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1 Overview

1.1 Scope

This standard applies only to Link 16/JTIDS/MIDS. It does not address Link 16 over Satellite Communications (SATCOM). In developing a protocol for simulating Link 16 in Distributed Interactive Simulation (DIS) and High Level Architecture (HLA), it is recognized that there are widely varying requirements for achieving needed fidelity among different users. This standard establishes procedures that may be used by the vast majority of users, by establishing discrete, scalable, interoperable levels of fidelity for different users. This, in turn, allows for low cost initial implementation with a path toward upgrading to detailed Link 16 emulation as requirements evolve.

The DIS simulation protocol for Link 16 is described in terms of the established DIS Transmitter and Signal Protocol Data Units (PDUs). There has been no change to the Transmitter or Signal PDUs described in Reference 4. Link 16 specific enumerations have been created to populate the standard fields and records. The implementation of Link 16 exploits the fact that both these PDUs are variable length. In the case of the Transmitter PDUs, this protocol sets forth how the variable length Modulation Parameters field must be populated. In the case of the Signal PDU, Link 16 specific information is relegated to the variable length Data field.

The Link 16 HLA specification is defined in the form of a Federation Object Model (FOM) module, in compliance with Reference 6. For actual exchange within an HLA federation, it should be incorporated into a FOM; in particular, the Real-time Platform Reference (RPR) FOM. Furthermore, a mapping is provided between the DIS PDU implementations and the corresponding HLA objects and interactions.

1.2 Purpose

There are immediate operational requirements for existing military simulations to exchange Link 16 data using a single interoperable standard. Several protocols have evolved to satisfy specific needs. The NATO STANAG 5602 Standard Interface for Multiple Platform Link Evaluation (SIMPLE) Link 16 standard [9] is one such protocol. As military distributed simulation evolves further in mission scale and complexity, tactical data link implementations need to interoperate.

1.3 Objectives

The objective of this document is to establish a standard for Link 16 message exchange and JTIDS network simulation in the DIS and HLA interoperability frameworks. The intent is to prescribe the content of the standard fields of the Transmitter and Signal PDUs (and the corresponding Link 16 FOM module interactions) and establish procedures for their use. Compliance with these procedures will facilitate interoperability among Link 16 simulation systems.

1.4 Intended Audience

This standard is intended to be used by implementers of Link 16 data link message exchange over DIS or HLA protocols.

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2 References

The following documents are referenced herein. For undated references, the latest published version of the document applies, including any amendments. If a conflict exists with a referenced document, this document shall take precedence.

Ref #	Document Number	Title
1	SISO-STD-001.1	Standard for Real-time Platform Reference Federation Object Model, Version 2.0, 10 August 2015
2	SISO-STD-001	Standard for Guidance, Rationale, and Interoperability Modalities for the Real-time Platform Reference Federation Object Model, Version 2.0, 10 August 2015
3	SISO-REF-010	Reference for Enumerations for Simulation Interoperability
4	IEEE Std 1278.1™	IEEE Standard for Distributed Interactive Simulation – Application Protocols
5	IEEE Std 1516™	IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)
6	IEEE Std 1516.2™	IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) – Object Model Template (OMT) Specification
7	MIL-STD-6016	Department Of Defense Interface Standard Tactical Data Link (TDL) 16 Message Standard
8	STANAG 5516	NATO STANAG 5516, Tactical Data Exchange - Link 16
9	STANAG 5602	NATO STANAG 5602, Standard Interface for Multiple Platform Link Evaluation (SIMPLE)
10	ISBN-10: 0877798095	Merriam-Webster's Collegiate Dictionary, Eleventh Edition forward
11	RFC 5905	Network Time Protocol Version 4: Protocol and Algorithms Specification, June 2010
12	SSS-M-10201	System Segment Specification for the Multifunctional Information Distribution System (MIDS) Low-Volume Terminal and Ancillary Equipment for Block Upgrade 2
13	135-02-005	Understanding Voice and Data Link Networking, Northrop Grumman's Guide to Secure Tactical Data Links

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3 Definitions, Acronyms, and Abbreviations

English words are used in accordance with their definitions in the latest edition of Merriam-Webster's Collegiate Dictionary [10] except when special SISO product-related technical terms are required.

3.1 Definitions

Term	Definition
Epoch	A 12.8-minute time interval consisting of 98,304 time slot intervals, each of 7.8125 milliseconds duration. The time slots in each epoch are organized into three sets (A, B, or C) of 32,768 time slots each. There are 112.5 epochs in a 24-hour period.
Free Text Message	The Free Text Message format is a type of Link 16 message structure that uses all bits for data. A bit-oriented message whose information bits may be used to represent digitized voice, teletype, and other forms of free text information. Not the same as the fixed word format J28.2 message. In this protocol, Free Text Messages are used to support JTIDS Free Text Voice Data.
Fidelity Level	In terms of this standard, a fidelity level is a measure of the level of functionality of the implementation of this Link 16 Simulation standard. This allows for a standard nomenclature to be used within the community to describe the functionality of implementations of this standard. See section 4.1.2 for additional information and Table 2 for definitions of fidelity levels in this standard.
Fixed Word Format (FWF)	A 70-bit structure consisting of a formalized arrangement of predefined fields of fixed length and sequence.
Fixed Word Format Message	A J-Series message utilizing Fixed Word Format (FWF). An FWF message is started by an initial word that may be then followed by one or more extension and/or continuation words.
Initial Entry	The procedure by which a JTIDS/MIDS unit initially synchronizes with network time sufficient to receive network messages.
Initial Entry JTIDS/MIDS Unit (IEJU)	Any JTIDS/MIDS unit that transmits the Initial Entry message in the appropriate time slot.
Joint Tactical Information Distribution System (JTIDS)	See MIDS.
JTIDS/MIDS Net	A code division structure. There are 128 unique code divisions for waveform and data encryption in a time slot for the cryptovariable that may be employed during the time slot. The code division used by the terminal is by specification of a seven-bit number.
JTIDS/MIDS Network	The JTIDS/MIDS structure (usable only with Mode 1 communications) having a total usable capacity of 98,304 time slots per epoch per net and 128 nets. All nets are synchronized so that each time slot of each net is time-coincident with the corresponding time slot (same set and number) of every other net. The signal characteristics of all data distributed within a specified multi-netted structure are determined by a cryptographic variable in conjunction with a set of net numbers that define the structure.

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Term	Definition
JTIDS/MIDS Unit (JU)	A unit communicating directly on Link 16. JU is used within the context of this standard to indicate a simulated TADIL J terminal.
JTIDS Voice	Voice communications over a JTIDS network. For additional information on JTIDS voice, see References 12 and 13.
J-Word	JTIDS Word.
Link 16 Header Word	The leading bits of each message which are coded as a Reed-Solomon code word that provides 35 bits of information.
Link 16 Message	A functionally oriented, variable length string of one or more 70 bit words.
Machine Receipt	A machine verification function whereby a terminal that receives a message addressed to it retransmits a copy of that message back to the source during a later time slot, verifying the receipt of the original message.
Mode 1 Communications	Mode 1 JTIDS/MIDS transmissions consist of a sequence of wide-band transmission symbol packets (single pulse, 13-microsecond packets and double-pulse, 26-microsecond packets), the pulses of which are formed by continuous phase shift modulation (CPSM) of the carrier frequency. The signal processing required to transform base-band data to the JTIDS signal waveforms for transmission includes base-band data encryption, forward error correction encoding, error detection encoding, cyclic code shift keying (CCSK) encoding, data symbol interleaving, and the selection of a variable start time.
Mode 2 Communications	Mode 2 JTIDS/MIDS transmissions are identical to Mode 1, except that Mode 2 operates in the narrow-band mode.
Mode 4 Communications	Mode 4 JTIDS/MIDS transmissions have signal waveform characteristics identical to Mode 2, except that Mode 4 does not employ base-band data encryption signal processing.
Multifunctional Information Distribution System (MIDS)	The MIDS is a system which provides an Integrated Communication, Navigation, and Identification (ICNI) capability. The MIDS provides a reliable, secure, jam resistant, high capacity, ICNI capability through the use of direct-sequence, spread-spectrum, frequency-hopping, and error detection and correction techniques. JTIDS is synonymous with MIDS. For the purpose of this document, there is no difference.
Navigation Controller	The Navigation Controller establishes the origin and North orientation of the U, V relative grid for the Relative Navigation function.
Net	See "JTIDS/MIDS Net."
Net Number	A 7-bit code that identifies each net as a decimal number (0 through 127).
Network	See "JTIDS/MIDS Network".
Network Participation Group (NPG)	An agreed upon list of messages specified by label/sublabel used to support a technical function. Messages of the NPG are transmitted in time slots assigned to the JTIDS/MIDS Unit for the NPG without regard to subscriber identities.
Network Time Reference (NTR)	A subscriber terminal that is assigned as the reference for system time for each synchronized netted system. The NTR terminal's clock time is never updated by system information and is the reference to which all other terminals synchronize their own clocks. There is only one NTR per network.

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Term	Definition
Network Synchronization ID	An unsigned integer that identifies a simulated Link 16 network. Network Synchronization ID is a simulation-only construct which supports multiple simultaneous independent Link 16 networks. Higher fidelity simulations also use it to simulate the Link 16 network time synchronization process. Network Synchronization ID is not to be confused with NPG Number or Net Number which are real-world constructs that support various forms of stacked nets or multi-netting within a single Link 16 network.
Pulse (JTIDS/MIDS)	A 6.4-microsecond burst of carrier frequency continuous phase shift modulated at a 5-megabit-per-second rate by the transmission symbol.
Precise Participant Location and Identification (PPLI)	The PPLI function provides network participation status, identification, and position of JUs on the Link 16 interface.
Recurrence Rate	The total number of time slots per epoch in a single block assignment, specified as an integer, R from 0 to 15 where 2^R is the number of time slots.
Reed-Solomon Code	As applied to JTIDS/MIDS, a forward error correction encoding scheme. In this protocol, when Reed-Solomon encoding is indicated in the Signal PDU, the data area is still comprised of 75-bit non-Reed-Solomon encoded Link 16 messages.
Relative Navigation (RELNAV)	A procedure used by a terminal to determine its position and velocity in a common reference coordinate system by passive observations of Position and Status messages transmitted by other terminals. To make use of RELNAV, the simulation system must achieve medium-fidelity synchronization.
Round-Trip-Timing (RTT)	The process used by a JTIDS/MIDS terminal to directly determine the offset between its clock and that of another JTIDS/MIDS terminal. This is used to achieve and maintain fine synchronization and to improve the terminal's time quality. This process involves the exchange of RTT Interrogation and Reply Messages.
RTT Addressed (RTT A)	The RTT A message provides the means for a JTIDS Terminal to synchronize with system time using the active synchronization procedure. A specific terminal with a time quality greater than the interrogating terminal is interrogated and responds with the RTT Reply. Typically the interrogating terminal addresses the NTR.
RTT Broadcast (RTT B)	The RTT B message provides the means for a JTIDS Terminal to synchronize with the system time using the active synchronization procedure. The RTT B message is not addressed to a specific terminal. The interrogating terminal transmits the RTT B message on the net number of the highest time quality PPLI that it has received. Any terminal with a time quality equal or higher than that net number shall reply.
RTT Reply	The RTT reply message provides the means for a JTIDS terminal to support the active synchronization procedure by providing time-of-arrival data in response to either an RTT A or RTT B interrogation.
Stacked Net	The coordinated use of specific blocks of time slots on different nets in a JTIDS/MIDS network by different communities of users.
Subscriber	A participant in the use of the system, either actively (transmission of information) or passively (receiver of information only), or both.

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Term	Definition
Synchronization	Active Synchronization: A procedure used by a JTIDS/MIDS terminal to effect and maintain fine synchronization with system time based on the Round-Trip-Timing (RTT) process. Passive Synchronization: A procedure used by a terminal to effect and maintain fine synchronization with system time by passive observations of Position and Status messages transmitted by other terminals. The synchronizing terminal is not required to transmit any information. Coarse Synchronization: The state of synchronization with system time that allows a terminal to receive and process messages and to achieve fine synchronization. Fine Synchronization: The state of synchronization with system time that allows a terminal to transmit messages. A terminal may utilize a passive or an active synchronization procedure to achieve fine synchronization. Low-Fidelity Synchronization: Simulated fine synchronization without using RTT messages. Medium-Fidelity Synchronization: Simulated fine synchronization using RTT messages.
Tactical Digital Information Link (TADIL)	A Joint Chiefs of Staff (JCS) approved standardized communications link suitable for transmission of digital information. A data link is characterized by its standardized message formats and transmission characteristic.
TADIL J	Tactical Digital Information Link J. A secure, jam-resistant, nodeless data link that utilizes the Joint Tactical Information Distribution System (JTIDS), and the protocols, conventions, and Link 16 fixed word message formats defined by Reference 7.
TADIL TALES	Tactical Digital Information Link Technical Advice and Lexicon for Enabling Simulation.
Time (System)	The time maintained by the terminal assigned as the Network Time Reference (NTR) to which all other participating terminals are synchronized.
Time (Terminal)	The estimate of system time derived by a terminal as a result of executing either the active or a passive synchronization procedure.
Time Quality	A measure of the quality of a terminal's state of synchronization with system time reported in the terminal's PPLI message. Time quality is reported as an integer from 0 to 15 where the higher numbers correspond to the higher levels of quality, that is, lower errors in timing.
Time Slot	A 7.8125-millisecond time interval during which messages may be transmitted and received.
Time Slot Allocation (TSA) Level	In this simulation standard a TSA level corresponds to one of five selectable levels of fidelity. See Table 2 for a description of each level.
Time Slot Assignment	The designation to the terminal of the specific time slot block in which it will transmit or receive messages.
Time Slot Block	A collection of time slots spaced uniformly in time over each epoch and belonging to a single time slot set. A block is defined by indexing time slot number (0 to 32,767) set (A, B, or C), and a recurrence rate number (0 to 15).
Time Slot Number	A 17-bit code that identifies each full time slot. The code consists of a 2-bit set field (set A, B, or C) and a 15-bit slot field representing the decimal numbers zero to 32,767.

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Term	Definition
Unique Identifier	Enumeration fields have values and descriptions defined in SISO-REF-010. The table for each enumeration is identified by a Unique Identifier (UID) in the form "[UID nnn]". In this standard, references to SISO-REF-010 tables use the same UID syntax; for example, "see [UID 874]".
Variable Message Format (VMF)	A message structure using predefined fields of fixed length employing internal syntax and a header extension. The internal syntax specifies the presence, absence, and recurrence of fields as selected by the user. The VMF message format is not to be confused with MIL-STD-6017.

