ALERT2™ AirLink Protocol Specification

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Version 1.2

ALERT2™ Protocol Technical Working Group - Technical Working Group of the Standards and Guidance Committee of the National Hydrologic Warning Council

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Acknowledgement

The ALERT2™ AirLink Layer Protocol Specification is derived from the *Final Report of the Prototype Reference Design of an Open Source High Bit Rate RF Modem* by R. Chris Roark, January 28, 2008.

1 Overview

This document contains the specification for Version 1.2 of the AirLink layer of the ALERT2™ protocol suite. ALERT2™ is the next generation successor to the ALERT (Automated Local Evaluation in Real Time) protocol, widely in use for the transmission of hydrologic and meteorologic data used to support flood preparedness and public safety decision making. The ALERT2™ protocol suite is optimized for the connectionless transmission of short messages by radio, and offers improved channel efficiency, greater flexibility, error detection and forward error correction, and many other features not available in ALERT.

The need to meet three primary criteria of the existing ALERT community drove the development of the ALERT2™ protocol, and in particular, the AirLink Layer. These three criteria are:

1. The protocol must reside in the public domain, and not require proprietary methods or services.
2. The protocol must provide a common air interface, i.e. the "on-the air" modulation and framing is compatible with multiple brands of commercial, off-the-shelf radio transceivers readily available to manufacturers, system integrators and users.
3. The protocol must address the limitations of ALERT – primarily low channel capacity and high data loss – while providing bit and packet error rate performance equal to or better than legacy 300 bps ALERT.

This document is intended primarily for those interested in implementing the ALERT2™ protocols in software and hardware.

1.1 Protocol Architecture

The ALERT2™ protocol suite has a three-layer architecture.

The Application Layer supports the encoding and decoding of data into and out of formats and structures used by ALERT2™ applications. At the Application Protocol Device (APD), data is formed into structures understood by the receiving application software. Similarly, the MANT Protocol and AirLink Protocol devices add information to the Application data that are understood by other MANT and AirLink Protocol devices respectively. Each layer provides independent functionality and operates asynchronously to the others. Physically, all three layers may be integrated into a single device, or separated into three physical devices. When the MANT Protocol and AirLink Protocol are implemented by a single device it is referred to as an Intelligent Network Device (IND) and its interface is by the Application Layer Application Program Interface (API) specification.

The Network and Transport (MANT) layer provides the addressing, port multiplexing, acknowledgement, and other services to logically transport application and network control data across the ALERT2™ radio network. When the MANT layer receives an Application Protocol Data Unit (PDU) from the Application Protocol Device, it provides the requested services, adds a header to the Application PDU to form a MANT PDU and forwards the MANT PDU to the AirLink layer. When the MANT layer receives a MANT PDU from the AirLink layer, it inspects the attached MANT Header and provides the appropriate services to the PDU, then sends the Application PDUs to the application port on the Application Protocol Device. The MANT layer exchanges information with other MANT layer devices on the network using MANT PDUs to provide network services, configuration and control.

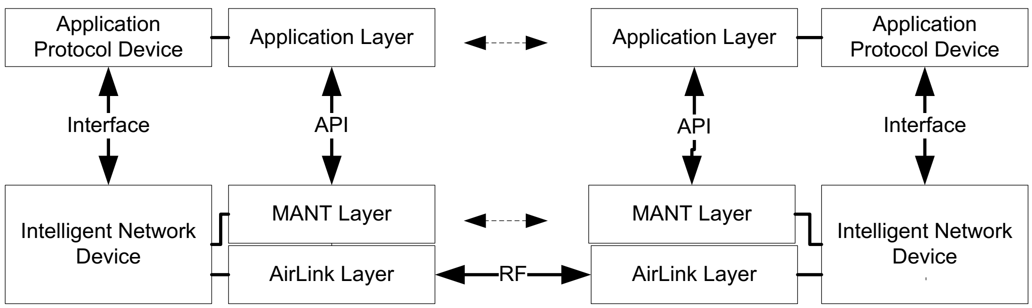

Figure 1-1 ALERT2™ Physical and Logical Architecture

The AirLink Protocol modem transmits the PDUs received from the MANT layer since its last transmission. An AirLink frame is created and transmitted at a time determined by the type of media access selected and that method's configuration parameters. The AirLink Frame is created by aggregating all buffered PDUs, adding an AirLink Header, and blocking, scrambling and forward error correcting this aggregate to form an AirLink Frame Payload. The final AirLink Frame is created by pre-pending a preamble and adding a tail. The AirLink Protocol modem controls an FM transceiver's Push to Talk (PTT) as required and transforms the digital data frame into an analog signal sent to the audio input of an FM radio. An AirLink Protocol modem receives and creates MANT PDUs to send to the MANT layer device by reversing the transmission process. When an AirLink Frame is detected on the RF media, the audio waveform is converted to a bit stream, forward error correction decoded and framed into the MANT PDUs.

