CHAPTER 27

RF Network Access Layer

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27. CHAPTER 27

27.1 Introduction

This chapter defines the mechanisms and processes for managing the physical layer of RF links within the RF Network. The RF Network implements an Open Systems Interconnect (OSI) model approach (Figure 27-1) to data transmission, where data moves through the OSI stack from the application layer to the physical layer, from physical layer to physical layer through some transmission medium, then back up the stack to another application on the receiving side. Because the system is network-based, transmissions occur in bursts that are scheduled as data arrives.

OSI Model					
Layer		Data Unit	Function	Examples	
Host Layers	7. Application	Data	High Level APIs, including resource sharing, remote file access, directory services and virtual terminals	HTTP, FTP, SNMP, SSH, TELNET	
	6. Presentation		Translation of data between a networking service and an application, including character encoding, data compression and encryption/decryption	HTML, CSS, GIF	
	5. Session		Managing communications sessions, i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes	RPC, PAP, SSL, SQL	
	4. Transport	Segments/Datagram	Managing communications sessions, i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes	TCP, UDP, NETBEUI	
Media Layers	3. Network	Packet	Structuring and managing a multi-node network, including addressing, routing and traffic control	IPv4 IPv6, IPSec, Apple Talk, ICMP	
	2. Data Link	Frame	Reliable transmission of data frames between two nodes connected by a physical layer	PPP, IEE 802.2 L2TP, MAC, LLDP	**IRIG 106 Chapter 28**
	1. Physical	Bit	Transmission and reception of raw bit streams over a physical medium	Ethernet physical layer, DSL USB, ISDN, DOCSIS	**Covered by this chapter**

Figure 27-1 - OSI Model as related to the TmNS RF Network

Chapter 27 describes the low-level waveform content (e.g. Frequency, Modulation, Framing, etc.). Chapter 28 focuses on access to and management of the RF portion of the TmNS network. The bit numbering, bit ordering, and byte ordering conventions used in this chapter are described in Appendix 21B.

27.2 Radio Access Network Concepts and Definitions

27.2.1 Data Link Layer Framing

The RF Network provides a standards-based IP network (IETF RFC 791 and RFC 2474). Layers supporting this IP layer are unique to the RF Network. Figure 27-2 shows an overview of the protocol layers associated with sending an IP packet over the data link layer and RF physical interface. The IP packets are referred to as RF MAC Service Data Units (MSDUs) and are comprised of complete IP packets containing user data. The MSDUs are placed into payload blocks with aggregation and fragmentation performed to meet the maximum transmission unit (MTU) of the RF channel. The length limited payload blocks are separated into RF MAC frames and link layer header information is added. Forward error correction is added to the RF MAC frames to create Low Density Parity Check (LDPC) blocks suitable for transmission over the RF link. Details of the higher levels of this protocol are covered in Chapter 28.

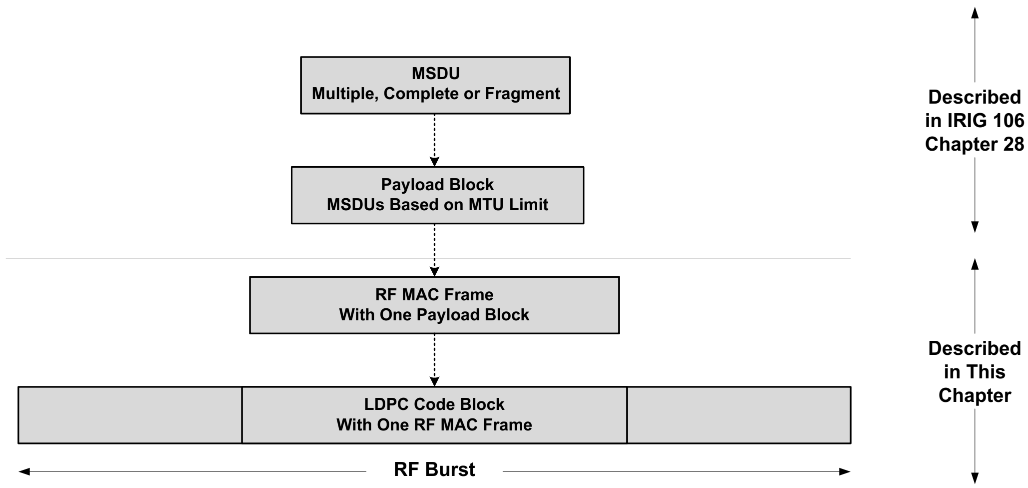


Figure 27-2 - Data Link Layer Framing Overview

On the receiving end of the RF link, the physical layer recovers the transmitted bitstream by decoding and concatenating codeblocks arriving in the TxOps time slots. Each decoded codeblock contains one Media Access Control (RF MAC) frame. These RF MAC frames contain complete IP packets or an IP packet composed of multiple MAC Service Data Unit (MSDU) fragments. MSDUs are described in more detail in Chapter 28.

When a link layer frame is constructed for transmission in the process described here, the completed link layer frame sent shall not exceed the remaining portion of the current TxOp.

27.2.2 RF Media Access Control Layer

The RF MAC layer is responsible for providing access to the physical media (i.e. the wireless RF network). On the transmission side, it is responsible for framing IP packets for physical transmission (adding in the layer 2 hardware addresses for the source/destination pair of the link). On the receive side it is responsible for validating the checksum sent with each packet (known as the Frame Check Sequence, Section 27.2.7) and de-framing the received packet.