3.2 Acronyms and Abbreviations

Acronym/Abbreviation	Definition
BOM	Base Object Model
C2	Command and Control
CCSK	Cyclic Code Shift Keying
CPSM	Continuous Phase Shift Modulation
CVLL	Crypto Variable Logic Label
CVSD	Continuous Variable Slope Delta (modulation)
DIF	Data Interchange Format
DIS	Distributed Interactive Simulation
DM	Declaration Management
EDAC	Error Detection and Correction
FOM	Federation Object Model
FWF	Fixed Word Format
GPS	Global Positioning System
HLA	High Level Architecture
IAW	In Accordance With
ICNI	Integrated Communications, Navigation, and Identification
IEEE	Institute of Electrical and Electronics Engineers
IEJU	Initial Entry JTIDS unit
JCS	Joint Chiefs of Staff
JTIDS	Joint Tactical Information Distribution System
JU	JTIDS Unit
LET	Link 16 Enhanced Throughput
LPC	Linear Predictive Coding
MIDS	Multifunctional Information Distribution System
MIL STD	Military Standard
M&S	Modeling and Simulation

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Acronym/Abbreviation	Definition
MSEC	Message Security Encryption Code
NATO	North Atlantic Treaty Organization
NDL	Network Data Load
NPG	Network Participation Group
NTP	Network Time Protocol
NTR	Network Time Reference
OMT	Object Model Template
PDU	Protocol Data Unit
PPLI	Precise Participant Location and Identification
RPR	Real-time Platform Reference
RELNAV	RELative NAVigation
RTT	Round Trip Timing
SATCOM	SATellite COMmunications
SIMPLE	Standard Interface for Multiple Platform Link Evaluation
SISO	Simulation Interoperability Standards Organization
STANAG	STANdardization AGreement
TADIL	Tactical Digital Information Link
TADIL J	Tactical Digital Information Link J
TDMA	Time Division Multiple Access
TDL	Tactical Data Link
TSA	Time Slot Allocation
TSEC	Transmission Security Encryption Code
UID	Unique IDentifier
UTC	Coordinated Universal Time
VMF	Variable Message Format
WAN	Wide Area Network
XML	Extensible Markup Language

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4 Requirements

4.1 JTIDS Operating Characteristics

JTIDS uses the principle of Time Division Multiple Access (TDMA) to divide network time, and capacity, into divisions called time slots. Each time slot is 7.8125 milliseconds long with 128 time slots per second. Time slots are organized into three interleaved sets (A, B, and C). An epoch is 12.8 minutes long comprised of 98,304 time slots. There are 112.5 epochs in a 24-hour day. Therefore, the current epoch, set, and time slot number can be calculated from the current time. Operationally, groups of time slots are assigned to a common function known as a Network Participation Group (NPG). Time slot assignments are published in a Network Data Load (NDL) (by a central net design agency), with participation groups identified by the time slot set, the “offset” of the time slot, and the time slot recurrence rate. The recurrence rate is expressed as an exponential power of 2, representing how often the time slot assigned to the NPG occurs within the set. [13]

TDMA architecture requires that each JTIDS participant, known as a JTIDS Unit (JU), must know when its transmit time slots occur. JUs must be synchronized with a common network time to receive and transmit on the network. In JTIDS, one JU in a network is designated as the Network Time Reference (NTR). [13]

Link 16 also uses frequency hopping to provide jam resistance on the Link 16 network. Hopping is done on a pulse by pulse basis, with each hop being 13 microseconds long which allows 76,923 hops per second. The frequency sequence is pseudo-randomly selected using a crypto variable to force any potential jammer to spread its energy over a wider frequency range when it cannot follow the sequence. [13]

4.1.1 General Requirements

This section describes general requirements for simulation of Link 16 independent of the simulation protocol used. The specific requirements for implementation under DIS are described in section 4.2. The specific requirements for implementation under HLA are described in section 4.3.

1. Simulators in compliance with this standard shall as a minimum have the capability to identify the NPG and net number of transmitted data to allow them to operate at Time Slot Allocation (TSA) level 0 and 1.
2. All Link 16 messages shall be bit encoded in accordance with the Reference 7 and Reference 8 TADIL J specification. In the specification, each time slot contains one 35-bit header, padded to 48 bits, and a varying number of 75-bit messages, padded to 80 bits, unless the Message Type Identifier specifies otherwise.
3. It is not required to perform error detection encoding for the Link 16 messages. If error detection encoding is not performed, the parity bits of the 75-bit messages shall be set to 0. Usage of error detection encoding and interpretation of the parity bits may be specified in exercise agreements.
4. When the header indicates Reed-Solomon encoding, the data area shall still be comprised of non-Reed-Solomon encoded Link 16 messages.
5. Regardless of level of fidelity, all transmission modulation parameter fields shall be filled with valid data in accordance with this standard.
6. Any simulator that is not emulating JTIDS NDL throughput shall have the ability to configure the maximum number of Link 16 words transmitted per second, but shall not exceed the JTIDS maximum of 1536 J-words per second (twelve J-words per Pack-4 Single Pulse time slot multiplied by 128 time slots per second). This upper limit shall not apply to JTIDS Link 16 Enhanced Throughput (LET) packets. For additional information see Reference 12.

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7. The J31.7 No Statement message is a 1-word J Message used by terminals to pad time slot message structures to either 3, 6, or 12 words. When issuing a Link 16 signal message, simulations may use J31.7 messages to pad to 3, 6, or 12 words in accordance with the time slot message packing format, but this is not recommended. When receiving a Link 16 signal message, simulations shall process the message whether or not J31.7 padding is included, i.e., the receiver shall treat any missing words as J31.7 padding.

8. If the number of J Words in a signal message is greater than prescribed by the packing format, the extra J Words shall be ignored.

9. When receiving a Link 16 signal message, simulations shall only process complete J Messages that are properly formatted in terms of initial, extension, and/or continuation words IAW References 7 and 8.

10. A Link 16 signal message may include multiple J Messages. For example, in Link 16 simulation, a 6-word time slot message packing format may be used to represent one or more J Messages as long as the total number of J Words is 6 or less.

11. Systems shall wait until their time slot occurs to transmit data in order to receive the latest update to data (i.e., time slots shall not be "pre-sent"). Receiving systems shall buffer messages after the time slot has occurred to account for network delays. The amount of time to buffer messages for a time slot shall be a runtime configuration item. The amount of time entered shall be the same for all participants in the same network and will cause the simulations to all "retire" a particular time slot at the same time. This effect is not important for lower levels of fidelity (TSA Levels 0, 1) but is critical for all fidelity levels that tie a message to a particular time slot along with a NDL. If the effects of messages arriving later than the time slot are not important (multiple JUs transmitting in the same time slot, contention access, or data arriving while the receiving JU is transmitting), or the physical network infrastructure has low delays (less than 3 millisecond), the buffer time can be set to a low number or to zero. When TSA Level 0 or 1 systems interoperate with higher-fidelity systems, the buffer has to be the same for all participants. When network is composed exclusive of TSA Level 0 and 1 systems, the buffer may be set to a low number or zero.

12. All systems set at TSA Level 2 or higher shall have their system times synchronized to a common time reference. Any error in the clock synchronization times (e.g., average Network Time Protocol (NTP) error) must be added to the network delays (the buffer time) before retiring a time slot. For real-time DIS or HLA simulation applications, NTP (or equivalent) is recommended. For non-real-time simulation applications, HLA time management is recommended.

13. All systems should have some representation of a terminal clock time. If medium-fidelity synchronization is to be accomplished, the system shall model a terminal clock (and its associated drift).

14. At TSA Level 2 or greater, if multiple messages are received with identical Transmission Security Encryption Codes (TSEC), net number, and time slot, receivers shall not process messages except from the closest transmitting entity (in the simulation space).

15. There are three communication modes for a real JTIDS/MIDS network: modes 1, 2, and 4 (See Table 1). The selected communication mode determines whether or not the network can operate on multiple nets (by employing frequency hopping) and the transmitted data are encrypted. All JUs in a JTIDS/MIDS network must operate in the same communication mode.

    A. The normal JTIDS communication mode is mode 1. Frequency hopping and crypto variables shall be simulated appropriately to the specified level of fidelity.

    B. When operating with JTIDS communication mode 2, there will be no frequency hopping, but encryption shall still be used, depending on the level of fidelity. The explicit frequency of 969 MHz shall be set in the transmission message frequency field and the bandwidth will be 3 MHz. The net number in the signal message shall be zero for all transmissions (no multi-netting).

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C. Mode 4 eliminates communications security in addition to the features of communications mode 2. The TSEC and MSEC encryption fields shall be set to 255 when in communications mode 4 in addition to specifying the explicit transmit frequency as in communications mode 2.

Table 1: JTIDS Communication Modes

Communication Mode	Frequency Hopping	Data Encrypted
1	Yes	Yes
2	No	Yes
3	Not Used	Not Used
4	No	No

16. Time slots shall be numbered sequentially, such that time slot 0 represents time slot A-1, and time slot 98303 represents C-32767. When the epoch is 112, the last valid time slot is 45151 (end of the day).

17. Generated machine receipts shall use time slots as assigned in the network description. There is no special consideration given to machine receipts; therefore, they are treated as any other Link 16 fixed format message.

18. Relay is accomplished by transmitting relay information in assigned time slots. There is no special mechanism necessary to simulate relay transmissions.

19. Transmission messages shall be issued in accordance with Reference 4 (Issuance of the Transmitter PDU), or for as far as applicable to the equivalent HLA object, with the exception of the requirement to issue the Transmitter PDU before and after each group of Link 16 Signal PDUs, i.e., Transmitter PDU “bracketing” is not required. Transmitter PDU bracketing of Link 16 Signal PDUs is allowed but is not recommended. Once the Transmit State of the Link 16 transmitter is set to On and Transmitting, the Transmit State should remain in that mode indefinitely, i.e., until the radio is turned off or otherwise leaves the network. All other Reference 4 Transmitter PDU issuance rules apply for Link 16 simulation, including issuance for Transmit State changes and for heartbeats. When receiving transmission and signal messages, Link 16 simulations should be tolerant of implementations that use Transmitter PDU bracketing with or without Transmit State toggling, no bracketing, or other variations.

20. All information in the Link 16 Message Data field following the Link 16 Simulation Network Header of the Signal PDU, and the corresponding parameters of the HLA interactions derived from Link16RadioSignal, shall be treated as a bit stream. The individual bit fields of the bit stream shall be packed into bytes (octets) as follows:

    A. Bit 0 of the first bit field shall begin at bit 0 of the first octet in the bit stream and continue until the number of bits in the field are consumed.

    B. Bit 0 of the next bit field shall begin in the next available bit of the current octet or in bit 0 of the next octet if all bits of the current octet have been consumed exactly.

    C. If insufficient bits remain in an octet for a bit field, as many bits as will fit in the current octet shall be consumed, then the bit field shall continue to be packed starting with bit 0 of the next octet.

    D. Subsequent bit fields shall be packed in a like manner.

    E. Individual bit fields may span multiple octets as necessary to fit all bits in the bit field.

    See Table 17 for an example of packing the JTIDS message bit stream data starting at Octet 20. This table also shows how bytes are ordered for the Link 16 Simulation Network Header in octets 0 to 19, which is not a bit stream.

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4.1.2 TSA Levels of Fidelity

This protocol allows simulations to achieve different levels of fidelity by assigning one of five Time Slot Allocation (TSA) levels. If the simulator allows for a settable level of fidelity, the level of fidelity shall be set at runtime. The TSA Level shall be set in Modulation Parameter #1 of the transmitter message with an enumeration of 0-4 as described in Table 2 and Reference 3 [UID 172].

Table 2: Link 16 Simulation TSA Levels

TSA Level	TSA Fidelity	Time Synchronization Fidelity [1]	Issues	Recommended Usage
0	Low	None or Low	May simulate simplified segregation of messages on separate virtual networks, but does not emulate detailed TDMA network characteristics. Data rates are not constrained. Intended for legacy use.	Experiments and/or training concerned with message format and/or message content only.
1	Low	None or Low	May simulate simplified segregation of messages on separate virtual networks, but does not emulate detailed TDMA network characteristics.	Experiments and/or training where total network throughput is important. Allows for bandwidth throttling to emulate Link 16 network throughputs without assigning messages to specific time slots. Network Data Loads can be loaded into terminal simulation equipment to simulate data rates in NPGs on the Link 16 network.
2	Medium	Low	Network delay must be sufficiently small if time slot sensitive conversations are required to duplicate live Link 16 networks (e.g., relay emulation, RELNAV, messages requiring responses).	Experiments and/or training concerned with throughput limits of the Link 16 network. Also suitable for experiments/training emulating message traffic and timing of Link 16 networks without emulating effects of RTTs, RELNAV, or stacked/multi-nets.
3	Medium	Low	Same as TSA Level 2.	Experiments and/or training concerned with emulating detailed TDMA time slots and encryption associated with stacked nets, multi-nets, and crypto-nets.

[1] Time Synchronization Fidelity levels are discussed below in section 4.1.4.

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TSA Level	TSA Fidelity	Time Synchronization Fidelity [1]	Issues	Recommended Usage
4	High	Medium	Extremely sensitive to network latency.	Experiments and/or training concerned with effects deriving from emulation of detailed network entry timing and synchronization maintenance.

4.1.2.1 TSA Level 0, Low Fidelity

TSA Level 0 is the lowest level of fidelity. For the transmitter message Modulation Parameters, the Time Slot Allocation Level field, Transmitting Terminal Primary Mode, and Transmitting Terminal Secondary Mode fields shall be populated. In addition, the Synchronization State field shall be set to Fine Synchronization (3) IAW paragraph 4.1.4.1. The Network Synchronization ID shall be set to zero to indicate it is not used, or to a unique non-zero value if participation in a distinct simulated network is desired. For the signal message Link 16 Simulation Network Header, the NPG Number, Net Number, Message Type Identifier, and SISO-STD-002 Version fields shall be populated. All bits of the TSEC CVLL, MSEC CVLL, Time Slot ID, and Perceived Transmit Time fields shall be set to one to indicate a no statement/wildcard. Multiple messages are permitted in a single signal message. All messages within the signal message shall be of the same NPG Number, Net Number, and assumed packing format. Simulation participants may compare the NPG Number and Net Number values in the signal message to their own simulated terminal settings to model simplified stacked network reception effects. There is no TSA or metering with up to the maximum number of messages (as specified in the DIS standard) packed into the data area of a single signal message. No or low-fidelity time synchronization is allowed under TSA Level 0. No time synchronization shall be accomplished in accordance with paragraph 4.1.4.1. Low-fidelity time synchronization shall be achieved in accordance with paragraph 4.1.4.2.

4.1.2.2 TSA Level 1, Low Fidelity

TSA Level 1 is similar to TSA Level 0 except that there is minimal metered data. For the transmitter message, all Modulation Parameter fields have the same valid values as TSA Level 0, except Synchronization State may be set to 2 or 3. For the signal message, one time slot worth of information shall be in one signal message, and all Link 16 Simulation Network Header fields shall be populated as in TSA Level 0. No or low-fidelity time synchronization is allowed under TSA Level 1. No time synchronization shall be accomplished in accordance with paragraph 4.1.4.1. Low-fidelity time synchronization shall be achieved in accordance with paragraph 4.1.4.2.