Figure1.1 illustrates the flow of data through the protocol layers, and associates them with one possible physical architecture.

1.2 The AirLink Layer

The AirLink encompasses the physical transport of data through the RF medium, including the mechanical, electrical, procedural and functional characteristics to access the physical medium. When put in the context of the ISO 7 layer protocol stack, the AirLink consists of the Physical layer and the lower portions of the Link layer, including Media Access Control and error detection, part of the logical link layer. Figure 1-2 summarizes the AirLink processes.

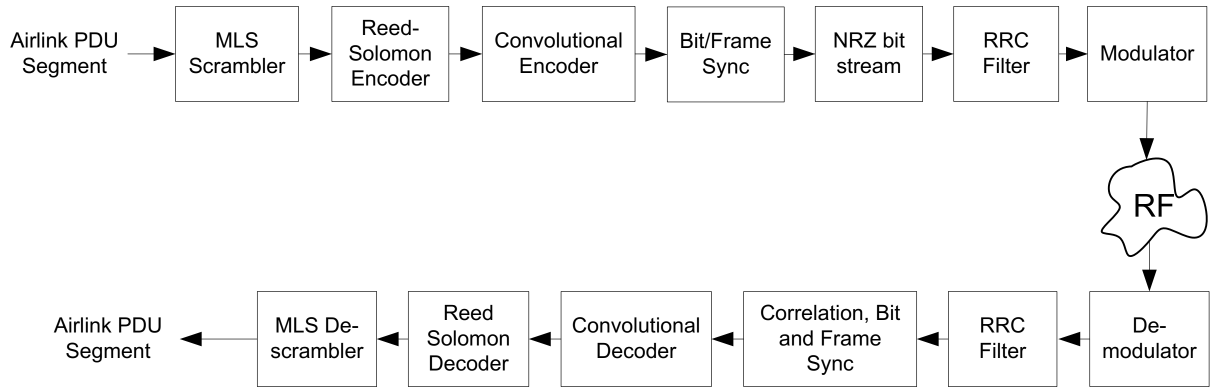

Figure 1-2 AirLink Processes

This specification is split into three sections:

- The Air Interface, providing the very short message capability through a high bit rate and short preamble length;
- The Forward Error Correction and blocking, providing the coding gain necessary to achieve the BER performance goal; and
- The Media Access Protocol, enabling the contentionless ALERT2™ radio network architecture.

The AirLink specification is concerned with the generation of AirLink frames, their transport over a frequency-modulated radio channel, and their demodulation, decoding and reassembly into AirLink Frame Payloads at the receiving end. AirLink frames are formed by control of the power, push-to-talk (PTT) and audio inputs to an FM transceiver. Version 1.2 of the AirLink specification introduces configurable Forward Error Correction levels, allowing more efficient transport of data over radio paths where a higher level of error correction is not required.

This specification defines the AirLink compatible media access, forward error correction, framing and modulation. Unless stated otherwise, discussions of a process for creating the media access, forward error correction, framing and modulation is informational and not normative.

No separate interface specification for the AirLink portion of the ALERT2™ Protocol suite is defined; the AirLink generally is embedded into an ALERT2™ Intelligent Network Device, whose interface is described in the MANT API Specification. The MANT API specification includes the AirLink configuration and informational I/O.

This document discusses the AirLink primarily in the context of two separate devices: an encoder & modulator and a decoder & demodulator. The latter has a significantly greater computational complexity and power demand than the encoder. Integration of the two into a single cost-effective modem/IND is desirable, however, and nothing in the descriptions or standards in this document is intended to prohibit such an implementation.

2 Air Interface and AirLink Frame

2.1 AirLink Frame

The ALERT2™ AirLink frame is the entire transmitted packet, from exertion of Push-to-Talk (PTT) to the end of the RF transmission.

