP.

3.4.6 MODULATION

3.4.6.1 The PCM data shall be Bi-Phase-L encoded and modulated directly onto the carrier.

3.4.6.2 Residual carrier shall be provided with modulation index of 60° ± 5%.

3.4.6.3 The symmetry of PCM Bi-Phase-L waveforms shall be such that the mark-to-space ratio is between 0.98 and 1.02.

3.4.6.4 A positive-going signal shall result in an advance of the phase of the radio frequency carrier. For directly modulated Bi-phase-L waveform,

a) a symbol ‘1’ shall result in an advance of the phase of the radio frequency carrier at the beginning of the symbol interval;

b) a symbol ‘0’ shall result in a delay.

3.4.7 DATA RATES

The Proximity-1 link shall support one or more of the following 12 discrete forward and return data rates, shown in bits per second: 1000, 2000, 4000, 8000, 16000, 32000, 64000, 128000, 256000, 512000, 1024000, 2048000.

3.5 PERFORMANCE REQUIREMENTS

3.5.1 DELIVERED BIT STREAM ERROR RATE

Link margins shall be designed to provide a Bit Error Rate (BER) less than or equal to 1×10^{-6} for asynchronous links.

3.5.2 CARRIER FREQUENCY STABILITY REQUIREMENTS

3.5.2.1 The long term oscillator stability (over the life of the mission) including all effects and over all operating conditions shall be 10 ppm.

3.5.2.2 The short term oscillator stability over 1 minute shall be 1 ppm.

3.5.3 RESIDUAL AMPLITUDE MODULATION

Residual amplitude modulation of the phase modulated RF signal shall be less than 2% RMS.

3.5.4 CARRIER PHASE NOISE

The minimum specification for the oscillator phase noise at 437.1 MHz shall be limited by the template shown in figure 3-1. The figure shows normalized power in dBc (where dBc refers to the power relative to the carrier power) vs. frequency offset from the carrier in Hz.

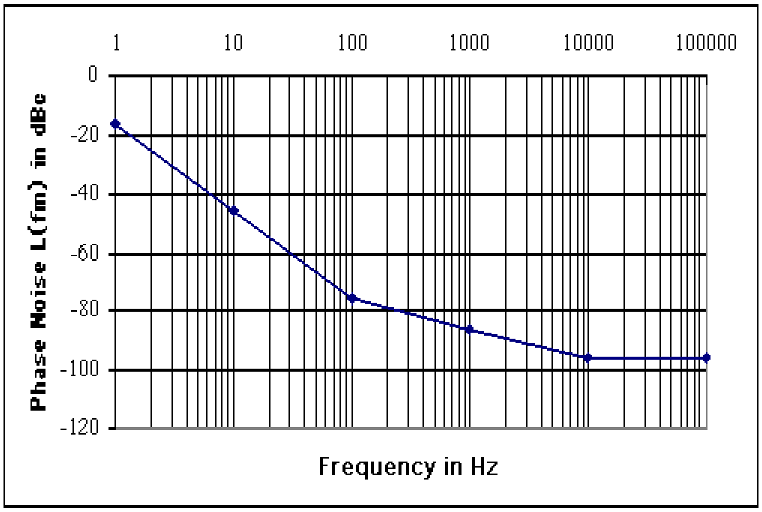

Figure 3-1: Oscillator Phase Noise

NOTE – This specification is applicable for non-coherent mode only.

3.5.5 OUT OF BAND SPURS

The spurious spectral lines of the transmit RF signal shall be limited by the template shown in the figure 3-2. The figure shows normalized power in dBc vs. normalized frequency $(f-f_c)/A$ (where $A = 2*R_b$, f_c = carrier frequency) when convolutional coding is not applied. The factor of 2 is due to the use of Manchester bi-phase code. R_b is the bit rate (raw data).

NOTE $A = 4*R_b$ if convolutional coding is used.

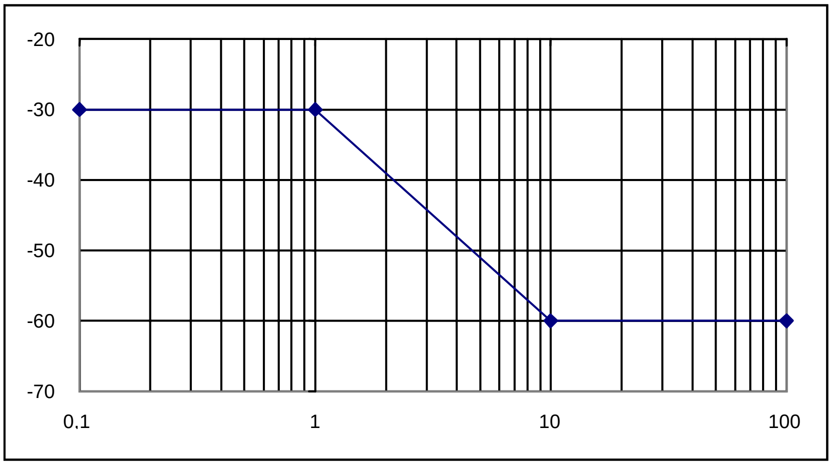

Figure 3-2: Discrete Lines Template for the Transmitter (Normalized Power in dBc vs. Normalized Frequency: $(f-f_c)/A$

3.5.6 DOPPLER TRACKING AND ACQUISITION REQUIREMENTS

NOTE – The Doppler acquisition and tracking requirements imposed on any of the network elements are specified according to radio frequencies employed on the link. The requirement applies to the RF interface between all E1 and E2 elements. In the case of the coherent RF interface between E2c elements, there is an additional offset of Δf caused by the turnaround ratio of the responding element that must be tracked.

3.5.6.1 UHF Frequencies

a) Doppler frequency range: ±10 kHz;

b) Doppler frequency rate:

   1) 100 Hz/s (non-coherent mode),

   2) 200 Hz/s (coherent mode).

NOTE – The Doppler frequency rate does not include the Doppler rate required for tracking canister or worst-case spacecraft-to-spacecraft cases.

3.5.6.2 S-Band Frequencies

S-Band frequency requirements are intentionally left unspecified until a user need for them is identified.

NOTE – If such a need arises, users are requested to contact the CCSDS Secretariat at: ccsds@lists.hq.nasa.gov.

3.5.6.3 X-Band Frequencies

X-Band frequency requirements are intentionally left unspecified until a user need for them is identified.

NOTE – If such a need arises, users are requested to contact the CCSDS Secretariat at: ccsds@lists.hq.nasa.gov.

3.5.6.4 Ka-Band Frequencies

Ka-Band frequency requirements are intentionally left unspecified until a user need for them is identified.

NOTE – If such a need arises, users are requested to contact the CCSDS Secretariat at: ccsds@lists.hq.nasa.gov.

ANNEX A

DIRECTIVES AFFECTING THE PROXIMITY-1 PHYSICAL LAYER

(This annex is part of the Recommendation)

This annex simply lists for completeness the Proximity-1 Space Link Protocol directives which affect the Physical Layer. These directives are defined in annex A of reference [4].

SET TRANSMITTER PARAMETERS

SET RECEIVER PARAMETERS

SET PL EXTENSIONS