4.1.2.3 TSA Level 2, Medium Fidelity

TSA Level 2 allows for metered data with no encryption. For the transmitter message, all Modulation Parameter fields have the same valid values as TSA Level 1. For TSA Level 2, all signal messages shall be assigned to individual time slots (i.e., setting a valid Time Slot ID). All other Link 16 Simulation Network Header fields shall be populated as in TSA Level 1. Low-fidelity time synchronization shall be achieved in accordance with paragraph 4.1.4.2.

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4.1.2.4 TSA Level 3, Medium Fidelity

This level enables full TSA to include encryption. When TSA Level is set to 3, more detailed timing characteristics of stacked nets, multi-nets, and crypto-nets can be emulated. For the transmitter message, all Modulation Parameter fields are required to be populated with meaningful data. The Synchronization State field is initially set to Initial Net Entry (1), then progresses to Coarse Synchronization (2) when an acceptable J0.0 message is received, and then to Fine Synchronization (3) if able to transmit. The Network Synchronization ID shall be set to a non-zero, 32-bit unsigned integer generated by the NTR. For the signal message, all Link 16 Simulation Network Header fields from TSA Level 2 are populated plus the TSEC CVLL and MSEC CVLL fields. Low-fidelity time synchronization shall be achieved in accordance with paragraph 4.1.4.2.

4.1.2.5 TSA Level 4, High Fidelity

If the TSA Level is set to 4, everything from TSA Level 3 is emulated, with the addition of the medium-fidelity synchronization procedures. All transmitter message Modulation Parameter fields shall be populated as described for TSA Level 3. All Link 16 Simulation Network Header fields in the signal message, except Link 16 Version, shall be populated with meaningful values. Medium fidelity time synchronization shall be achieved in accordance with paragraph 4.1.4.3.

4.1.2.6 Fidelity Level Summary

Tables 3 and Table 4 summarize the valid field values for the different TSA Levels for Link 16 modeling for transmitter and signal messages. Signal message fields with all bits set to one are treated as a no statement/wildcard.

Table 3: Transmitter Message Modulation Parameters - Valid Field Values for Different TSA Levels

Modulation Parameter #	Field Name	TSA Level				
		0	**1**	**2**	**3**	**4**
1	Time Slot Allocation Level	0	1	2	3	4
2	Transmitting Terminal Primary Mode	Required				
3	Transmitting Terminal Secondary Mode	Required				
4	Synchronization State	3	2 or 3		1, 2, or 3	
5	Network Synchronization ID	0, or non-zero, 32-bit unsigned integer			Non-zero, 32-bit unsigned integer	

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Table 4: Signal Message Link 16 Simulation Network Header - Valid Field Values for Different TSA Levels

Field Name	TSA Level				
	0	1	2	3	4
NPG Number	Required				
Net Number	Required				
TSEC CVLL	255			Required	
MSEC CVLL	255			Required	
Message Type Identifier	Required				
SISO-STD-002 Version	Required				
Link 16 Version	Optional (Default: "No Statement")				
Time Slot ID	4 294 967 295		Required		
Perceived Transmit Time	4 294 967 295 and 4 294 967 295				Required

4.1.3 Communication Between JUs with Different Fidelity Levels

In the event that participants in a simulated Link 16 network cannot set their respective simulations to operate at a common TSA Level, the following procedures shall apply:

1. If a TSA Level 0 or 1 network participant attempts net entry into a simulated Link 16 network with a higher-fidelity NTR, the network participant shall follow the low-fidelity synchronization procedures in paragraph 4.1.4.2 by skipping the RTT synchronization process and may proceed to Fine Synchronization state once it receives a J0.0 Initial Entry message from the NTR or any IEJU. A TSA Level 0 or 1 participant should not proceed past Coarse Synchronization while its simulated terminal is in a non-transmitting (i.e., Silent) state.

2. If a higher-fidelity network participant is in a simulated Link 16 network with a lower-fidelity NTR, the higher-fidelity participant shall either follow the low-fidelity synchronization procedures in paragraph 4.1.4.2 or achieve fine sync with other high-fidelity simulators. This may be accomplished by exchanging RTT B messages or by passively synchronizing with other available high-fidelity simulators. If no other high-fidelity simulators are available to synchronize with, the high-fidelity participant shall skip the RTT exchange, and directly enter Fine Synchronization once the J0.0 message is received. If the participant's simulated terminal is in a non-transmit (i.e., Silent) state, it may not proceed past Coarse Synchronization until placed in a transmitting state.

3. If the NTR is a lower-fidelity simulation and unable to simulate full NTR duties, the NTR shall still have the ability to transmit net entry messages. If a low-fidelity simulation models time slots, then it may provide time slot information in the J0.0 message continuation word, otherwise it shall set the time slot information to zero. RTT emulation is not required of low-fidelity NTRs.

4. A lower-fidelity JU entering the net shall use the Network Synchronization ID received from the NTR/IEJU in its transmitter messages. It shall then issue Precise Participant Location and Identifications (PPLIs) at the assigned rate. This is nominally once every 12 seconds (equivalent to the A-0-6 time slot block). All simulators, regardless of fidelity, shall accept another terminal's statement of synchronization capability if the Network Synchronization ID matches its own Network Synchronization ID, or if either Network Synchronization ID is zero (i.e., wildcard).

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5. In a low-fidelity synchronization simulation, non-reception of a PPLI message pair (two PPLI messages from the same JU) for 60 seconds shall indicate that the unit has fallen out of the data link. Synchronization procedures shall be re-accomplished; i.e., reception of a PPLI message stating Fine Synchronization must occur before data from the JU will be accepted.

4.1.4 Time Synchronization

Modeling of Link 16 time synchronization under this standard can be implemented at one of three levels of fidelity, None, Low, or Medium as described in subsequent sections.

4.1.4.1 No Time Synchronization

When operating at TSA Levels 0 or 1, no NTR or time synchronization of any kind is required and the Synchronization State shall be set to Fine Synchronization (3).

4.1.4.2 Low-Fidelity Time Synchronization

1. Low-fidelity time synchronization is applicable to simulation systems interested primarily in providing tactical data link information as part of an operational scenario. The low-fidelity synchronization procedure allows such systems to exchange Link 16 messages without being encumbered by the actual exchange of RTT messages and the associated network latency.
2. When operating under low-fidelity time synchronization, systems may optionally set Synchronization State directly to Fine Synchronization (3) without starting at Coarse Synchronization (2).
3. The NTR shall begin by issuing net entry message pairs at a rate in accordance with the Link 16 terminal specification (typically in time slot A-0-6 at a rate of every 12 seconds). For TSA Levels 0-2, the Network Synchronization ID may be set to zero (wildcard), or to a unique non-zero value if low-fidelity participation in a distinct simulated network is desired. For TSA Level 3, a unique key shall populate the Network Synchronization ID field. The Transmitting Terminal Primary Mode field shall contain an NTR enumeration IAW Reference 3 [UID 173].
4. For TSA Level 3, if the simulated terminal is in a transmit-capable state, modulation Parameter 4 (Synchronization State) in the transmission message shall be allowed to progress to Fine Synchronization after reception of an acceptable J0.0 Initial Entry message from the IEJU or NTR. If the simulated terminal is currently in a non-transmitting (silent) state, it may only progress to the Coarse Synchronization state until it is placed into a transmitting state. Once reaching either the Coarse or Fine Synchronization state, the simulated terminal shall update its own Network Synchronization ID to match that of the accepted NTR and update its own terminal time statement to match that conveyed in the accepted NTR's J0.0 message.

4.1.4.3 Medium-Fidelity Time Synchronization

1. Medium-Fidelity Synchronization corresponds to only the high-fidelity TSA Level 4. It is applicable to those systems for which simulation of the fine synchronization methodology is paramount, potentially for high-fidelity training, network testing, and network experimentation. Because the latency of WANs (latencies up to hundreds of milliseconds) is orders of magnitude higher than in a real Link 16 network (latencies up to 3ms), this methodology will not meet the needs of sub-millisecond accuracy. Communities with the need for sub-millisecond accuracy will need to use a centralized server on a real-time operating system to simulate the microsecond intricacies of the Link 16 network. The term "High-Fidelity Synchronization" will be reserved for synchronization mechanisms that are able to model the sub-millisecond accuracy of the Link 16 network.
2. The accuracy of the synchronization mechanism shall have an error less than the simulated time of propagation. The accuracy of the synchronization mechanism shall be taken into account when modeling fine synchronization.

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3. The Medium-Fidelity Synchronization procedure is as follows:

   A. The NTR shall begin by issuing net entry message pairs at a rate in accordance with the Link 16 terminal specification (typically in time slot A-0-6 at a rate of every 12 seconds). The synchronization state shall be set to Initial Net Entry (1).

   B. The NTR shall populate the Network Synchronization ID field with a unique randomly generated key. The Transmitting Terminal Primary Mode field shall contain an NTR enumeration IAW Reference 3 [UID 173]. At this point, the JU is considered to have achieved Coarse Synchronization.

   C. Before the synchronization process starts, the JU shall set the Synchronization state to Initial Net Entry (1). The JU shall then transmit the appropriate RTT message (A or B). After RTT message transmission, the Synchronization State shall be set to Coarse Synchronization. The JU shall use its own terminal perceived time in the Perceived Transmit Time field.

   D. The appropriate NTR/JU shall answer (in accordance with the Link 16 terminal specification), using the JU perceived time and the entity distance to calculate the perceived receive time. The RTT is then transmitted.

   E. The transmitting JU shall fill its own terminal perceived time with the received transmit time field. The formula for filling in the receive time in the RTT reply is:

      $$RTT_{reply} = RT_{terminal} - t_{delay} + t_{propagate}$$

      The t_{delay} is computed by: $t_{delay} = RT_{time} - TT_{time}$

      Where

      RT_{time} is the actual time held by the receiving/replying participant (Derived from NTP, GPS, etc)

      $RT_{terminal}$ is the value of the simulated Link 16 terminal clock at the receiving/replying participant.

      TT_{time} is the actual time held of transmitting participant (Derived from NTP, GPS, etc).

      t_{delay} is the difference between the receiver's real-time clock at the time of receipt and the sender's real-time clock at the time of transmission (i.e., it approximates the emulation network latency), and

      $t_{propagate}$ is the propagation time of the radio frequency message in the simulated environment.

      This formula computes the perceived time of receipt by the receiving simulator with respect to the simulated terminal clock of the sender.

4. The originating JU shall then update its own terminal time in accordance with the simulator model and the Link 16 fine synchronization procedures.

5. After the appropriate number of RTT exchanges have occurred (depending whether the RTT A or RTT B method of synchronization was used and the internal Link 16 terminal simulation model), the JU shall consider itself to be in fine synchronization and shall continually issue RTT message pairs to maintain synchronization at rates specified within the Link 16 terminal specification. Once the terminal emulator model has met the requirements for fine synchronization, normal message transmissions shall occur in accordance with References 7 and 8.

4.1.4.4 General Time Synchronization Provisions

General time synchronization provisions are described below.

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1. For TSA Level 0, If no simulators in a simulated Link 16 net are capable of acting as a NTR, participants shall be able to set the Network Synchronization ID to zero and transmit the Synchronization State of Fine Synchronization. A zero in the Network Synchronization ID field indicates it is not being used and will match any Network Synchronization ID.
2. For TSA Levels 1-2, the Network Synchronization ID may be set to zero to indicate it is not being used if universal message exchange is desired across any simulated Link 16 net in the exercise. If participation on a specific simulated Link 16 net is desired, the Network Synchronization ID may be preset to a non-zero value corresponding to that of an intended NTR and/or a set of intended participants intended to share the simulated net. For TSA Levels 3-4, the Network Synchronization IDs shall be a non-zero, 32-bit unsigned integer uniquely generated by the NTR. Use of a preset Net Synchronization ID can allow low-fidelity participants to forego net entry procedures and be initialized as already established in a simulated network.
3. If a system in the real world is NTR capable, any corresponding simulator shall also be capable, at a minimum, of acting as a low-fidelity NTR.
4. If a non-zero Network Synchronization ID accompanying received data does not match a JU's own non-zero Network Synchronization ID, the data shall be considered as having not been received.
5. Simulated terminals shall accept net entry messages (J0.0) from any simulated transmitting terminal. Simulations may also accept J0.0 messages only during net entry attempts, and may reject J0.0 messages from a candidate NTR/IEJU if its time statement is not within compatible tolerance of the recipient's own terminal time.
6. When medium-fidelity synchronization is applicable (TSA Level 4), and the net entry message has a Network Synchronization ID different than the local Network Synchronization ID, the JU shall revert back to Coarse Synchronization, use the new Network Synchronization ID, cease sending Link 16 data, and attempt re-synchronization with the new network in accordance with the Link 16 terminal specification. If the new Network Synchronization ID is the same as the locally held key (e.g., during changeover of NTR or multiple IEJUs), the JU shall not revert to Coarse Synchronization status and shall not stop transmitting Link 16 data.
7. If an initial net entry message is received from a unit that does not have a Transmitting Terminal Primary Mode of IEJU or NTR, it shall still be accepted. Depending upon implementation, the simulation operator may be notified so that the sending simulator can correct this error condition.
8. All simulators shall have at least a low-fidelity simulation of a terminal clock, possibly independent of the simulator's (or live equipment's) clock. Since whatever time an NTR has set is considered correct, an NTR may transmit a time that significantly varies from the actual simulated wall clock. In high-fidelity simulation systems, the terminal clock may model the clock drift of an actual Link 16 terminal. It is not expected that terminal clocks will be modeled at a high level of fidelity and the actual level of emulation is left to the implementer.
9. When transmitting data link messages, Modulation Parameter 4 (Synchronization State) in the transmission message shall always be set to Fine Synchronization (3).

4.2 Link 16 Implementation Using DIS

This section contains the requirements for simulation of Link 16 using the DIS Transmitter and Signal PDUs. For the DIS Application Protocols, issuance and receipt of PDUs, and general service requirements, refer to Reference 4.

4.2.1 Transmitter PDU

Table 5 shows the format and values of the Transmitter PDU for Link 16 simulation.