27.2.3 Epoch Structure

An epoch based scheme is used to separate transmission signals over a time-shared medium. The RF Network implements an epoch based transmission scheduling scheme to provide an efficient utilization over a shared bandwidth. Link management messages support dynamic adjustment of the epoch schedule being utilized by components comprising a RF Network.

27.2.4 Transmission Opportunities (TxOps)

A transmission opportunity (TxOp) is a time allocated opportunity for a radio to transmit data. A TxOp is a window in time over which a radio may transmit over its associated RF interface. The TxOp contains a frequency, a start time and a stop time that is relative to the epoch, and a timeout field that indicates the number of consecutive epochs that the TxOp is valid for. The frequency associated with the TxOp is the carrier frequency at which the transceiver shall transmit on for the duration of the TxOp. At the stop time, the transceiver remains tuned to the TxOp’s carrier frequency in order to receive incoming transmissions at the frequency. The epoch is settable to a number of discrete times during radio initialization.

27.2.5 Timing

The RF link management and all radios under its control shall have their clocks synchronized. The timing of access to the RF media shall be synchronized to and match the timing with the management layer described in Chapter 22. The format of the time in RF Network Messages is defined in Chapter 24.

27.2.6 Radio Link State Non-Volatile Storage

Operating parameters of a radio shall be stored to maintain communications with RF link management after a power interruption or software initiated reset. Parameters to be stored include as a minimum the operating frequency of the radio, the TxOp allocations that contain a non-expiring timeout setting, and the heartbeat value.

27.2.7 Frame Check Sequence (FCS)

The FCS contained at the end of an RF MAC frame shall serve as a link layer error checking mechanism. The FCS generation and verification is described in Section 27.5.5.

27.2.8 ARQ

TBD

27.3 Physical Layer

The physical layer focuses on describing the operating bands, waveform modulation/demodulation characteristics, carrier stability and synchronization/acquisition characteristics, and coding/decoding techniques. The TmNS capability on the range supports multiple concurrent test missions on one or more iNET frequency channels. The frequency channels available for use in the TmNS network are as defined in section 27.3.1.2. Allowable adjacent channel interference for transmissions is defined in the Section 27.3.2. Each transmission is performed as discrete bursts within start and stop times which are provisioned within a configured epoch time by an external configuration file and/or RF link management as defined in Chapter 28.

Transmissions between radios on test articles and those contained in the ground network shall use the same carrier frequency in both directions. Single carrier frequency usage is supported by employing a time-domain duplex channel access method. In this method radios use re-occurring epoch based transmissions defined by start and stop times which are provisioned by RF link management.

27.3.1 Data Rates and Spectrum

27.3.1.1 Radio Air Data Rates

The data rates and link performance in terms of packet loss rate stated below are provided based on 1000 byte-long Ethernet packet (see Appendix 27B for additional details). Assuming the codeblock error events to be independent, the relation between codeblock error rate (CBER) and packet loss rate (PLR) is then given by CBER = 1 – sqrt(1 - PLR). For example, for a PLR of 1×10^{-4}, the corresponding CBER is 5×10^{-5}.

In order to ensure interoperability, the air data rates that radios shall comply with are detailed in Section 27.3.2.2.2.

Rate requirements can be viewed from various aspects. When viewed from an OSI 7-layer protocol stack perspective, the RF communications link is at Layer-2. This implies that all overhead affiliated with Layers-3 through Layers-7, including any IP and HAIPE headers, are regarded as user data. The effective packet loss rate is referenced to a mean packet size and is described in Appendix 27B.

NOTE The air data rates are derived from a model that assumes a certain IP packet distribution such that the airborne network and throughput goals are met. Details concerning how to get from IP data payload rate to the air data rate are in Appendix 27B.

27.3.1.2 Spectrum

The center frequencies shall be selectable from 4800-4994 MHz. Center frequency selections are available in 250 kHz steps.

27.3.2 Regulatory Specifications, Spectral Mask

27.3.2.1 SOQPSK-TG Single-Carrier Waveform – Spectral Mask

The RF emission spectral mask (Appendix 27A, reference [1]) shall be adopted for the single-carrier waveform. Peak waveform power density for the SOQPSK-TG waveform is estimated to be -25dBc/30kHz using the equation in ref [2] with R_b=20Mbps, K=-61, and m=4.

$$M(f) = -61 + 90logR - 100log|f - f_c|;\ |f - f_c| \geq 5$$

NOTE Figure 27-3 shows a simulated SOQPSK-TG waveform and overlay with single-carrier spectral mask. The power spectra was calculated for 20 Mbps channel bit rate and compared with the continuous stream power spectra for a resolution bandwidth of 30 kHz.