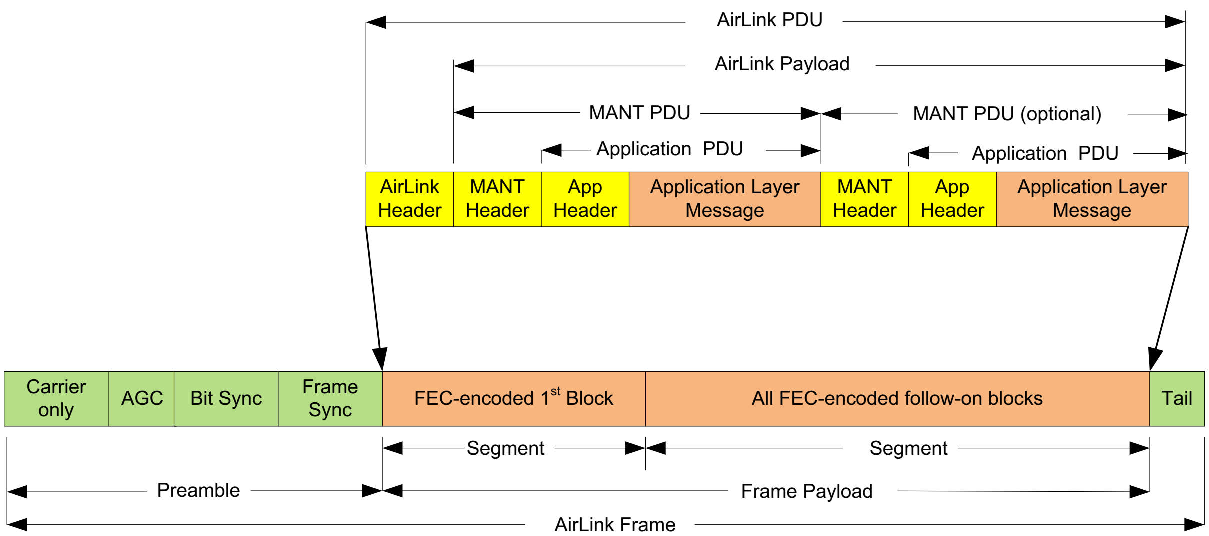

Figure 2-1 AirLink Terminology

Figure 2-1 shows the AirLink frame structure and terminology. The frame-building process begins with the Application Layer, which encodes the data to be sent and adds a header to form the Application PDU. It is exported to the MANT Layer, which performs addressing, network and timestamp services and adds the MANT header to create the MANT PDU. This is handed off to the AirLink Layer as the AirLink Payload, and the AirLink adds its own header. The resulting AirLink PDU is divided into blocks for Reed-Solomon FEC encoding, with the R-S parity bytes added at the end each R-S block. The first block is convolutionally coded separately from all the other blocks to create two segments. This expanded form of the AirLink PDU is referred to as the Frame Payload. The preamble is pre-pended to the Frame Payload, which is transmitted in a continuous bit stream ending with a short carrier-only tail.

Figure 2-2 shows the physical AirLink frame in the time domain. PTT is exerted to initiate transmissions of an unmodulated carrier signal. Next a 2000 to 2500 Hz tone is placed on the audio input to enable AGC lock at the receiver. This is followed by placing the analog signal, consisting of bit sync, frame sync and the FEC-encoded AirLink Frame Payload, all clocked onto the audio input at 4800 bits per second. A 1 millisecond unmodulated carrier tail is typically sufficient to ensure complete message reception.