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Transmitter PDUs used in Link 16 simulation shall comply with requirements established in References 4 and 3, and the following requirements:

1. *Radio Type Category*. This field shall be set to 21 for Link 16 Terminal IAW Reference 3 [UID 22]. Radio Type Category value Link 16 Surrogate for Non-NATO TDL Terminal (33) may also be used when simulating a non-NATO tactical data link (see section 4.2.1 item 10.E).
2. *Transmit State*. This field shall specify the transmit state of the Link 16 radio IAW Reference 3 [UID 164]. Once the Link 16 radio has joined a network, the Transmit State is set to On and Transmitting (2) and should remain in that mode indefinitely, i.e., until the radio is turned Off (0) or otherwise leaves the network. If Transmitter PDU bracketing is used, then the Transmit State is toggled between On and Transmitting (2) and On but Not Transmitting (1).
3. *Input Source*. This field shall be set to 8 for Digital Data Device IAW Reference 3 [UID 165].
4. *Frequency*. This field shall specify the JTIDS center frequency of 1 131 000 000 Hz for communications mode 1. For communications mode 2 or 4, a frequency of 969 000 000 Hz shall be used.
5. *Transmit Frequency Bandwidth*. This field shall contain the bandwidth of the JTIDS signal, simulating the use of the entire frequency band as an average over time. The field shall be represented by a 32-bit float value of 240 000 000 Hz, unless operating in communications mode 2 or 4, and then a value of 3 000 000 Hz shall be used.
6. *Modulation Type*. This field shall contain enumerations for the major and detail modulation fields:
   A. The Spread Spectrum field is a 16-bit record and shall be set to 1 for frequency hopping only for JTIDS communications mode 1. For modes 2 or 4, the Spread Spectrum field shall be set to 0.
   B. The Major Modulation field is a 16-bit enumeration and shall be set to 7 for Carrier Phase Shift Modulation (CPSM) IAW Reference 3 [UID 155].
   C. The Detail modulation field is a 16-bit enumeration and shall contain a 0 for Other IAW Reference 3 [UID 162].
   D. The Radio System field is a 16-bit enumeration and shall be set to 8 for JTIDS/MIDS IAW Reference 3 [UID 163].
7. *Crypto System*. This field shall be set to 0 for No Encryption Device IAW Reference 3 [UID 166].
8. *Crypto Key ID*. This field shall be set to zero.
9. *Length of Modulation Parameters*. This field shall specify the length in octets of the Modulation Parameters. This field shall be set to 8.
10. *Modulation Parameters*. These fields shall specify the modulation type-specific characteristics of the Link 16 portion of the Transmitter PDU, and are highlighted in yellow in Table 5.
    A. *Modulation Parameter 1*. This field shall contain the TSA Level with an enumeration of 0-4 for TSA Level 0-4 as described in section 4.1.2 and Reference 3 [UID 172].
    B. *Modulation Parameter 2*. This field shall contain the transmitting terminal's primary mode IAW Reference 3 [UID 173]. Setting the enumeration to 1 shall indicate that the entity is the NTR. Setting it to 2 shall indicate that the entity is a JU participant.
    C. *Modulation Parameter 3*. This field shall contain the transmitting terminal's secondary mode, with the following enumerations: 0=None, 1=Net Position Reference, 2=Primary Navigation Controller, 3=Secondary Navigation Controller IAW Reference 3 [UID 174].

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D. *Modulation Parameter 4*. This field shall contain the synchronization state IAW Reference 3 [UID 175]. See section 4.1.4 for time synchronization details.

E. *Modulation Parameter 5*. This field shall contain the Network Synchronization ID which is a simulation-only construct that may be used to support multiple independent (individually synchronized) Link 16 networks in an exercise. When implemented, these are completely independent networks, unlike network partitions or subnets (e.g., fighter channels) that are created by use of NPG Number or Net Number. Non-zero Network Synchronization ID numbers are used to identify and separate the messages for multiple independent Link 16 networks. Link 16 simulations shall only accept and process messages when the received Network Synchronization ID matches its own configured Network Synchronization ID, or if either is zero. A zero in this field is accepted as a wildcard matching any Network Synchronization ID, and a Link 16 terminal model configured with a Network Synchronization ID of zero shall process all Link 16 messages regardless of Network Synchronization ID values received.

For TSA Level 0-2, Network Synchronization ID may be set to zero (i.e., wildcard), or to a unique pre-defined non-zero value if low-fidelity participation in a specific simulated network is desired. For TSA Level 3-4, Network Synchronization ID shall be set to a non-zero 32-bit random integer which only an NTR can generate. All other participants shall use the ID obtained from the NTR to which they are synchronized.

It should be noted that non-NATO tactical data links can also be simulated, based on this standard, by using the TDL Type [UID 178] value of Link 16 Surrogate for Non-NATO TDL (113) and the Radio Kind Category [UID 22] value of Link 16 Surrogate for Non-NATO TDL Terminal (33). Leveraging the Link 16 simulation standard in this manner can be an effective means of implementing a non-NATO tactical data link simulation capability.

Table 5: Transmitter PDU for Link 16

Field Size (bits)	Transmitter PDU Fields			Value
96	PDU Header	Protocol Version	8-bit enumeration	
		Exercise ID	8-bit unsigned integer	
		PDU Type	8-bit enumeration	
		Protocol Family	8-bit enumeration	
		Timestamp	32-bit unsigned integer	
		Length	16-bit unsigned integer	
		PDU Status	8-bit record	
		Padding	8 bits unused	
48	Radio Reference ID	Site Number	16-bit unsigned integer	
		Application Number	16-bit unsigned integer	
		Reference Number	16-bit unsigned integer	

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Field Size (bits)	Transmitter PDU Fields			Value
16	Radio Number		16-bit unsigned integer	
64	Radio Type	Entity Kind	8-bit enumeration	
		Domain	8-bit enumeration	
		Country	16-bit enumeration	
		Category	8-bit enumeration	21 (Link 16 Terminal) 33 (Link 16 Surrogate for Non-NATO TDL Terminal)
		Subcategory	8-bit enumeration	
		Specific	8-bit enumeration	
		Extra	8-bit enumeration	
8	Transmit State		8-bit enumeration	
8	Input Source		8-bit enumeration	8 (Digital Data Device)
16	Number of Variable Transmitter Parameters Records (*N*)		16-bit unsigned integer	
192	Antenna Location	X component	64-bit floating point	
		Y component	64-bit floating point	
		Z component	64-bit floating point	
96	Relative Antenna Location	x component	32-bit floating point	
		y component	32-bit floating point	
		z component	32-bit floating point	
16	Antenna Pattern Type		16-bit enumeration	
16	Antenna Pattern Length (*A*)		16-bit unsigned integer	
64	Frequency		64-bit unsigned integer	1 131 000 000 (for Communication Mode 1) 969 000 000 (for Communication Mode 2 or 4)
32	Transmit Frequency Bandwidth		32-bit floating point	240 000 000 (for Communication Mode 1) 3 000 000 (for Communication Mode 2 or 4)
32	Power		32-bit floating point	

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Field Size (bits)	Transmitter PDU Fields			Value
64	Modulation Type	Spread Spectrum	16-bit record	1 (for Communication Mode 1) 0 (for Communication Mode 2 or 4)
		Major Modulation	16-bit enumeration	7 (Carrier Phase Shift Modulation (CPSM))
		Detail	16-bit enumeration	0 (Other)
		Radio System	16-bit enumeration	8 (JTIDS/MIDS)
16	Crypto System		16-bit enumeration	0 (Other)
16	Crypto Key ID		16-bit unsigned integer	0
8	Length of Modulation Parameters (*M*)		8-bit unsigned integer	8 (8 octets)
8	Padding		8 bits unused	
16	Padding		16 bits unused	
8	Modulation Parameter #1	Time Slot Allocation Level	8-bit enumeration	See [UID 172]
8	Modulation Parameter #2	Transmitting Terminal Primary Mode	8-bit enumeration	See [UID 173]
8	Modulation Parameter #3	Transmitting Terminal Secondary Mode	8-bit enumeration	See [UID 174]
8	Modulation Parameter #4	Synchronization State	8-bit enumeration	See [UID 175]
32	Modulation Parameter #5	Network Synchronization ID	32-bit unsigned integer	TSA Levels 0-2, may be set to 0 (wildcard) or the unique 32-bit value of a simulated net. TSA Level 3,4, set to the unique 32-bit value of a simulated net
8*A*	Antenna Pattern			
As Required	Variable Transmitter Parameters record #1 ... #*N*			

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Field Size (bits)	Transmitter PDU Fields	Value
Total Link 16 Transmitter PDU size = 896 + 8*A* + 8 Σ *Ki* bits, for *i* = 1 to *N* where *A* is the length of the Antenna Pattern record in octets, which must be a multiple of 8 *N* is the number of Variable Transmitter Parameters records *Ki* is the total length of the Variable Transmitter Parameters record *i* in octets, including padding required in the Variable Transmitter Parameters record to make its length a multiple of 8 octets		

4.2.2 Signal PDU

Table 7 shows the format and values of the Signal PDU for Link 16 simulation.

Signal PDUs used in Link 16 simulation shall comply with requirements established in References 4 and 3 and the following requirements:

1. *Encoding Scheme*. Bits 0-13 of this field shall contain the number of Link 16 words for JTIDS Header/Message, JTIDS LET, and JTIDS VMF message types, or shall contain the value 1 for RTT and JTIDS Voice message types. Bits 14-15 shall contain the value 1 to indicate an Encoding Class of Raw Binary Data IAW Reference 3 [UID 270].
2. *TDL Type*. This field shall specify the TDL type as a 16-bit enumeration field, and shall be set to 100 for Link 16 Standardized Format (JTIDS/MIDS/TADIL J) IAW Reference 3 [UID 178]. TDL Type value Link 16 Surrogate for Non-NATO TDL (113) may also be used when simulating a non-NATO tactical data link.
3. *Sample Rate*. The sample rate shall be set to 0.
4. *Data Length*. This field shall contain the number of bits in the Data field. The Data field may end on a non-byte boundary, i.e., the length is not required to be a multiple of 8. Padding that follows the Data field to end the PDU on a 32-bit boundary shall not be included in the Data Length. Padding bits at the end of Link 16 Message Data as specified in Table 9 through Table 16 are considered part of the Data field and shall be included in Data Length. The Data Length field shall be represented by a 16-bit unsigned integer.
5. *Samples*. This field shall be set to 0.
6. *Data*. For Link 16, the Data field shall consist of two parts, a Link 16 Simulation Network Header portion and a Link 16 Message Data portion as shown in Table 7 and described below.

   A. *Link 16 Simulation Network Header*. The Link 16 Simulation Network Header portion of the Signal PDU Data field shall be 160 bits long and shall use the same byte order as the Signal PDU. These fields are shown in Table 8, and shall be set as follows:

      i. *NPG Number*. This field is a 16-bit unsigned integer (0-511) used to segregate information within a JTIDS/MIDS network. It creates virtual networks of participants.

      ii. *Net Number*. This field is an 8-bit unsigned integer (0-127) used to create virtual sub-circuits within NPG for stacked nets or between NPGs for multi-net operations.

      iii. *TSEC CVLL*. This field is an 8-bit unsigned integer that is used for transmission security and allows for simulated crypto netting. For TSA Levels 0-2 this field shall be set to 255 (all bits set to one) indicating a no statement/wildcard.

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iv. *MSEC CVLL*. This field is an 8-bit unsigned integer that is used for message security in conjunction with the TSEC CVLL and allows for simulated crypto netting. For TSA Levels 0-2 this field shall be set to 255 (all bits set to one) indicating a no statement/wildcard.

v. *Message Type Identifier*. This field shall specify the format for the type of Link 16 message in the PDU. This field shall be set with an enumeration in accordance with Table 6 and Reference 3 [UID 176]. The message type formats are described in detail in Table 9 through Table 16.

Table 6: Message Type Identifier

Message Type Identifier	Enumeration
JTIDS Header/Messages	0
RTT A/B	1
RTT Reply	2
JTIDS Voice CVSD	3
JTIDS Voice LPC10	4
JTIDS Voice LPC12	5
JTIDS LET	6
VMF	7

vi. *SISO-STD-002 Version*. This field shall be set IAW Reference 3 [UID 736] and indicates which SISO-STD-002 version was used, i.e., whether byte swapping has or has not been used in the Link 16 Message Data field (0 = SISO-STD-002-2006, legacy byte swapping employed; 1 = SISO-STD-002-2021, new method, bit stream, no byte swapping employed).

vii. *Link 16 Version*. This field shall be set IAW Reference 3 [UID 800] and indicates which version of Reference 7 or Reference 8 is being used.

viii. *Time Slot ID*. This field is a 32-bit unsigned integer, and shall contain time slot information for time slot and epoch number in accordance with Reference 7 and Reference 8. Time Slot Number is bits 0 – 16. Time Slot 0 represents time slot A-1, Time Slot 98 303 represents C-32 767. When the Epoch is 112, the last valid Time Slot is 45 151. Bits 17 – 23 are padding. Bits 24 – 31 are the Epoch number. An epoch is 12.8 minutes long, and there are 112.5 epochs in a 24-hour day. For TSA Level 0-1, this field shall be set to 4 294 967 295 (all bits set to one including the padding field) to indicate a no statement/wildcard.

ix. *Perceived Transmit Time*. The Perceived Transmit Time (in NTP timestamp format) shall indicate the time the Link 16 message was sent, in seconds relative to 0 hours on 1 January 1900 Coordinated Universal Time (UTC). It includes a 32-bit unsigned seconds field spanning 136 years and a 32-bit fraction field resolving 232 picoseconds. See Reference 11 for detailed format. Both fields shall be set to 4 294 967 295 (all bits set to one) to indicate a no statement/wildcard.

B. *Link 16 Message Data*. The Link 16 Message Data portion of the Data field is a bit stream that shall contain the Link 16 message data corresponding to the message type specified in the Message Type Identifier field. Link 16 message data bit orientation shall be accomplished in accordance with paragraph 4.1.1 item 20. Table 17 shows an example of bit ordering for the Link 16 Fixed Format Message, Message Type Identifier 0 (Table 9). Link 16 message types illustrated in Table 10 through Table 16 have a similar structure.

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Table 7: Signal PDU for Link 16

Field Size (bits)	Signal PDU Fields			Value
96	PDU Header	Protocol Version	8-bit enumeration	
		Exercise ID	8-bit unsigned integer	
		PDU Type	8-bit enumeration	
		Protocol Family	8-bit enumeration	
		Timestamp	32-bit unsigned integer	
		Length	16-bit unsigned integer	
		PDU Status	8-bit record	
		Padding	8 bits unused	
48	Radio Reference ID	Site Number	16-bit unsigned integer	
		Application Number	16-bit unsigned integer	
		Reference Number	16-bit unsigned integer	
16	Radio Number		16-bit unsigned integer	
16	Encoding Scheme		16-bit record	Bits 0-13 shall contain the number of Link 16 words for JTIDS Header/Message, JTIDS LET, and JTIDS VMF message types, or shall contain the value 1 for RTT and JTIDS Voice message types. Bits 14-15 shall contain the value 1 to indicate an Encoding Class of Raw Binary Data.
16	TDL Type		16-bit enumeration	100 (Link 16 Standardized Format) 113 (Link 16 Surrogate for Non-NATO TDL)
32	Sample Rate		32-bit unsigned integer	Audio sample rate in samples per second, otherwise set to 0.
16	Data Length (*K*)		16-bit unsigned integer	
16	Samples		16-bit unsigned integer	0
Start of Data field				
160	Link 16 Simulation Network Header			See Table 8.