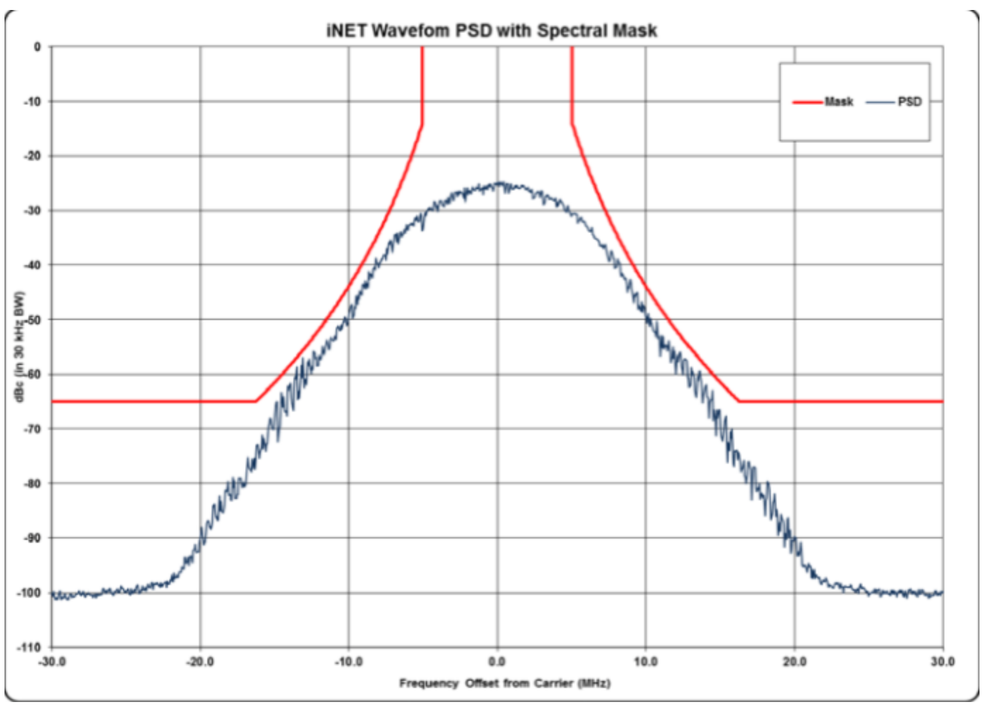


Figure 27-3 – iNET Waveform PSD with Spectral Mask Overlay

See Distribution Statement A

27.3.2.2 SOQPSK-TG Single-Carrier Waveform - Bandwidth

27.3.2.2.1 Occupied Bandwidth

The SOQPSK-TG single-carrier waveform characteristics are defined in [1]. This waveform operating bands are defined in Section 27.3.1.2. The occupied bandwidth (OBW) is defined as the width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage B/2 of the total mean power of a given emission. In this chapter, B/2 is taken as 0.5%, i.e., OBW is the 99% power bandwidth, and it is based on Table A2, Appendix A of reference [2]. Because the OTCR=20Mbps, an OBW of 99% is 15.6 MHz.

The center channel frequency shall be settable to all frequencies within the bands of operation that comply with the regulations and channelization plans contained in the current edition of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management and the guidelines contained in the current edition of the RCC Telemetry Standards.

27.3.2.2.2 Air Information Bit Rate

With the OTCR fixed at 20Mbps, the available rate for a single user is 12,614,370 bits per second. This bitrate is applicable to the Layer 2 rate. Parameters and estimates used to compute the information bit rate for the air interface are provided in Appendix 27B.

27.3.2.2.3 Guard-Bands and Band Edge Spurious Level

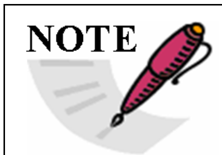
Spurious emissions are limited to -25dBm. Guard-bands are identified via Adjacent Channel Interference criteria as defined in IRIG-106. See Appendix A of IRIG-106.

27.3.2.3 Multiple-Carrier Waveform – Spectral Mask

TBD.

27.3.2.4 Multiple-Carrier Waveform - Bandwidth

TBD.

	Note: Multiple-carrier waveform spectrum is subject to ongoing evaluation.

27.3.3 Carrier and Clock Frequency Error, Phase Noise, Spurs, Receiver Sensitivity

27.3.3.1 SOQPSK-TG Single-Carrier Transmission

27.3.3.1.1 Carrier Frequency Error

The radio carrier frequency error shall be bounded by ±5 ppm. This corresponds to a frequency shift of ±25 kHz at a transmission frequency of 5 GHz.

27.3.3.1.2 Transceiver Phase Noise

Random transceiver phase noise at the transceiver RF output port, $L(|\Delta f|)$ in dBc/Hz, shall not exceed the mask limits in Table 27-1. The parameter $|\Delta f|$ is offset from the carrier frequency and R_b is the radio air channel bit rate in bits per second. The total power in discrete (deterministic) spurious noise components shall not exceed -30 dBc in the same frequency offset range. Compliance with the mask shall be checked while the transceiver is producing an un-modulated continuous carrier signal at both the minimum and maximum power levels available for modulated burst transmission.

Table 27-1 Transceiver Phase Noise Mask

$L(\|\Delta f\|)\ dBc/Hz$	Frequency Offset Range
$-40 - 10\log(\|\Delta f\|)$	$10\ Hz \leq \|\Delta f\| \leq 100\ kHz$
-90	$100\ kHz \leq \|\Delta f\| \leq (R_b \times 0.78)$

The upper limit of the single sideband phase noise described by Table 27-1 is depicted in Figure 27-4.