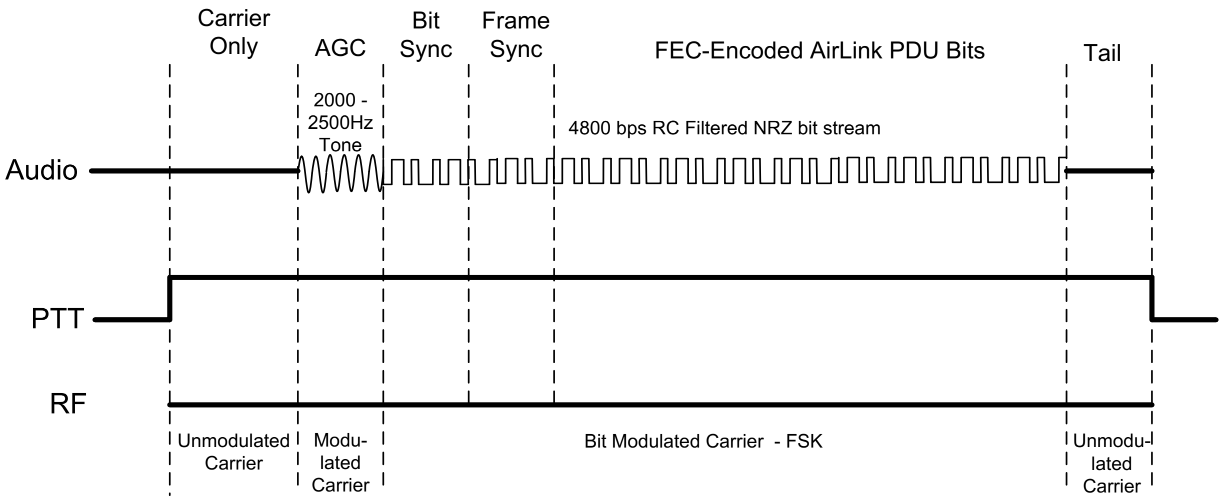

Figure 2-2 The AirLink Physical Signal

2.2 Preamble

The preamble's data elements are pre-pended to the AirLink Frame Payload (the AirLink PDU after the PDU has been bit scrambled and forward error correction (FEC) encoded).

2.2.1 Unmodulated Carrier

The preamble may begin with unmodulated carrier, or this may be omitted and the preamble may begin with the AGC step.

2.2.2 Automatic Gain Control (AGC)

To achieve AGC lock at the receiver, the unmodulated carrier is followed by a period of tone-modulated carrier. Typical durations range from 25 to 70 milliseconds although some site configurations may require a longer time. The tone shall be in the range 2000 to 2500 Hz.

2.2.3 Bit Synchronization and Correlation

Following the AGC tone-modulated carrier, the signal detection and bit synchronization modulated carrier must be transmitted. The carrier must be FM modulated, according to the FM modulation specified below, with a 48 bit synchronization pattern (also referred to herein as the correlation pattern) which must be the concatenation of the following:

- The NASA standard 16 bit frame synchronization pattern 0xEB90 (Consultative Committee for Space Data Systems, 2006)
- The CCIR Report M.903-2 standard 16 bit sync pattern 0xB433 (International Telecommunications Union - Radiocommunication Sector, 1990)
- 16 bits of alternating '1's and '0's: 0xAAAA.

The complete pattern is:

0xEB90B433AAAA.

The bit sequence must be transmitted most significant bit of each byte transmitted first, and the most significant byte (left most) must be transmitted first.

2.2.4 Frame Synchronization

Following the bit synchronization and correlation a frame synchronization pattern modulated carrier must be transmitted. The carrier must be FM modulated, according to the FM modulation as specified below, with a 32-bit (4-byte) pattern that defines the forward error correction scheme used in the AirLink frame.

FEC Mode	Frame Sync Sequence
0	0x352E F853
1	0x5898 233E
2	0xEE43 4E88

Figure 2-3 Frame Sync Sequences

The frame synchronization sequence for FEC Mode 0 is derived from the Consultative Committee for Space Data Systems (CCSDS) Attached Sync Marker (ASM) for Embedded Data Streams pattern (Consultative Committee for Space Data Systems, June, 2001). The sequences for FEC Modes 1 and 2 were chosen to ensure a significant number of bit differences between any two of the three sequences.

The bit sequence must be transmitted most significant bit of each byte transmitted first, and the most significant byte (left most) must be transmitted first.

2.2.5 Bit Synchronous

The transmission is bit synchronous, i.e. there must be no "start" or "stop" or other bits framing the bytes. Additionally, there must be no gaps or framing separators between blocks.

It is recommended that bits be parsed from the received signal using a bit clock recovered from the bit stream itself, and that some form of bit clock recovery algorithm be designed into the demodulator to allow correct decoding with mismatches in system clocks. The first Frame Payload bit must immediately follow the Frame Synchronization pattern. The parsing of bits into bytes and bytes into blocks must be done based on the defined Frame Payload structure that starts immediately following the frame synchronization bit sequence.