Field Size (bits)	Signal PDU Fields		Value
K-160	Link 16 Message Data	Bit stream	The Link 16 message data, corresponding to the message type specified in the Message Type Identifier field and described in Table 9 through Table 16.
End of Data field			
P	Padding	Padding to 32-bit boundary	

Total Link 16 Signal PDU size = 256 + *K* + *P* bits

where

K is the length of the Data field in bits

P is the number of padding bits, which is $\lceil K/32 \rceil 32 - K$

$\lceil x \rceil$ is the largest integer < x+1

Note:

P = 16 for Message Type Identifiers 1 and 2

P = 16 for Message Type Identifiers 0, 6, and 7 if the number of J Words is even

P = 0 for Message Type Identifiers 0, 6, and 7 if the number of J Words is odd

For Message Type Identifiers 3, 4, and 5, *P* will vary between 0 and 31 depending on the length of the JTIDS Free Text Voice Data

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Table 8: Link 16 Simulation Network Header

<table>
<tr><th>Field Size (bits)</th><th colspan="4">Field Name and Data Type</th><th>Valid Range</th><th>Value</th></tr>
<tr><td rowspan="12">160</td><td rowspan="12">Link 16 Simulation Network Header</td><td colspan="2">NPG Number</td><td>16-bit unsigned integer</td><td>0-511</td><td></td></tr>
<tr><td colspan="2">Net Number</td><td>8-bit unsigned integer</td><td>0-127</td><td></td></tr>
<tr><td colspan="2">TSEC CVLL</td><td>8-bit unsigned integer</td><td>0-127 [255 no statement/ wildcard]</td><td></td></tr>
<tr><td colspan="2">MSEC CVLL</td><td>8-bit unsigned integer</td><td>0-127 [255 no statement/ wildcard]</td><td></td></tr>
<tr><td colspan="2">Message Type Identifier</td><td>8-bit enumeration</td><td></td><td>[UID 176]</td></tr>
<tr><td colspan="2">SISO-STD-002 Version</td><td>8-bit enumeration</td><td>0-1</td><td>[UID 736]</td></tr>
<tr><td colspan="2">Link 16 Version</td><td>8-bit enumeration</td><td>0-255</td><td>[UID 800]</td></tr>
<tr><td rowspan="3">Time Slot ID</td><td>Time Slot Number</td><td>Bits 0-16</td><td>0-98 303 [131 071 no statement/ wildcard]</td><td></td></tr>
<tr><td>Padding</td><td>Bits 17-23</td><td>0 [127 if no statement/ wildcard]</td><td></td></tr>
<tr><td>Epoch Number</td><td>Bits 24-31</td><td>0-112 [255 no statement/ wildcard]</td><td></td></tr>
<tr><td rowspan="2">Perceived Transmit Time</td><td>Integer Part</td><td>32-bit unsigned integer</td><td>0-4 294 967 295 [2]</td><td rowspan="2"></td></tr>
<tr><td>Fraction Part</td><td>32-bit unsigned integer</td><td>0-4 294 967 295 [2]</td></tr>
</table>

The following tables describe in detail the Signal PDU Message Data for each message format indicated in the Message Type Identifier field in Table 8 above.

[2] All bits for both fields set to one, i.e., both field values being 4 294 967 295, indicates no statement/ wildcard.

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Table 9: Message Type Identifier = 0, JTIDS Header/Messages

Field Size (bits)	Link 16 Message Fields		Bits	Description
48	Link 16 Header Word	Time Slot Type	Bits 0-2	[7, 8]
		Relay Transmission Indicator	Bit 3	[7, 8]
		Source Track Number of Sender	Bits 4-18	[7, 8]
		Secure Data Unit Serial Number	Bits 19-34	[7, 8]
	Padding		Bits 35-47	
80	Message 1/ Word 1	FWF Message Data	70 Bits	[7, 8]
		Parity	5 Bits	[7, 8]
	Padding		5 Bits	
	⋮			
80	Message 1/ Word W	FWF Message Data	70 Bits	[7, 8]. W is the number of J Words in a given J Message.
		Parity	5 Bits	[7, 8]
	Padding		5 Bits	
	⋮			
80	Message M/ Word 1	FWF Message Data	70 Bits	[7, 8]. M is the number of J Messages in the Signal PDU.
		Parity	5 Bits	[7, 8]
	Padding		5 Bits	
	⋮			
80	Message M/ Word W	FWF Message Data	70 Bits	[7, 8]
		Parity	5 Bits	[7, 8]
	Padding		5 Bits	

Table 10: Message Type Identifier = 1, RTT A/B

Field Size (bits)	Link 16 Message Fields		Bits	Description
48	RTT A/B	RTT A/B	Bits 0-34	[7, 8]
	Padding		Bits 35-47	

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Table 11: Message Type Identifier = 2, RTT Reply

Field Size (bits)	Link 16 Message Fields		Bits	Description
48	RTT Reply	RTT Reply	Bits 0-34	[7, 8]
	Padding		Bits 35-47	

Table 12: Message Type Identifier = 3, JTIDS Voice CVSD

Field Size (bits)	Link 16 Message Fields		Bits	Description
48	Link 16 Header Word	Time Slot Type	Bits 0-2	[7, 8]
		Relay Transmission Indicator	Bit 3	[7, 8]
		Source Track Number of Sender	Bits 4-18	[7, 8]
		Secure Data Unit Serial Number	Bits 19-34	[7, 8]
	Padding		Bits 35-47	
225-1860	JTIDS Free Text Voice Data	CVSD Encoded Voice Data	225-1860 bits	[7, 8]. Size of data area is dependent upon Time Slot Type and Type Modification.

Table 13: Message Type Identifier = 4, JTIDS Voice LPC10

Field Size (bits)	Link 16 Message Fields		Bits	Description
48	Link 16 Header Word	Time Slot Type	Bits 0-2	[7, 8]
		Relay Transmission Indicator	Bit 3	[7, 8]
		Source Track Number of Sender	Bits 4-18	[7, 8]
		Secure Data Unit Serial Number	Bits 19-34	[7, 8]
	Padding		Bits 35-47	
225-1860	JTIDS Free Text Voice Data	LPC10 Encoded Voice Data	225-1860 bits	[7, 8]. Size of data area is dependent upon Time Slot Type and Type Modification.

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Table 14: Message Type Identifier = 5, JTIDS Voice LPC12

Field Size (bits)	Link 16 Message Fields		Bits	Description
48	Link 16 Header Word	Time Slot Type	Bits 0-2	[7, 8]
		Relay Transmission Indicator	Bit 3	[7, 8]
		Source Track Number of Sender	Bits 4-18	[7, 8]
		Secure Data Unit Serial Number	Bits 19-34	[7, 8]
	Padding		Bits 35-47	
225-1860	JTIDS Free Text Voice Data	LPC12 Encoded Voice Data	225-1860 bits	[7, 8]. Size of data area is dependent upon Time Slot Type and Type Modification.

Table 15: Message Type Identifier = 6, JTIDS LET

Field Size (bits)	Link 16 Message Fields		Bits	Description
48	LET Header Word	LET ID Symbol	Bits 0-3	[12]
		Relay Transmission Indicator	Bit 4	[12]
		LET Message Packing Type	Bits 5-8	[12]
		Source Track Number of Sender	Bits 9-23	[12]
		Secure Data Unit Serial Number	Bits 24-39	[12]
	Padding		Bits 40-47	
80	Word 1	FWF Message Data	70 Bits	[7, 8]
		Parity	5 Bits	[7, 8]
	Padding		5 Bits	
	⋮			
80	Word W	FWF Message Data	70 Bits	[7, 8]. W is the number of J Words in the Signal PDU.
		Parity	5 Bits	[7, 8]
	Padding		5 Bits	

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Table 16: Message Type Identifier = 7, VMF

Field Size (bits)	Link 16 Message Fields		Bits	Description
48	Link 16 Header Word	Time Slot Type	Bits 0-2	[7, 8]
		Relay Transmission Indicator	Bit 3	[7, 8]
		Source Track Number of Sender	Bits 4-18	[7, 8]
		Secure Data Unit Serial Number	Bits 19-34	[7, 8]
	Padding		Bits 35-47	
80	Word 1	Word Format	2 Bits	[7, 8]
		VMF Message Data	68 Bits	
		Parity	5 Bits	[7, 8]
	Padding		5 Bits	
	⋮			
80	Word W	Word Format	2 Bits	[7, 8]. W is the number of J Words in the Signal PDU.
		VMF Message Data	68 Bits	
		Parity	5 Bits	[7, 8]
	Padding		5 bits	

Table 17 below depicts the Signal PDU Data field, showing the Link 16 Simulation Network Header in yellow (for DIS versions that use big endian octet ordering) followed by a Link 16 Fixed Format Message (Message Type Identifier 0). Note that the displayed octet ordering switches after octet 19 due to the change from octet-oriented data to bit stream data.

Table 17: Signal PDU Data field with Link 16 Simulation Network Header and Fixed Format Message

Octet 0								Octet 1							
15															0
NPG Number															

Octet 2							
7							0
Net Number							

Octet 3							
7							0
TSEC CVLL							

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<table>
<tr><td colspan="8">Octet 4</td></tr>
<tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="8">MSEC CVLL</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 5</td></tr>
<tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="8">Message Type Identifier</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 6</td></tr>
<tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="8">SISO-STD-002 Version</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 7</td></tr>
<tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="8">Link 16 Version</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 8</td><td colspan="8">Octet 9</td><td colspan="8">Octet 10</td><td colspan="8">Octet 11</td></tr>
<tr><td>31</td><td></td><td></td><td></td><td></td><td></td><td></td><td>24</td><td>23</td><td></td><td></td><td></td><td></td><td></td><td>17</td><td>16</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="32">Time Slot ID</td></tr>
<tr><td colspan="8">Epoch Number</td><td colspan="7">Padding</td><td colspan="17">Time Slot Number</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 12</td><td colspan="8">Octet 13</td><td colspan="8">Octet 14</td><td colspan="8">Octet 15</td></tr>
<tr><td>31</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="32">Perceived Transmit Time – Integer Part</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 16</td><td colspan="8">Octet 17</td><td colspan="8">Octet 18</td><td colspan="8">Octet 19</td></tr>
<tr><td>31</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="32">Perceived Transmit Time – Fraction Part</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 23</td><td colspan="8">Octet 22</td><td colspan="8">Octet 21</td><td colspan="8">Octet 20</td></tr>
<tr><td>31</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>19</td><td>18</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>4</td><td>3</td><td>2</td><td></td><td>0</td></tr>
<tr><td colspan="13">Secure Data Unit Serial Number (SDUSN) Start</td><td colspan="15">Source Track Number of Sender
(5 octal values of 3 bits each)</td><td>R
T
I</td><td colspan="3">Time Slot Type</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 27</td><td colspan="8">Octet 26</td><td colspan="8">Octet 25</td><td colspan="8">Octet 24</td></tr>
<tr><td>63</td><td></td><td>61</td><td>60</td><td></td><td>58</td><td>57</td><td></td><td>55</td><td>54</td><td></td><td></td><td></td><td>50</td><td>48</td><td>48</td><td>47</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>35</td><td>34</td><td></td><td>32</td></tr>
<tr><td colspan="3"></td><td colspan="3">Msg Length Indicator</td><td colspan="3">J Msg Sub-label</td><td colspan="5">J Message Label</td><td colspan="2">J Word Format</td><td colspan="13">Padding</td><td colspan="3">SDUSN End</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 31</td><td colspan="8">Octet 30</td><td colspan="8">Octet 29</td><td colspan="8">Octet 28</td></tr>
<tr><td>95</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>64</td></tr>
<tr><td colspan="32">First J-Word Continued</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 35</td><td colspan="8">Octet 34</td><td colspan="8">Octet 33</td><td colspan="8">Octet 32</td></tr>
<tr><td>127</td><td></td><td></td><td></td><td>123</td><td>122</td><td></td><td></td><td></td><td>118</td><td>117</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>96</td></tr>
<tr><td colspan="5">Padding</td><td colspan="5">Parity</td><td colspan="22">First J-Word Continued</td></tr>
</table>

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<table>
<tr><td colspan="8">Octet 39</td><td colspan="8">Octet 38</td><td colspan="8">Octet 37</td><td colspan="8">Octet 36</td></tr>
<tr><td>159</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>130</td><td>129</td><td>128</td></tr>
<tr><td colspan="30">Second J-Word</td><td colspan="2">J-Word Format</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 43</td><td colspan="8">Octet 42</td><td colspan="8">Octet 41</td><td colspan="8">Octet 40</td></tr>
<tr><td>191</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>160</td></tr>
<tr><td colspan="32">Second J-Word Continued</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 47</td><td colspan="8">Octet 46</td><td colspan="8">Octet 45</td><td colspan="8">Octet 44</td></tr>
<tr><td>223</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>210</td><td>209</td><td>208</td><td>207</td><td></td><td></td><td></td><td>203</td><td>202</td><td></td><td></td><td></td><td>198</td><td>197</td><td></td><td></td><td></td><td></td><td>192</td></tr>
<tr><td colspan="14">Third J-Word (bits 15--2)</td><td colspan="2">J Word Format</td><td colspan="5">Padding</td><td colspan="5">Parity</td><td colspan="6">Second J-Word Continued (bits 69-64)</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 51</td><td colspan="8">Octet 50</td><td colspan="8">Octet 49</td><td colspan="8">Octet 48</td></tr>
<tr><td>255</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>224</td></tr>
<tr><td colspan="32">Third J-Word Continued</td></tr>
</table>

<table>
<tr><td colspan="8">Octet 55</td><td colspan="8">Octet 54</td><td colspan="8">Octet 53</td><td colspan="8">Octet 52</td></tr>
<tr><td>287</td><td></td><td></td><td></td><td>283</td><td>282</td><td></td><td></td><td></td><td>278</td><td>277</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>256</td></tr>
<tr><td colspan="5">Padding</td><td colspan="5">Parity</td><td colspan="22">Third J-Word Continued</td></tr>
</table>

4.3 Link 16 Implementation Using HLA

Link 16 TDL simulation is typically part of a larger distributed federation, where the HLA implementation of the Link 16 protocol will be part of the Federation Object Model (FOM). Such federations are used for many purposes including system development, test and evaluation, and training.

The HLA design for Link 16 implementation is defined in a FOM module in the HLA 1516-2010 FOM format [6]. However, not every federation that will use the Link 16 FOM module has the same FOM. FOMs that incorporate the Link 16 FOM module may already have definitions for basic concepts such as radio transmitters and radio signals, or their equivalents. If these definitions were included in the Link 16 FOM module then there would be duplication and potentially incompatibilities with existing definitions in the "parent" FOM in which the Link 16 module is incorporated. Therefore the Link 16 FOM module does not include definitions for some basic concepts, and relies on the parent FOM to provide suitable definitions. The Link 16 FOM module can be considered as a "template" for creating a concrete FOM module for inclusion in the parent FOM.

In addition, the Link 16 FOM module is designed to build upon existing datatypes and classes in the RPR FOM [1], allowing an integration with the RPR FOM 2.0 without changing any of its existing capabilities. See section 4.3.7 for a detailed description.