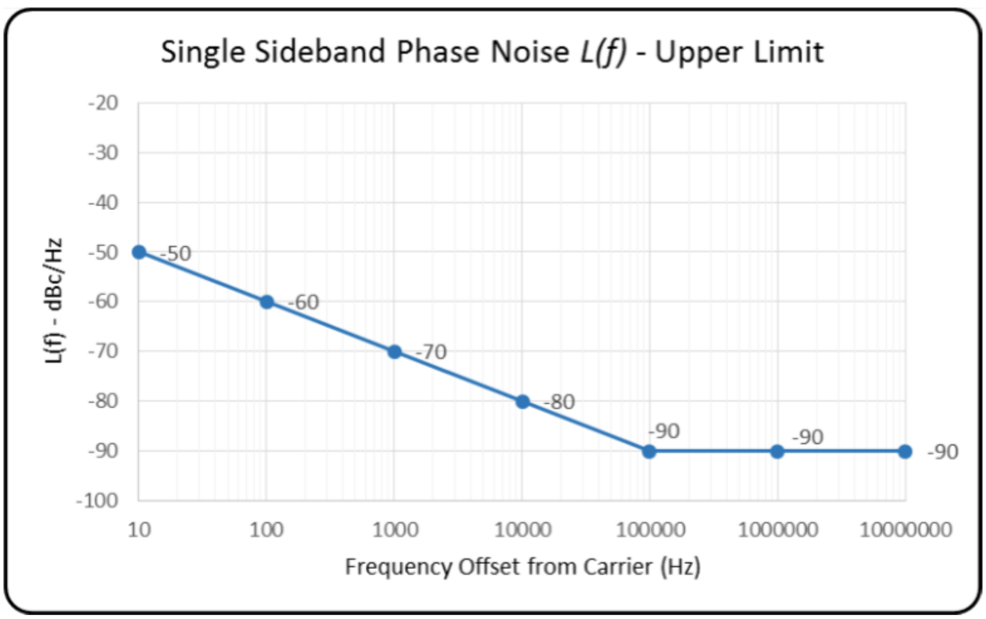


Figure 27-4 – Single Sideband Phase Noise

27.3.3.1.3 Receiver Sensitivity

It is recommended that the sensitivity of the receiver should be no less than -88 dBm at a packet loss rate (PLR) of 1×10^{-4}.

27.3.3.1.4 Frequency Error Attributed to Doppler

The radio transmission frequency error seen at the receiver due to Doppler effects shall be bounded by ±2.5 ppm. This corresponds to a frequency error spread of ±12.5 kHz at a transmission frequency of 5 GHz. This frequency shift due to Doppler effects is budgeted for the combined total of relative motion between two antennas, either between a stationary antenna and a moving antenna or between two moving antennas. The maximum Doppler shift for a set of example carrier frequencies is provided in Table 27-2 below.

Table 27-2 Maximum Doppler Shift

Carrier Frequency	Maximum Doppler Shift (±2.5 ppm)
5 GHz	12.5 kHz
2.4 GHz	6 kHz
1.5 GHz	3.75 kHz

27.3.3.1.5 Symbol Clock Frequency Error

The radio transmission symbol clock frequency error shall be bounded by ±5 ppm.

27.3.3.1.6 Transmission Time Accuracy

The radio transmission shall begin within ±1 μs of the intended transmission time.

27.3.3.2 Multiple-Carrier Transmission

TBD.

NOTE	Note: Multiple-carrier waveform spectrum is subject to ongoing evaluation.

27.4 RF Burst Format

The RF burst format is displayed in Figure 27-5.

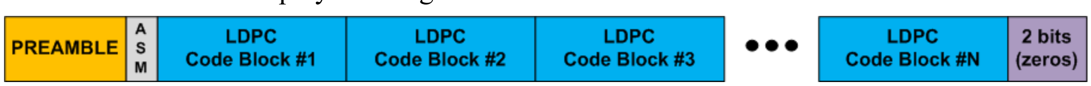


Figure 27-5 - RF Burst Format

27.4.1 Physical Layer Modulation

A single-carrier shaped offset quadrature phase shift keying (SOQPSK) modulation scheme shall be used. The waveform shall be implemented as defined in Section 2.4.3.2 Characteristics of SOQPSK-TG found in reference [1].

27.4.2 Preamble

For the SOQPSK-TG waveform adopted for the single-carrier physical layer modulation format, the burst preamble is formed as described below. Starting from a flushed trellis (00 state), alternate the in-phase (I) and quadrature (Q) bits as follows.

$$\left.\begin{array}{ll}\text{In-phase:} & b_{2k} = 1,0,1,0,1,0,1,0 \\ \text{Quadrature:} & b_{2k+1} = 1,0,1,1,0,1,0,0\end{array}\right\} \text{ for } k = 0,\ldots,7$$

$$\text{repeated } 128/16 = 8 \text{ times}$$

This leads to a period-16 ternary symbol sequence {(k} with the following structure.

$$(\underbrace{+1,+1,+1,+1,+1,+1,+1}_{7\ +1\text{s}},0,\underbrace{-1,-1,-1,-1,-1,-1,-1}_{7\ -1\text{s}},0,\ldots)$$

For a 128-bit preamble, there shall be 8 full cycles of the period-16 preamble present in the transmitted SOQPSK-TG waveform.

27.4.3 Attached Synchronization Marker (ASM)

For codeblock frame synchronization, a 64-bit ASM (64’h0347 76C7 2728 95B0) shall be used for each codeblock frame that consists of an integer multiple, minimum of 1 and up to maximum of 16, of codeblocks. This burst synchronizer can also be used for resolving phase ambiguity at the receiver.