4.3.1 The Link 16 FOM Module

4.3.1.1 Assumptions

The Link 16 FOM module assumes that the parent FOM contains:

1. An object class that represents a radio transmitter with the general transmitter capabilities as described in section 4.1.
2. An interaction class that represents a tactical data link capable radio signal. This class will act as a base class for the TDLBinaryRadioSignal defined in the Link 16 FOM module with the general transmission capabilities as described in section 4.1.

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3. A mechanism for determining the number of TDL messages contained in the signal interaction.
4. A mechanism for associating any instance of the radio signal interaction class with an instance of the radio transmitter object class that it emanated from.

4.3.1.2 Naming Convention

Conventions within the Link 16 FOM module follow those adopted by the RPR FOM version 2.0 [1]. These conventions are described in more detail in the RPR FOM GRIM, section 6.8.1 [2].

4.3.1.3 Representations

The Link 16 FOM module file (named Link_16_v2.0.xml and available on the SISO website), in compliance with the HLA Evolved FOM schema, shall be considered normative, while the human-readable tables in Annex A shall be considered informative. If any statement in this document is interpreted to be in conflict with the Link 16 FOM module in XML format, the content of the XML file shall take precedence.

4.3.2 Levels of Fidelity

The HLA levels of fidelity are directly equivalent to the corresponding DIS levels of fidelity as defined in section 4.1.2. The requirements for mixed TSA Levels as defined in section 4.1.3 also apply to the usage of the Link 16 FOM module.

4.3.3 Time Synchronization

For time-managed HLA federations the logical time shall be used as a time source for all time references.

For non-time managed HLA federations the system time shall be used as a time source for all time references. See also section 4.1.1 requirement 12. In this case the HLA time synchronization mechanism is directly equivalent to the corresponding mechanism for DIS as defined in section 4.1.4

A time-managed HLA federation requires a common understanding of logical time by all federates. According to the description of rule 10 in the HLA standard (IEEE Std 1516-2010, section 6.5): "Federation designers will identify their time management approach as part of their implementation design. Federates shall adhere to the time management approach of the federation." Federation designers need to make agreements on the mapping of the HLA logical time to the time value in Link16RadioSignal messages, including agreements on the time value that corresponds with the HLA logical time zero (the start time of the federation execution). A federate shall implement these agreements and shall provide the HLA logical time in the RTI time management service calls for which the data in the Link16RadioSignal message is valid.

4.3.4 Protocol Implementation Details

This section defines how Link 16 FOM module-compliant federates shall implement the Link 16 protocol. The HLA protocol implementation details are directly equivalent to the corresponding details for DIS as defined in section 4.2.

4.3.4.1 Object Class Data

The Link 16 FOM module defines no new object classes. Instead, the FOM module defines a single fixed record datatype (JTIDSTransmitterStruct, see section A.10) that corresponds to the modulation parameters in the DIS Transmitter PDU defined in section 4.2.1. This datatype should be added to the parent FOM either directly into the radio transmitter object class or into a suitable subclass of the radio transmitter object class. The datatype can be added as an attribute or into another data structure in an existing attribute.

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The modulation parameters requirements as specified under item 10 in section 4.2.1 also apply to the usage of the JTIDSTransmitterStruct. Refer to Table 18 for a mapping between the JTIDSTransmitterStruct fields and the DIS Transmitter PDU fields. All other requirements defined in section 4.2.1 apply to the equivalent attributes of this object class.

Table 18: JTIDSTransmitterStruct Mapping to DIS Modulation Parameters

JTIDSTransmitterStruct Field Name	Transmitter PDU Field	
TimeSlotAllocationLevel	Modulation Parameter #1	Time Slot Allocation Level
TransmittingTerminalPrimaryMode	Modulation Parameter #2	Transmitting Terminal Primary Mode
TransmittingTerminalSecondaryMode	Modulation Parameter #3	Transmitting Terminal Secondary Mode
SynchronizationState	Modulation Parameter #4	Synchronization State
NetworkSynchronizationID	Modulation Parameter #5	Network Synchronization ID

4.3.4.2 Interaction Class Data

The Link 16 FOM module includes a family of interactions that have been developed to support other data link implementations. The family of interactions is a hierarchy in which the base class for the Link 16 interactions is a generic class, the TDLBinaryRadioSignal interaction. This class is a class without parameters, and this class cannot be published nor subscribed to. The specific parameters are properties of the various subclasses of this generic base class, and these are the subclasses that are published and subscribed to. This hierarchy of interaction classes provides for Declaration Management (DM) filtering, enabling the federate to only receive the data link messages it is interested in.

The Link16RadioSignal interaction, a subclass of the TDLBinaryRadioSignal interaction (see Table A-3), contains parameters for the Link 16 Simulation Network Header fields (see Table 8) as shown in Table A-4. The field 'Message Type Identifier' is represented in the Link 16 FOM module by the eight subclasses of Link16RadioSignal.

These subclasses, JTIDSMessageRadioSignal, RTTABRadioSignal, RTTReplyRadioSignal, JTIDSVoiceCVSDRadioSignal, JTIDSVoiceLPC10RadioSignal, JTIDSVoiceLPC12RadioSignal, JTIDSLETRadioSignal, and VMFRadioSignal are the actual interactions that can be published within the HLA federation. These classes contain the Link 16 message data as shown in Table 9 through Table 16 respectively.

It is uncommon in HLA FOMs to use datatypes with sizes other than 8, 16, 32, or 64 bits. Since it is required that the content of the Link 16 message is exactly bit encoded as per the TADIL J specification (see section 4.1.1), a field identification as per the aforementioned tables has not been applied to the datatypes used by the interaction class parameters. Instead, arrays of octets are used, either directly for the parameter datatype or indirectly in a fixed record datatype. However, the 48 bits (6 octets) of the headers are separated from the rest of the message data. Also, due to the requirement for encoding as per the TADIL J messages, the IEEE Std 1516.2™ [6] variable array encoding cannot be used, as this includes the number of elements in the array. Instead, the RPRlengthlessArray is used, an encoding without the array length, as defined in the RPR FOM GRIM, section 6.8.5.1 [2].

The TDLBinaryRadioSignal interaction class (and its child classes) shall be integrated in a FOM as a subclass equivalent of the DIS Signal PDU (see 4.3.1.1). All other requirements defined in section 4.2.2 apply to the equivalent parameters, when present, of this interaction class.

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4.3.5 FOM Module Definition

The complete Link 16 FOM module is defined in Link_16_v2.0.xml and can be downloaded from the SISO website. It is also represented in human-readable form in Annex A.

For the special case where the parent FOM is the RPR FOM version 2.0, a complete set of pre-built FOM modules can be downloaded from the SISO website.

4.3.6 Adding the Link 16 FOM Module to a Parent FOM

Note: If the parent FOM is the RPR FOM then see section 4.3.7 instead.

Adding the Link 16 FOM module to a parent FOM consists of the following steps:

1. Identify the object class representing a radio transmitter.
    - A. If the parent FOM does not contain such a class then a Radio Transmitter object class should be added to the parent FOM.
    - B. If the parent FOM already contains such a class and is designed to support subscription based filter using declaration management then it may be desirable to create a subclass to act as a Link 16 Radio Transmitter.
2. Add the usage of the JTIDSTransmitterStruct structure to the object class identified above.
3. Identify the interaction class representing a radio signal.
    - A. If the parent FOM does not contain such a class then a Radio Signal interaction class should be added to the parent FOM.
    - B. If the parent FOM does contain a suitable interaction class then add the TDLBinaryRadioSignal as a subclass.
4. Add the datatypes defined in Table A-6 through Table A-9.

4.3.7 Adding the Link 16 FOM Module to the RPR FOM

If an unmodified RPR FOM 2.0 [1] for HLA Evolved is being used, then it is recommended that the pre-built RPR FOM with Link 16 FOM modules provided are used. However, if the RPR FOM has been modified for some other federation-specific reason then it will be necessary to integrate the Link 16 FOM module as follows:

Adding the Link 16 FOM module to the RPR FOM consists of the following steps:

1. Update the RPR FOM Communications module to add Link 16 specific types and extend the RPR FOM SpreadSpectrumVariantStruct variant record to include the JTIDSTransmitterStruct structure as one of the alternatives.
2. Update the RPR FOM Enumerations module to add Link 16 specific enumerations and the JTIDS_MIDS_SpectrumType enumerator value.
3. Update the Link 16 FOM module to:
    - A. Add the TDLBinaryRadioSignal as a subclass of the RPR FOM RawBinaryRadioSignal. The resulting RadioSignal interaction class hierarchy is shown in Table 19, with the Link 16 FOM module classes shaded in yellow.
    - B. Remove elements included elsewhere in the modified RPR FOM modules.

Detailed instructions are contained in the following sections.

4.3.7.1 Updating the RPR FOM Communications Module

1. Add the fixed record datatype JTIDSTransmitterStruct from Table A-9.

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2. Add the alternative for enumerator JTIDS_MIDS_SpectrumType, using the JTIDSTransmitterStruct, to the variant record datatype SpreadSpectrumVariantStruct, as shown in yellow in Table 21.
3. Update the modelIdentification name, version, modificationDate, and description, and add a useHistory as appropriate.

The RawBinaryRadioSignal parameter SignalData shall not be used to publish the Link 16 messages. Consequently, the RawBinaryRadioSignal parameter SignalDataLength shall either not be published or shall be set to 0. As per the DIS requirement in section 4.2.2 item 3, the RawBinaryRadioSignal parameter DataRate shall be set to 0.

NOTE: DIS to HLA gateways respecting this standard cannot simply forward Signal PDUs as corresponding RPR FOM RadioSignal based interactions based on the Encoding Class, copying 'Raw Binary Data' into the SignalData parameter of a RawBinaryRadioSignal interaction. See Annex B for a detailed guide for DIS-HLA gateway implementation.

4.3.7.2 Updating the RPR FOM Enumerations Module

1. Add the following enumerated datatypes from Table A-7:
   A. JTIDSPrimaryModeEnum8
   B. JTIDSSecondaryModeEnum8
   C. JTIDSSynchronizationStateEnum8
   D. Link16VersionEnum8
   E. SISOSTD002VersionEnum8
   F. TimeSlotAllocationLevelEnum8
2. Add the enumerator JTIDS_MIDS_SpectrumType (value 2) to the enumerated datatype SpreadSpectrumEnum16 as shown in yellow in Table 20.
3. Update the modelIdentification name, version, modificationDate, and description, and add a useHistory as appropriate.

Alternatively, the Enumerations module (RPR-Enumerations_v2.0.xml) can be used as provided with SISO-REF-010 from version 30 onwards.

4.3.7.3 Updating the Link 16 FOM Module

1. Remove the object class RadioTransmitter.
2. Replace the interaction class parent by scaffolding classes for HLAinteractionRoot.RadioSignal.RawBinaryRadioSignal, i.e., replace:

```
<interactions>
   <interactionClass notes="Link16_2">
     <name>Parent</name>
       <sharing>PublishSubscribe</sharing>
       <transportation>HLAbestEffort</transportation>
       <order>Receive</order>
       <interactionClass>
           <name>TDLBinaryRadioSignal</name>
           ...
       </interactionClass>
   </interactionClass>
 </interactions>
```

With the following:

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```
<interactions>
  <interactionClass>
    <name>HLAinteractionRoot</name>
    <interactionClass>
      <name>RadioSignal</name>
      <interactionClass>
        <name>RawBinaryRadioSignal</name>
        <interactionClass>
          <name>TDLBinaryRadioSignal</name>
          ...
        </interactionClass>
      </interactionClass>
    </interactionClass>
  </interactionClass>
</interactions>
```

3. Delete the RPR FOM datatypes RPRunsignedInteger16BE, RPRunsignedInteger32BE, BitsUnsignedInteger16, Octet, and UnsignedInteger32 (it is assumed that these datatypes have not been modified in the base RPR FOM Foundation and Base modules).
4. Delete the datatypes added to the Enumerations and Communication modules:
    A. JTIDSPrimaryModeEnum8
    B. JTIDSSecondaryModeEnum8
    C. JTIDSSynchronizationStateEnum8
    D. Link16VersionEnum8
    E. SISOSTD002VersionEnum8
    F. SpreadSpectrumEnum16
    G. TimeSlotAllocationLevelEnum8
    H. JTIDSTransmitterStruct
5. Delete the notes Link16_1 and Link16_2.
6. Add a Dependency to the Real-time Platform Reference Communication FOM module in the modelIdentification.
7. Update the modelIdentification name, version, modificationDate, and description, and add a useHistory as appropriate.

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Table 19: RPR FOM Link 16 FOM Module Interactions Class Structure Table

RadioSignal (N)	ApplicationSpecifcRadioSignal (PS)			
	DatabaseIndexRadioSignal (PS)			
	EncodedAudioRadioSignal (PS)			
	RawBinaryRadioSignal (PS)	TDLBinaryRadioSignal (N)	Link16RadioSignal (S)	JTIDSMessageRadioSignal (PS)
				RTTABRadioSignal (PS)
				RTTReplyRadioSignal (PS)
				JTIDSVoiceCVSDRadioSignal (PS)
				JTIDSVoiceLPC10RadioSignal (PS)
				JTIDSVoiceLPC12RadioSignal (PS)
				JTIDSLETRadioSignal (PS)
				VMFRadioSignal (PS)

Table 20: SpreadSpectrumEnum16 with Link 16 FOM Module Modifications

Name	Representation	Enumerator	Values	Semantics
SpreadSpectrumEnum16	RPRunsignedInteger16BE	None	0	The type of spread spectrum characteristics employed by a transmitter.
		SINCGARSFrequencyHop	1	
		JTIDS_MIDS_SpectrumType	2	

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Table 21: SpreadSpectrumVariantStruct with Link 16 FOM Module Modifications

Record name	Discriminant			Alternative			Encoding	Semantics
	Name	Type	Enumerator	Name	Type	Semantics		
SpreadSpectrumVariantStruct	SpreadSpectrumType	SpreadSpectrumEnum16	SINCGARSFrequencyHop	SINCGARSModulation	SINCGARSModulationStruct	Modulation parameters for SINCGARS radio system.	HLAvariantRecord	Identifies the actual spread spectrum technique in use.
			JTIDS_MIDS_SpectrumType	JTIDSTransmitterData	JTIDSTransmitterStruct	Modulation parameters for Link 16 radio system according to SISO-STD-002.		

Annex A Link 16 FOM Module (Informative)

A.1 Object Model Identification Table

General introduction: *The purpose of this table is to document certain key identifying information within the object model description.*

For detailed information on the table format, see Reference 6.

Table A-1: Object Model Identification

Category	Information
Name	SISO-STD-002 - Link 16 Simulation FOM module
Type	FOM
Version	2.0
Modification Date	2021-11-08
Security Classification	Unclassified
Purpose	Defines the Link 16 model in an HLA federation
Application Domain	C4ISR & C2 platform simulations
Description	This module provides the full definition of the SISO-STD-002 Standard for Link 16 Simulation for implementation using HLA. Note that this Link 16 FOM module relies upon a parent FOM to provide suitable class definitions for radio transmitters and radio signals. Typically, it cannot be directly used within a federation. This module can be considered as a template for creating a concrete FOM module for inclusion in the parent FOM. See SISO-STD-002-2021 section 4.3 for more information. Note also that for HLA Evolved a pre-built RPR FOM 2.0 with Link 16 FOM module can be downloaded from the SISO website.
POC	
POC Type	Primary author
POC Name	TADIL TALES Product Development Group and Product Support Group
POC Organization	SISO - Simulation Interoperability Standards Organization
POC Telephone	+1 (407) 882-1348

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Category	Information
POC Email	siso-help@sisostds.org
References	
Type	Text Document
Identification	SISO-STD-002-2021 Standard for Link 16 Simulation Version 2.0 8 November 2021
Type	Text Document
Identification	SISO-STD-001-2015 Standard for Guidance, Rationale, and Interoperability Modalities for the Real-time Platform Reference Federation Object Model Version 2.0 10 August 2015
Type	Text Document
Identification	SISO-STD-001.1-2015 Standard for Real-time Platform Reference Federation Object Model Version 2.0 10 August 2015
Type	Text Document
Identification	SISO-REF-010-2020 Reference for Enumerations for Simulation Interoperability Version 29 19 May 2021

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Category	Information
Other	Copyright © 2021 by the Simulation Interoperability Standards Organization, Inc. 7901 4th St. N, Suite 300-4043 St. Petersburg, FL 33702, USA All rights reserved. Schema and API: SISO hereby grants a general, royalty-free license to copy, distribute, display, and make derivative works from this material, for all purposes, provided that any use of the material contains the following attribution: “Reprinted with permission from SISO Inc.” Should a reader require additional information, contact the SISO Inc. Board of Directors. Documentation: SISO hereby grants a general, royalty-free license to copy, distribute, display, and make derivative works from this material, for noncommercial purposes, provided that any use of the material contains the following attribution: “Reprinted with permission from SISO Inc.” The material may not be used for a commercial purpose without express written permission from the SISO Inc. Board of Directors. SISO Inc. Board of Directors 7901 4th St. N, Suite 300-4043 St. Petersburg, FL 33702, USA

A.2 Object Class Structure Table

General introduction: *The object class structure of an object model is defined by a set of relations among classes of objects from the simulation or federation domain. The object class structure table represents the class-subclass hierarchy of object classes. It is populated from the most general object classes in the left-most column, followed by all of their immediate subclasses in the next column, and then further levels of subclasses, as required. Finally, the most specific object classes are specified in the right-most column.*

Each object class in the object class structure table is followed by information on publication and subscription capabilities enclosed in parentheses:

- *P (Publish): At least one federate is capable of publishing at least one attribute of the object class.*
- *S (Subscribe): At least one federate is capable of subscribing to at least one attribute of the object class.*
- *PS (PublishSubscribe): At least one federate is capable of publishing at least one attribute and at least one federate is capable of subscribing to at least one attribute of the object class.*
- *N (Neither): No federate is capable of either publishing or subscribing to any attributes of the object class.*

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Explanatory information with individual table entries may be included by using a notes pointer. Pointers to notes consist of a uniquely identifying note label (or a series of comma-separated labels) preceded by an asterisk and enclosed by brackets. The notes themselves are included in the notes table.

For detailed information on the table format, see Reference 6.

There are no Link 16 unique object classes in the Link 16 FOM module. The RadioTransmitter object shown in Table A-1 is a scaffolding class to hold note Link16_1. Refer to this note (see Table A-10) for information on the integration of datatype JTIDSTransmitterStruct.

Table A-2: RadioTransmitter Object

RadioTransmitter (PS) *[Link16_1]

A.3 Interaction Class Structure Table

General introduction: *The interaction class structure of an object model is defined by a set of relations among classes of interactions from the simulation or federation domain. The interaction class structure table represents the class-subclass hierarchy of interaction classes, in much the same way that objects are described in the object class structure table.*

Each interaction class in the interaction class structure table is followed by information on publishing and subscribing capabilities enclosed in parentheses:

- *P (Publish): At least one federate is capable of publishing the interaction class.*
- *S (Subscribe): At least one federate is capable of subscribing to the interaction class.*
- *PS (PublishSubscribe): At least one federate is capable of publishing and at least one federate is capable of subscribing to the interaction class.*
- *N (Neither): No federate is capable of either publishing or subscribing to the interaction class.*

Pointers to notes may be included, in the same way as described for the object class structure table.

For detailed information on the table format, see Reference 6.

Refer to note Link16_2 (see Table A-10) for information on the interpretation of the Parent class.

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Table A-3: Interaction Class Structure Table

Parent (PS) *[Link16_2]	TDLBinaryRadioSignal (N)	Link16RadioSignal (S)	JTIDSMessageRadioSignal (PS)
			RTTABRadioSignal (PS)
			RTTReplyRadioSignal (PS)
			JTIDSVoiceCVSDRadioSignal (PS)
			JTIDSVoiceLPC10RadioSignal (PS)
			JTIDSVoiceLPC12RadioSignal (PS)
			JTIDSLETRadioSignal (PS)
			VMFRadioSignal (PS)

A.4 Attribute Table

General introduction: *Each class of simulation domain objects is characterized by a fixed set of attribute types. These attributes are named portions of their object's state whose values can change over time. The attribute table describes all object attributes represented in a federation.*

For detailed information on the table format, see Reference 6.

There are no Link 16 unique object classes in the Link 16 FOM module. Refer to note Link16_1 (see Table A-10).

A.5 Parameter Table

General introduction: *Most interaction classes are characterized according to a list of one or more interaction parameters. Interaction parameters are used to associate relevant and useful information with classes of interactions. The parameter table describes all interaction parameters that may be represented in a federation.*

For detailed information on the table format, see Reference 6.

Table A-4: Parameter Table

Interaction	Parameter	Datatype	Available Dimensions	Transportation	Order
JTIDSLETRadioSignal	LETHeader	LETHeaderStruct	NA	HLAbestEffort	Receive
	TADILJMessage	TADILJWordStructLengthlessArray1Plus			

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Interaction	Parameter	Datatype	Available Dimensions	Transportation	Order
JTIDSMessageRadioSignal	JTIDSHeader	JTIDSHeaderStruct	NA	HLAbestEffort	Receive
	TADILJMessage	TADILJWordStructLengthlessArray1Plus			
JTIDSVoiceCVSDRadioSignal	DataLength	BitsUnsignedInteger16	NA	HLAbestEffort	Receive
	JTIDSHeader	JTIDSHeaderStruct			
	Data	OctetLengthlessArray29Plus			
JTIDSVoiceLPC10RadioSignal	DataLength	BitsUnsignedInteger16	NA	HLAbestEffort	Receive
	JTIDSHeader	JTIDSHeaderStruct			
	Data	OctetLengthlessArray29Plus			
JTIDSVoiceLPC12RadioSignal	DataLength	BitsUnsignedInteger16	NA	HLAbestEffort	Receive
	JTIDSHeader	JTIDSHeaderStruct			
	Data	OctetLengthlessArray29Plus			
Link16RadioSignal	NPGNumber	NetworkParticipationGroupNumber	NA	HLAbestEffort	Receive
	NetNumber	NetworkNumber			
	TSEC_CVLL	CryptoVariable			
	MSEC_CVLL	CryptoVariable			
	SISOSTD002Version	SISOSTD002VersionEnum8			
	Link16Version	Link16VersionEnum8			
	TimeSlotID	TimeSlotIdentifier			
	PerceivedTransmitTime	NTPTimestampStruct			
RTTABRadioSignal	RTTAB	RTTABStruct	NA	HLAbestEffort	Receive
RTTReplySignal	RTTReply	RTTReplyStruct	NA	HLAbestEffort	Receive
VMFRadioSignal	JTIDSHeader	JTIDSHeaderStruct	NA	HLAbestEffort	Receive
	MessageData	TADILJWordStructLengthlessArray1Plus			

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A.6 Basic Data Representation Table

General introduction: *Basic data representation is the underpinning of all OMT datatypes. These basic data representations cannot be directly used as a named datatype in any OMT datatype table, but rather are the basis upon which named datatypes are built.*

For detailed information on the table format, see Reference 6.

NOTE – Cells that are shaded in blue are defined in RPR FOM 2.0.

Table A-5: Basic Data Representation Table

Name	Size in bits	Interpretation	Endian	Encoding
RPRunsignedInteger16BE	16	Integer in the range [0, 2^16-1]	Big	16-bit unsigned integer.
RPRunsignedInteger32BE	32	Integer in the range [0, 2^32-1]	Big	32-bit unsigned integer.

A.7 Simple Datatype Table

General introduction: *The simple datatype table describes simple, scalar data items.*

For detailed information on the table format, see Reference 6.

NOTE – Cells that are shaded in blue are defined in RPR FOM 2.0.

Table A-6: Simple Datatype Table

Name	Representation	Units	Resolution	Accuracy	Semantics
BitsUnsignedInteger16	RPRunsignedInteger16BE	bit	1	perfect	Transmission size, in number of bits.
CryptoVariable	HLAoctet	NA	NA	NA	An integer identification of the crypto variable used for JTIDS transmission and message encryption. This variable allows for simulated crypto netting. Valid range: [0,127] and all bits set to one indicating no statement/wildcard.
NetworkNumber	HLAoctet	NA	NA	NA	Used to create virtual sub-circuits within NPG for stacked nets or between NPGs for multi-net operations. Valid range: [0,127].

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Name	Representation	Units	Resolution	Accuracy	Semantics
NetworkParticipationGroupNumber	RPRunsignedInteger16BE	NA	NA	NA	Used to segregate information within a JTIDS/MIDS network. Creates virtual networks of participants. Valid range: [0,511].
Octet	HLAoctet	NA	1	perfect	Uninterpreted 8-bit value.
TimeSlotIdentifier	RPRunsignedInteger32BE	NA	NA	NA	Bits 0-16 indicate the Time Slot Number; valid arrange [0,98303]. Time Slot 0 represents time slot A-1, and Time Slot 98303 represents C-32767. When the Epoch is 112, the last valid Time Slot is 45151 (end of the day). Bits 17-23 are padding and set to 0. Bits 24-31 indicate the Epoch number; valid range [0,112]. An epoch is 12.8 minutes long, 112.5 epochs in a 24 hour day. All bits set to one (including the padding field) indicate a no statement/wildcard.
UnsignedInteger32	RPRunsignedInteger32BE	NA	1	perfect	Integer in the range [0, 2^32-1].

A.8 Enumerated Datatype Table

General introduction: *The enumerated datatype table describes data elements that can take on a finite discrete set of possible values.*

For detailed information on the table format, see Reference 6.

NOTE – Cells that are shaded in blue are defined in RPR FOM 2.0.

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Table A-7: Enumerated Datatype Table

Name	Representation	Enumerator	Values	Semantics
JTIDSPrimaryModeEnum8	HLAoctet	NTR	1	The primary mode of a JTIDS system [UID 173].
		JTIDSUnitParticipant	2	
JTIDSSecondaryModeEnum8	HLAoctet	None	0	The JTIDS secondary mode of operation [UID 174].
		NetPositionReference	1	
		PrimaryNavigationController	2	
		SecondaryNavigationController	3	
JTIDSSynchronizationStateEnum8	HLAoctet	NoStatement	0	Describes the state of synchronization that the JTIDS system has achieved [UID 175].
		InitialNetEntry	1	
		CoarseSynchronization	2	
		FineSynchronization	3	
Link16VersionEnum8	HLAoctet	NoStatement	0	Link 16 version [UID 800].
		MIL-STD-6016C	1	
		MIL-STD-6016D	2	
		MIL-STD-6016E	3	
		MIL-STD-6016F	4	
		MIL-STD-6016FC1	5	
		STANAG5516Ed3	103	
		STANAG5516Ed4	104	
		STANAG5516Ed5	105	
		STANAG5516Ed6	106	
		STANAG5516Ed8	108	
SISOSTD002VersionEnum8	HLAoctet	SISO-STD-002-2006	0	SISO-STD-002 version [UID 736].
		SISO-STD-002-2021	1	

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Name	Representation	Enumerator	Values	Semantics
SpreadSpectrumEnum16	RPRunsignedInteger16BE	JTIDS_MIDS_SpectrumType	2	The type of spread spectrum characteristics employed by a transmitter.
TimeSlotAllocationLevelEnum8	HLAoctet	LowFidelityLevel0	0	Time Slot Allocation (TSA) level of fidelity. See SISO-STD-002 for detailed descriptions and requirements [UID 172].
		LowFidelityLevel1	1	
		MediumFidelityLevel2	2	
		MediumFidelityLevel3	3	
		HighFidelityLevel4	4	

A.9 Array Datatype Table

General introduction: *The array datatype table describes indexed homogenous collections of datatypes; these constructs are also known as arrays or sequences.*