27.4.4 Pseudo-Randomization

The pseudo-random sequence shall be generated using the following polynomial: $h(x) = x^8 + x^7 + x^5 + x^3 + 1$. It has a maximal length of 255 bits with the first 40 bits of the pseudo-random sequence from the generator as 40’b1111 1111 0100 1000 0000 1110 1100 0000 1001 1010. The sequence begins at the first bit of the first codeblock in a codeblock frame, and the sequence repeats after 255 bits, continuing repeatedly until the end of the last codeblock in a codeblock frame. The leftmost bit of the pseudo-random sequence is the first bit to be exclusive- ORed with the first bit of the codeblock. The randomizer is described in more detail in reference [3].

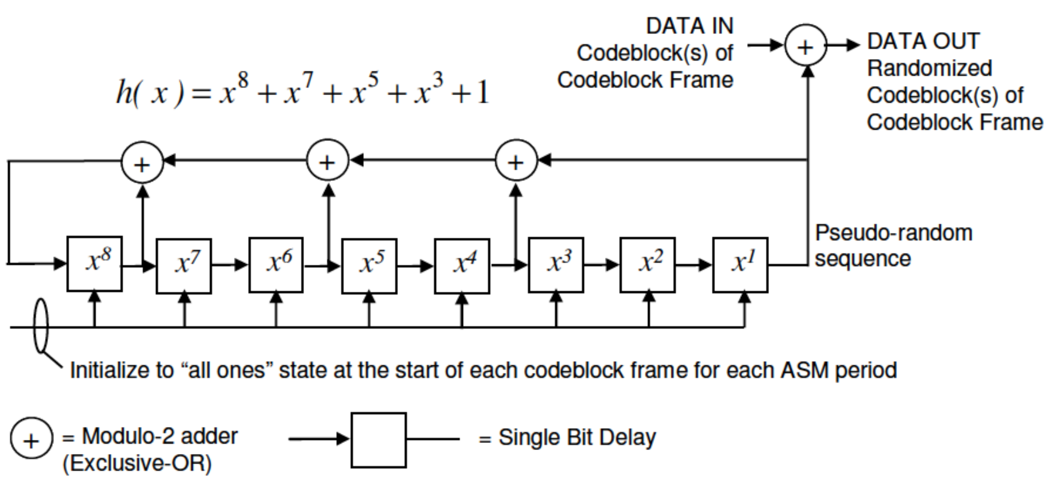


Figure 27-6 - Pseudo-Randomizer

At the transmitter, a set of codeblock(s) in a codeblock frame shall be randomized by exclusive-ORing the first bit of the first codeblock with the first bit of the pseudo-random sequence, followed by the second bit of the first codeblock with the second bit of the pseudo-random sequence, and so on. The pseudo-randomizer resets to the initial state of “all ones” at the start of each codeblock frame for each ASM period.

At the receiver, each original codeblock(s) of a codeblock frame shall be reconstructed using the same pseudo-random sequence. After locating the ASM, the pseudorandom sequence is exclusive-ORed with the received data bits immediately following the ASM. The pseudo-randomizer resets to the initial state of “all ones” at the start of each received codeblock frame for each ASM period.

The ASM, depicted in Figure 27-7, is not randomized. Randomization ensures that coded symbols are spectrally near-white, thus allowing each ASM to provide synchronization for a set of randomized codeblock(s) in a codeblock frame.

At the transmitter side, the ASM is prepended to each set of randomized codeblock(s) as the synchronization header. At the receiver side, the ASM is detected and located in the received data stream. Then the pseudo-random sequence is exclusive-ORed with the data bits immediately following the ASM location.

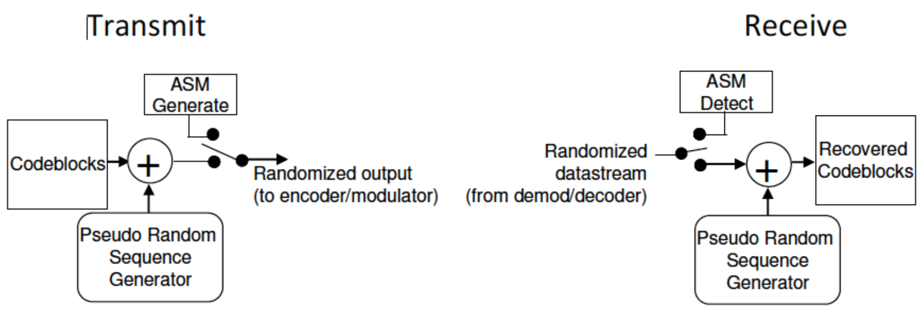


Figure 27-7 - Pseudo-Randomization Block Diagram

27.4.5 Low-Density Parity-Check (LDPC)

Each codeblock shall contain one 512-byte RF MAC frame or, if the RF MAC frame is not 512 bytes, padding bytes with values of zero shall be added after the FCS to fill a 512-byte codeblock before encoding.

The FEC code shall be a Low-Density Parity-Check (LDPC) code as specified in CCSDS 131.1-O-2, September 2007.

27.4.5.1 Encoder Implementation

A reference implementation of the LDPC is available from ref [4] using the values r=2/3 and k=4096.

27.5 RF Media Access Control Frame Structure

The media access control frame structure determines what RF transmissions are received by a receiving radio. The RF MAC filters received traffic, accepting only those RF transmissions that the radio is interested in receiving.

RF Network Message headers for RF MAC control frames contain the destination, source, and a sequence number. The destination address is either a RF MAC address of the destination radio or a RF multicast address which specifies the multicast group of one or more receiving radios. The source address is always the RF MAC address of the transmitting radio. A sequence number is included to allow for duplicate rejection and identification of a specific link layer command.

From a receiver's perspective, the physical layer recovers the transmitted bitstream by decoding and concatenating codeblocks arriving in the TxOps. Each decoded codeblock contains one RF MAC frame.

Each RF MAC frame shall contain an RF MAC header, a CCMP header, an RF MAC payload, a Message Integrity Code (MIC) field, and a 32-bit Frame Check Sequence (FCS). The RF MAC frame format is depicted in Figure 27-8.

Figure 27-8 - RF MAC Frame Structure

RF MAC frame processing shall proceed with an equivalent of the following steps:

1. Codeblock is received, and the LDPC is decoded
2. For successfully decoded LDPCs, the link layer processing checks the FCS.
3. RF MAC frames with correct FCS fields are further inspected for the Destination Address field in the RF MAC header.
4. Further processing is carried out for RF MAC frames that contain a Destination Address for which the receiving radio has been assigned to listen.
    a. If the Protected Frame bit indicates decryption is needed, the link layer processing then decrypts the frame and checks the MIC.
    b. Unencrypted and successfully decrypted RF MAC payloads are processed as network data as described in Chapter 28.

Rejection at any of the steps described above does not require further processing, and the RF MAC frame shall be discarded. However, statistics for discarded RF MAC frames shall be maintained as described in Chapter 25.

27.5.1 RF MAC Header

The RF MAC header is 64 bits long and shall consist of the fields as shown in Figure 27-9.

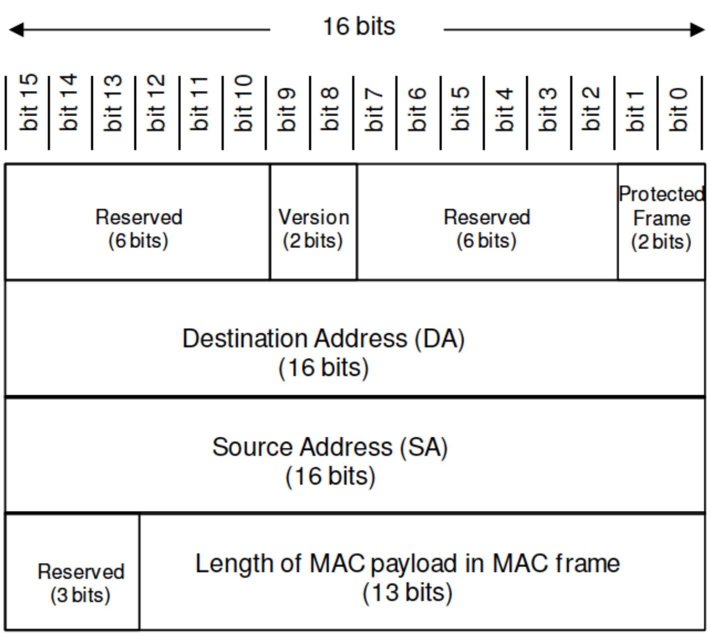


Figure 27-9 - RF MAC Header Structure

NOTE	In the future, it may be desirable to have a MAC frame that spans 1-16 codeblocks. To provide for this future capability, the LEN field in the MAC header is large enough to accommodate values up to 8192, i.e., [0 .. 8124] bytes (maximum of 16 codeblocks).

27.5.1.1 Frame Control

The Frame Control field of the RF MAC Header is 16-bit in length and shall contain the fields defined in Sections 27.5.1.1.1 through 27.5.1.1.4.

27.5.1.1.1 Reserved Field 1 (6 bits)

This field is reserved for future use. All bits shall be set to zero (6’b000000) on transmission; ignored on reception.

27.5.1.1.2 Version Field (2 bits)

This field specifies the version of the RF MAC Frame. This chapter defines the following versions:

- RF MAC Frame Version 1 (i.e., 2’b01)

27.5.1.1.3 Reserved Field 2 (6 bits)

This field is reserved for future use. All bits shall be set to zero (6’b000000) on transmission; ignored on reception.

27.5.1.1.4 Protected Frame Field (2 bits)

This field indicates whether or not the RF MAC Payload is encrypted. Transmitters shall set this field according to its configuration provided through an MDL file. Receivers shall use this field to determine how to process the RF MAC Payload.

This chapter defines the following versions:

- 2’b00 – Unprotected Frame
- 2’b01 – AES-CCMP
- 2’b10 – Reserved for future use
- 2’b11 – Reserved for future use

27.5.1.2 Destination Address (16 bits)

This 16-bit field contains the RF MAC address of the next hop destination radio or multicast RF MAC address. Additional details of RF MAC addressing are found in Chapter 28.

27.5.1.3 Source Address (16 bits)

This 16-bit field contains the RF MAC address of the transmitting radio. Additional details of RF MAC addressing are found in Chapter 28.

27.5.1.4 Reserved (3 bits)

This 3-bit field is reserved for future use. On transmission, the transmitting radio shall set this field to 3’b000. On reception, the receiving radio shall ignore these bits.

27.5.1.5 Length (13 bits)

This 13-bit field contains the length in bytes of the RF MAC payload in the RF MAC frame. This value does not include the length of the RF MAC Header or the associated frame check sequence (FCS). The valid range for this field is [0 .. 500].