For detailed information on the table format, see Reference 6.

Table A-8: Array Datatype Table

Name	Element type	Cardinality	Encoding	Semantics
TADILJWordStructLengthlessArray1Plus	TADILJWordStruct	[1..2147483647]	RPRlengthlessArray	Array of at least 1 TADILJWordStruct, encoded without the number of array elements.
OctetArray6	Octet	6	HLAfixedArray	Array of 6 octets.
OctetArray10	Octet	10	HLAfixedArray	Array of 10 octets.
OctetLengthlessArray29Plus	Octet	[29..2147483647]	RPRlengthlessArray	Array of at least 29 octets, encoded without the number of array elements.

A.10 Fixed Record Datatype Table

General introduction: *The fixed record datatype table shall be used to describe heterogeneous collections of types; these constructs are also known as records or structures. Each entry in the fixed record datatype table may contain fields that are of other types,*

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such as simple datatypes, fixed records, arrays, enumerations, or variant records. This enables building "structures of data structures".

For detailed information on the table format, see Reference 6.

Table A-9: Fixed Record Datatype Table

Record name	Field			Encoding	Semantics
	Name	Type	Semantics		
JTIDSHeaderStruct	Data	OctetArray6	In total 48 bits, with the following fields: Bits 0-2: Time Slot Type. Bit 3: Relay Transmission Indicator. Bits 4-18: Source Track Number of Sender. Bits 19-34: Secure Data Unit Serial Number. Bits 35-47: Padding, set to 0.	HLAfixedRecord	Link 16 Header Word (35 bits) for common messages, JTIDS voice, and VMF. Padded to 48 bits.

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Record name	Field			Encoding	Semantics
	Name	Type	Semantics		
JTIDSTransmitterStruct	TimeSlotAllocationLevel	TimeSlotAllocationLevelEnum8	TSA level of fidelity.	HLAfixedRecord	Contains JTIDS specific information about the JTIDS transmitter system.
	TransmittingTerminalPrimaryMode	JTIDSPrimaryModeEnum8	The primary mode of a JTIDS system.		
	TransmittingTerminalSecondaryMode	JTIDSSecondaryModeEnum8	The JTIDS secondary mode of operation.		
	SynchronizationState	JTIDSSynchronizationStateEnum8	The state of synchronization that the JTIDS system has achieved.		
	NetworkSynchronizationID	UnsignedInteger32	TSA Levels 0-2: may be set to 0 (wildcard) or the unique 32-bit value of a simulated net. TSA Levels 3 and 4: set to the unique 32-bit value of a simulated net. Only an NTR can generate a Network Synchronization ID; all other participants use the ID obtained from the NTR to which they are synchronized.		
LETHeaderStruct	Data	OctetArray6	In total 48 bits, with the following fields: Bits 0-3: LET ID Symbol. Bit 4: Relay Transmission Indicator. Bits 5-8: LET Message Packing Type. Bits 9-23: Source Track Number of Sender. Bits 24-39: Secure Data Unit Serial Number. Bits 40-47: Padding, set to 0.	HLAfixedRecord	Link 16 Enhanced Throughput (LET) Header Word (40 bits). Padded to 48 bits.

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Record name	Field			Encoding	Semantics
	Name	Type	Semantics		
NTPTimestampStruct	Seconds	UnsignedInteger32	Number of seconds since 0 h 1 January 1900 UTC.	HLAfixedRecord	64-bit timestamp format according to RFC 5905. All bits set to one in both fields indicate a no statement/wildcard.
	Fraction	UnsignedInteger32	Fraction of a second, in 1/(2^32) resolution (232 picoseconds).		
RTTABStruct	Data	OctetArray6	In total 48 bits, with the following fields: Bits 0-2: Time Slot Type. Bit 3: RTT Interrogation Type. Bits 4-18: variable content, see MIL-STD-6016 or STANAG 5516. Bits 19-34: Secure Data Unit Serial Number. Bits 35-47: Padding, set to 0.	HLAfixedRecord	JTIDS RTT A/B word (35 bits). Padded to 48 bits.
RTTReplyStruct	Data	OctetArray6	In total 48 bits, with the following fields: Bits 0-18: Time of Arrival. Bits 19-34: Secure Data Unit Serial Number. Bits 35-47: Padding, set to 0.	HLAfixedRecord	JTIDS RTT Reply word (35 bits). Padded to 48 bits.
TADILJWordStruct	Data	OctetArray10	In total 80 bits, with the following fields: Bits 0-1: Word Format. Bits 2-69: variable content, see MIL-STD-6016 or STANAG 5516 for FWF J-Words. Bits 70-74: Parity. Bits 75-79: Padding, set to 0.	HLAfixedRecord	TADIL-J word (75 bits) used for Fixed Word Format (FWF) messages and the Variable Message Format (VMF). Padded to 80 bits.

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A.11 Notes Table

General introduction: *Any entry within any of the OMT tables may be annotated with additional descriptive information outside of the immediate table structure. The mechanism for attaching one or more notes to an OMT table entry is to include a notes pointer in the appropriate table cell. The notes themselves are associated with the note label and included in the notes table. A single note may be referenced numerous times in OMT tables*

For detailed information on the table format, see Reference 6.

Table A-10: Notes Table

ID	Text
Link16_1	The RadioTransmitter class is a scaffolding class, i.e., it refers to a class (structure) in which the Link 16 FOM module is integrated. This class is to represent all capabilities as provided with the DIS Transmitter PDU, in accordance with IEEE Std 1278.1(tm)-2012, and contain an attribute using the JTIDSTransmitterStruct.
Link16_2	The Parent class is a scaffolding class, i.e., it refers to an interaction class (structure) in which the Link 16 FOM module is integrated. The TDLBinaryRadioSignal class (and its children classes) is to be integrated as a subclass of an interaction class providing the DIS Signal PDU capabilities, in accordance with IEEE Std 1278.1(tm)-2012.

A.12 Object Class Definition Table

General introduction: *The lexicon tables provides a means to define all object classes, interaction classes, object class attributes, and interaction parameters to achieve a common understanding of the semantics of the data. The object class definition table describes the object classes.*

For detailed information on the table format, see Reference 6.

There are no Link 16 unique object classes in the Link 16 FOM module.

A.13 Interaction Class Definition Table

General introduction: *The lexicon tables provides a means to define all object classes, interaction classes, object class attributes, and interaction parameters to achieve a common understanding of the semantics of the data. The interaction class definition table describes the interactions.*

For detailed information on the table format, see Reference 6.

Table A-11: Interaction Class Definition Table

Class	Definition
JTIDSLETRadioSignal	Link 16 radio signal containing Link 16 Enhanced Throughput (LET) encoded messages.

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Class	Definition
JTIDSMessageRadioSignal	Link 16 radio signal containing Fixed Word Format (FWF) TADIL-J messages.
JTIDSVoiceCVSDRadioSignal	Link 16 radio signal containing a voice message encoded using CVSD.
JTIDSVoiceLPC10RadioSignal	Link 16 radio signal containing a voice message encoded using LPC10.
JTIDSVoiceLPC12RadioSignal	Link 16 radio signal containing a voice message encoded using LPC12.
Link16RadioSignal	Link 16 radio signal common base class.
RTTABRadioSignal	Link 16 radio signal containing an RTT/A or RTT/B message.
RTTReplySignal	Link 16 radio signal containing an RTT Reply message.
TDLBinaryRadioSignal	Parent class for all TDL radio signals.
VMFRadioSignal	Link 16 radio signal containing Variable Message Format (VMF) messages.

A.14 Attribute Definition Table

General introduction: *The lexicon tables provides a means to define all object classes, interaction classes, object class attributes, and interaction parameters to achieve a common understanding of the semantics of the data. The attribute definition table describes the attributes that characterize object classes.*

For detailed information on the table format, see Reference 6.

There are no Link 16 unique object classes in the Link 16 FOM module.

A.15 Parameter Definition Table

General introduction: *The lexicon tables provides a means to define all object classes, interaction classes, object class attributes, and interaction parameters to achieve a common understanding of the semantics of the data. The parameter definition table describes the parameters that are associated with interaction classes.*

For detailed information on the table format, see Reference 6.

Table A-12: Parameter Definition Table

Class	Parameter	Definition
JTIDSLETRadioSignal	LETHeader	LET Header Word. Not optional.
	TADILJMessage	LET message data words. Not optional.

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Class	Parameter	Definition
JTIDSMessageRadioSignal	JTIDSHeader	Link 16 Header Word. Not optional.
	TADILJMessage	Link 16 message data words. Not optional.
JTIDSVoiceCVSDRadioSignal	DataLength	The length of the encoded voice in the Data parameter, in bits. Not optional.
	JTIDSHeader	Link 16 Header Word. Not optional.
	Data	JTIDS CVSD encoded voice data. Not optional.
JTIDSVoiceLPC10RadioSignal	DataLength	The length of the encoded voice in the Data parameter, in bits. Not optional.
	JTIDSHeader	Link 16 Header Word. Not optional.
	Data	JTIDS LPC10 encoded voice data. Not optional.
JTIDSVoiceLPC12RadioSignal	DataLength	The length of the encoded voice in the Data parameter, in bits. Not optional.
	JTIDSHeader	Link 16 Header Word. Not optional.
	Data	JTIDS LPC12 encoded voice data. Not optional.

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Class	Parameter	Definition
Link16RadioSignal	NPGNumber	Network/Needline Participation Group (NPG) number. Not optional.
	NetNumber	Network Number. Not optional.
	TSEC_CVLL	Transmission Security Crypto Variable Logic Label. Optional for TSA Levels 0-2; default value: all bits set to one (no statement/wildcard).
	MSEC_CVLL	Message Security Crypto Variable Logic Label. Optional for TSA Levels 0-2; default value: all bits set to one (no statement/wildcard).
	SISOSTD002Version	Indicates which SISO-STD-002 version was used, i.e., whether byte swapping has or has not been used in the Message Data field (0 = SISO-STD-002-2006, legacy byte swapping employed; 1 = SISO-STD-002-2021, new method, bit stream, no byte swapping employed). Not optional.
	Link16Version	Indicates which version of MIL-STD-6016 or STANAG 5516 is being used. Optional; default value: NoStatement.
	TimeSlotID	Time slot identification. Optional for low-fidelity TSA Levels (0, 1); default value: all bits set to one (no statement/wildcard).
	PerceivedTransmitTime	The time at which the radio signal is transmitted. Optional for low-fidelity synchronization (TSA Levels 0-3); default value: all bits set to one (no statement/wildcard).
RTTABRadioSignal	RTTAB	JTIDS RTT A/B message word. Not optional.
RTTReplySignal	RTTReply	JTIDS RTT reply message word. Not optional.
VMFRadioSignal	JTIDSHeader	Link 16 Header Word. Not optional.
	MessageData	Link 16 message data words with VMF information fields. Not optional.

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Annex B DIS to HLA Translations (Informative)

B.1 RPR FOM RadioTransmitter Object versus DIS Transmitter PDU

See the RPR FOM GRIM [2], sections 7.10.1.1 and 9.6.1, for the cross references between the RPR FOM 2.0 RadioTransmitter object class attributes and the DIS Transmitter PDU fields.

B.2 RPR FOM RadioSignal Based Interactions versus DIS Signal PDU

The RPR FOM defines four interaction classes, one for each of the encoding classes, as subclasses of the common parent class RadioSignal. Since the encoding class for the Link 16 DIS Signal PDU messages is set to Raw Binary Data, RawBinaryRadioSignal interactions are used in HLA federations based on the RPR FOM.

In addition, compliance to the Link 16 FOM module requires the Link 16 messages to be sent using one of the subclasses of the Link16RadioSignal, as per the Link 16 Message Type Identifier. Table B-1 shows the interaction class to be generated for each of the allowed values of the Message Type Identifier field [UID 176]. See Table B-3 in the next section for the location of the Message Type Identifier field, bits 40-47 (octet #5) of the Signal PDU Data field.

Table B-1: Link 16 Message Type Identifier to HLA Interaction Class Mapping

Message Type Identifier		HLA Interaction Class
Description	**Value**	
JTIDS Header/Messages	0	JTIDSMessageRadioSignal
RTT A/B	1	RTTABRadioSignal
RTT Reply	2	RTTReplyRadioSignal
JTIDS Voice CVSD	3	JTIDSVoiceCVSDRadioSignal
JTIDS Voice LPC10	4	JTIDSVoiceLPC10RadioSignal
JTIDS Voice LPC12	5	JTIDSVoiceLPC12RadioSignal
JTIDS LET	6	JTIDSLETRadioSignal
VMF	7	VMFRadioSignal

The following sections describe the translations of the DIS Signal PDU fields to the corresponding interaction class parameters. The first section covers the data common to all Link 16 Message Type Identifiers. Subsequent sections cover the specifics for each of the eight Message Type Identifiers, i.e., each of the Link16RadioSignal interaction subclasses.

The same tables can be used for the reverse translation from an HLA interaction to a DIS Signal PDU. Translating from HLA to DIS does not require selection of the appropriate PDU as it will always be to the Signal PDU. For fields not mapped (N/A), see the requirements from section 4.2.2 and the DIS standard for the values to be set.

B.2.1 Link 16 Common Data

Table B-2 shows the translations of the DIS Signal PDU fields to the corresponding RPR FOM and Link 16 FOM module interaction class parameters common to each of the Link 16 Message Type Identifiers. Most of the mapping of the Signal PDU fields to the RawBinaryRadioSignal parameters is as per the RPR FOM standard. The Data field however is not published in the parameter SignalData. Instead, the content of the Data field is to be extracted and published in parameters of the Link 16 FOM module interaction classes.

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The first 160 bits of the Data field, the Link 16 Simulation Network Header, is split into individual parameters of the Link16RadioSignal class. The subsequent Message Type Identifier-specific content of the Data field is covered in the next sections.

Table B-2: Link 16 Common Signal PDU to HLA Interaction Mapping

<table>
<tr><th colspan="5">Signal PDU fields</th><th colspan="2">HLA interaction</th></tr>
<tr><th colspan="2">Size (bits)</th><th colspan="3"></th><th>Class</th><th>Parameter</th></tr>
<tr><td colspan="2">96</td><td colspan="3">PDU Header</td><td colspan="2">N/A</td></tr>
<tr><td colspan="2">48</td><td colspan="3">Radio Reference ID</td><td rowspan="5">RawBinaryRadioSignal</td><td rowspan="2">HostRadioIndex</td></tr>
<tr><td colspan="2">16</td><td colspan="3">Radio Number</td></tr>
<tr><td colspan="2">16</td><td colspan="3">Encoding Scheme</td><td>Bits 0-13:
TDLMessageCount</td></tr>
<tr><td colspan="2">16</td><td colspan="3">TDL Type</td><td>TacticalDataLinkType</td></tr>
<tr><td colspan="2">32</td><td colspan="3">Sample Rate</td><td>DataRate</td></tr>
<tr><td colspan="2">16</td><td colspan="3">Data Length</td><td colspan="2">N/A [3]</td></tr>
<tr><td colspan="2">16</td><td colspan="3">Samples</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="9">160</td><td>16</td><td rowspan="10">Data</td><td rowspan="9">Link 16 Simulation Network Header</td><td>NPG Number</td><td rowspan="4">Link16RadioSignal</td><td>NPGNumber</td></tr>
<tr><td>8</td><td>Net Number</td><td>NetNumber</td></tr>
<tr><td>8</td><td>TSEC CVLL</td><td>TSEC_CVLL</td></tr>
<tr><td>8</td><td>MSEC CVLL</td><td>MSEC_CVLL</td></tr>
<tr><td>8</td><td>Message Type Identifier</td><td colspan="2">See section B.2</td></tr>
<tr><td>8</td><td>SISO-STD-002 Version</td><td rowspan="4">Link16RadioSignal</td><td>SISOSTD002Version</td></tr>
<tr><td>8</td><td>Link 16 Version</td><td>Link16Version</td></tr>
<tr><td>32</td><td>Time Slot ID</td><td>TimeSlotID</td></tr>
<tr><td>64</td><td>Perceived Transmit Time</td><td>PerceivedTransmitTime</td></tr>
<tr><td colspan="2">≥ 48</td><td colspan="2">Link 16 Message data</td><td colspan="2">See sections B.2.2 to B.2.9</td></tr>
<tr><td colspan="2">0-31</td><td colspan="3">Padding (if needed)</td><td colspan="2">Padding in the highest 0-7 bits of the last array element (if needed)</td></tr>
</table>

Table B-3 provides another perspective of the fields of the Link 16 Simulation Network Header in the Signal PDU Data field. The Link 16 Simulation Network Header occupies the first 160 bits, 20 octets, of the Data field. The lines below the DIS Data display the mapping of these bits/octets to the

[3] Data Length is NOT mapped to SignalDataLength as the RawBinaryRadioSignal parameter SignalData is not used; see section 4.3.7.1. See Table B-10, Table B-12, and Table B-13 for a mapping of the PDU field to the JTIDS voice message interactions.

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