The Length field in the RF MAC header is used to separate valid bytes from padding bytes in the RF MAC frame. If there are valid bytes in the RF MAC payload, the first fragmentation/packing sub-header (FPSH) is checked for the priority and length of the subsequent MSDU_block. The FPSH and its MSDU_block are then passed for further processing (if ARQ is enabled, then it is passed to the appropriate priority ARQ protocol for further processing). While valid bytes remain in the RF MAC payload, the next FPSH is checked and processing continues as above. Any padding bytes are discarded. Processing of bits within the RF MAC Payload are described in detail in Chapter 28.

27.5.2 CCMP Header

AN 8-byte CCMP header shall follow immediately after the RF MAC Header.

When AES encryption is employed, AES-CCMP encryption shall be used to generate the CCMP header, the encrypted payload, and the MIC. The CCMP Header, encryption, and MIC shall follow the recommendations described in NIST SP 800-97.

When AES encryption is not employed, the CCMP header field shall be set to zero (64’h0000 0000 0000 0000) for transmission; ignored on reception.

27.5.3 RF MAC Payload

The payload shall be encrypted or unencrypted according to the Protected Frame field of the RF MAC Header. The length of the payload shall be in the range of 0-500 bytes.

If encryption is enabled, the AES-CCMP process shall be used to generate the CCMP header.

27.5.4 Message Integrity Code

An 8-byte Message Integrity Code (MIC) is used. Details of the MIC are described NIST SP 800-97.

When AES encryption is not employed, the MIC field shall be set to zero (64’h0000) for transmission; ignored on reception.

27.5.5 Frame Check Sequence Field

A 32-bit frame check sequence, designated as FCS, shall be computed over the entire MAC frame, including the MAC header and the entire MAC payload (encrypted or unencrypted), using the IEEE 802.3 CRC-32 polynomial below:

$$x^{32}+ x^{26}+ x^{23}+ x^{22}+ x^{16}+x^{12}+ x^{11}+ x^{10}+ x^{8}+ x^{7}+x^{5}+ x^{4}+ x^{2}+ x+1.$$

27.6 Power Transients

27.6.1 Radio RF Power Transients Within a TxOp Allocation

A radio shall become capable of full power transmission 25 uS after the radio finishes receiving a transmission intended for it. Once a radio has ceased transmitting, the radio shall disable its transmission and be ready within 15 uS to receive a transmission from another radio using default modulation modes and burst rates. A radio shall be capable of receiving consecutive symbol-synchronous burst sequences with no time separation between burst sequences. Figure 27-10 provides an example TxOp timing allocation diagram that highlights the allowable transition times for the transceiver to transition between receiving and transmitting and vice versa. Any ramp up or ramp down times associated with a radio shall occur during the TxOp allocation of the radio. When a radio is not executing a TxOp, it shall be listening for RF transmissions from other radios.

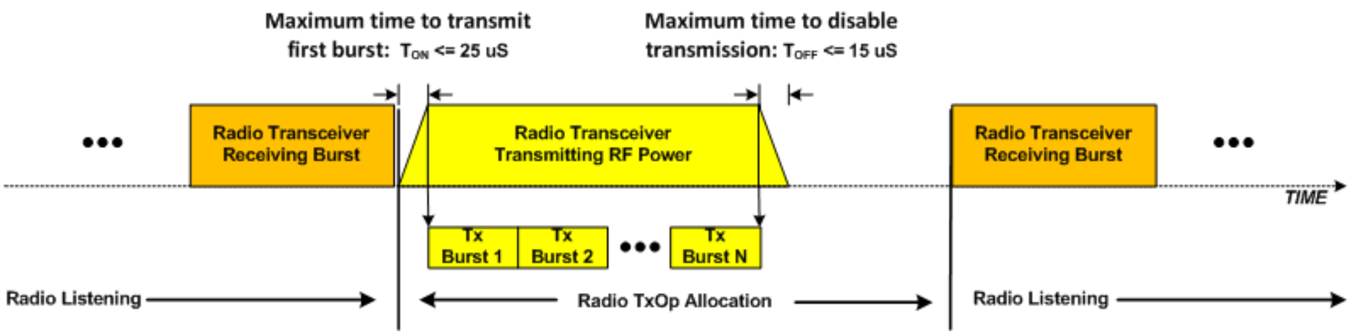


Figure 27-10 - Example TxOp Timing of a Single TxOp Allocation

In the example provided in Figure 27-10, the transmitting radio turned off its transmitter prior to the end of its TxOp allocation. If no additional data is available to send, a radio shall stop transmitting RF power.

Figure 27-11 provides an example of another example TxOp timing allocation. This particular example shows two back-to-back TxOp allocations for the same source radio. A radio is not required to shut down its power amplifier if its next allocated TxOp immediately follows the current one.

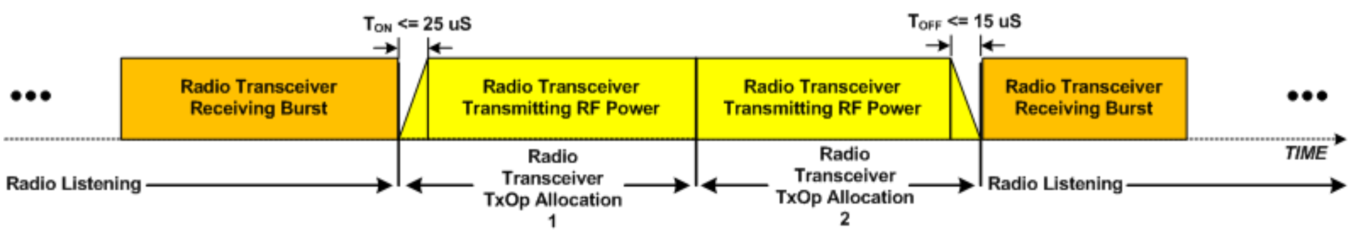


Figure 27-11 - Example TxOp Timing of Two Back-to-Back TxOp Allocations

APPENDIX 27A. REFERENCES

Range Commanders Council (RCC) Telemetry Group:

[1] Inter-Range Instrumentation Group Standards (IRIG) Standard 106 Chapter 2 of Range Commanders Council

[2] Inter-Range Instrumentation Group Standards (IRIG) Standard 106 Appendix A of Range Commanders Council

[3] TM Synchronization and Channel Coding, Blue Book, CCSDS 131.0-B-1, Chapter 7

[4] Inter-Range Instrumentation Group Standards (IRIG) Standard 106 Appendix R of Range Commanders Council

APPENDIX 27B. AIR DATA RATE MODEL

Calculations leading to the Standardized Air Data Rate for the RF Network are based on two spreadsheets. These spreadsheets move from an expected distribution of data use at the application level of the OSI model down through the details of each of the layers leading to the physical layer. Descriptions of the spreadsheets are provided below. While this path concerning the choices made is not directly part of this chapter, the spreadsheets are retained due to their usefulness in explaining the overhead and transformations that occurs at each layer of the overall stack.

Chapter_27_Appen
dixB1_TmNS_Data_

Chapter27_AppendixB1_TmNS_Data_Rate_Calculations.xls

- Three Tabs
  - FTP – RC – TCP
    - Just under “assumptions” are a set of cells that can be used as “knobs” to consider “what if” kinds of questions
    - The “User Data Rate” knob should be set to match the other spreadsheet (RANS.xls – see details below). It may be nice to connect these two together in the future. But, the evolution process may be smoother while the TmNS RF Network defined in this chapter and system specifications continue to be actively updated.
    - The combined use of the “TxOPs “per second and “TxOP size” allow for a way of slicing up the channel with respect to time – that is taking into account the TDMA. The current settings 10 and 100 basically say there is no slicing and there is no time reserved for guarding. That is, it is turned off. I have turned it off because a similar concept is found in the RANS.xls spreadsheet.
    - “Effective bit rate available to IP” really isn’t a knob (whoops). It allows for the calculation of the portion of the channel that is not available for this transfer since a TxOP is not active.
    - TCP is the underlying protocol of FTP and RC transfers. TCP is bidirectional. The ACKs must come back. The spreadsheet assumes perfectly efficient TxOPs of just the right length and at just the right time such that the radio pair performing the transfer will never leave any ‘dead air’. This could be done statically with no Link Manager (LM) being required or dynamically, but the static situation would be very contrived because any other network load would mess up the balance. The spreadsheet makes no assumptions concerning how or when the TxOP scheduling is done. Rather, it just assumes they are a perfect match to the TCP transfer underway and thereby allow for the needed opportunities to send the ACKs back.
    - The HAIPIE overhead is assumed to not require an FPL. Performance goes down if FPLs are required.
    - The spreadsheet assumes that the TCP window size has adjusted itself to be the perfect size. Time and performance during the adjustment period has been ignored.
    - The summary columns “Overhead” and “Ohd %” are based on the round trip communication for each TCP/IP Frame.
    - The “Transfer Rate” at the bottom of the sheet is a summary of the steady state data rate that can be transferred under these assumptions with the knobs set the way they are currently. That is, FTP transfer time for large file (assuming the network is the limiting rate) could be calculated by dividing the file size by the “transfer rate”. I have adjusted the “user data rate” knob in order to get the transfer rate up to TCRD value of about 8. This in turn says that the “user data rate” that must be support by the calculations described in the RANS.xls spreadsheet is about 9.3.

- LTC
    - This sheet shows the transfer performance of single directional LTC transfers utilizing UDP as the underlying mechanism.
    - Almost everything is the same with respect to knobs and outputs here.
    - FPL is shown here as well as the option of it not being required since it can really change efficiency dramatically.
    - A variety of "Acq Data" size values are show. "Acq Data" is only meant to be stuff that sensors have read. It does not include TmNS message or package headers or other overhead. The further overhead items are shown and added in explicitly and not considered as part of the "information" being transferred. Only one package header is assumed per message.
    - As is expected, under the depicted very optimistic assumptions LTC transfers of just the right size will be more efficient than TCP transfers.
- SM
    - This sheet shows the transfer performance of the bidirectional UDP SNMP transfers that SM will use.
    - While UDP is utilized by the SNMP it is bidirectional and thus the SNMP acknowledgement PDUs are taken into account.
    - Traps are not evaluated
    - No FPL is considered
    - The spreadsheet assumes no retries are needed

Chapter_27_AppendixB2_RANS.xlsx

Chapter27_AppendixB2_RANS.xls

- Many tabs, two described below
    - OH -SC SOQPSK (threshold)
        - "Required per radio air CH user data rate" needs to match the rates from the sheets described above.
        - Updates have been made for some of the parameters and equations to more closely match what is believed will come out in the updated IRIG 106 chapters and specifications, but it is likely some things have been missed or even done in a fashion that does not match.
        - I have adjusted the Number of codeblocks per codeblock frame "knob" (C8) to 1 as a matter of experimenting.

    - GS->TA (same CH, w UL LNA) is
        - Small dish – block 1
        - Updated to have the power and air bit rate that has been decided at the program level
        - Likewise for distance