The Frame Payload bits modulate the FM carrier as specified below and the Frame Payload must be transmitted most significant bit of each byte transmitted first, and the most significant byte (left most) must be transmitted first.

2.3 Modulation

The air interface RF modulation is frequency shift keying (FSK). An analog waveform is derived from the preamble synchronization and Frame Payload bits. This waveform must be used to frequency modulate the carrier. The waveform is designed to interface to the audio input of a commercial off-the-shelf (COTS) FM transceiver. The analog voltage level must be adjustable to allow an AirLink layer device to interface the various "standard" COTS FM transceiver audio inputs' requirements.

The data bits must be presented to the modulator most significant bit first beginning with the most significant byte of the preamble (i.e. the 0xE byte of the bit synchronization pattern), in a continuous stream as a non return to zero (NRZ) bit stream.

The data bits must be shifted out at 4800 bps, +/- 3%.

The analog modulating signal must be the output of the NRZ bit stream after filtering with a pulse shaping root raised cosine filter. The filter must have a frequency response defined by the square root of the absolute value of the following frequency response function:

$$H(f) = \begin{cases} T, & |f| \leq \frac{1-\beta}{2T} \\ \frac{T}{2}\left[1 + \cos\left(\frac{\pi T}{\beta}\left[|f| - \frac{1-\beta}{2T}\right]\right)\right], & \frac{1-\beta}{2T} < |f| \leq \frac{1+\beta}{2T} \\ 0, & \text{otherwise} \end{cases}$$

$$0 \leq \beta \leq 1$$

Where T shall be 1/4800 seconds and beta is 0.96. The filter specified will have an impulse response of:

$$h(t) = \begin{cases} 1 - \beta + 4\dfrac{\beta}{\pi}, & t = 0 \\ \dfrac{\beta}{\sqrt{2}}\left[\left(1+\dfrac{2}{\pi}\right)\sin\left(\dfrac{\pi}{4\beta}\right) + \left(1-\dfrac{2}{\pi}\right)\cos\left(\dfrac{\pi}{4\beta}\right)\right], & t = \pm\dfrac{T_s}{4\beta} \\ \dfrac{\sin\left[\pi\dfrac{t}{T_s}(1-\beta)\right] + 4\beta\dfrac{t}{T_s}\cos\left[\pi\dfrac{t}{T_s}(1+\beta)\right]}{\pi\dfrac{t}{T_s}\left[1-\left(4\beta\dfrac{t}{T_s}\right)^2\right]}, & \text{otherwise} \end{cases}$$

It is recommended that the filtering be implemented with a digital Finite Infinite Response (FIR) filter.

The root raised cosine filter is equivalently specified by a FIR filter with the following characteristics:

- 71 order;
- With a sample rate of 43.2 kHz;
- A multiply and accumulate (MAC) register of 32 bits, with rounding to a 16 bit value at the conclusion of each sample;
- Using the following16 bit filter coefficients, expressed as Q15 format integers, listed first to last: left to right, top to bottom:

16-Bit FIR Filter Coefficients							
-18	-9	5	18	23	17	1	-17
-31	-33	-19	5	31	45	38	11
-30	-65	-77	-54	1	70	122	124
55	-76	-228	-332	-302	-62	431	1163
2062	3001	3827	4394	4595	4394	3827	3001
2062	1163	431	-62	-302	-332	-228	-76
55	124	122	70	1	-54	-77	-65
-30	11	38	45	31	5	-19	-33
-31	-17	1	17	23	18	5	-9

Figure 2-4 FIR Filter Coefficients

- With the 16 bit FIR filter output converted to an analog output using a 12 bit digital to analog converter (DAC), with +/- 1 bit nonlinearity, 0.5% reference accuracy and with a settling time of 15 microseconds (or less); and.
- With a post DAC low pass smoothing filter implemented with the following characteristics:
    - Second-order Butterworth (Q = 1/sqrt(2)), with
    - With a 10 kHz 3 db cut-off frequency, +/- 2%; and.
    - With a Sallen-Key filter topology is recommended.

Analog or other digital filtering techniques may be used to filter the bit stream, so long as the frequency and impulse response match those specified by equation or by the FIR implementation defined above.

The audio output level must be continuously adjustable from +/- 50 millivolts peak to peak to +/- 500 millivolts peak to peak into a 600 ohm load to allow matching the audio output to various the FM transceiver audio inputs.

The output shall be DC coupled to the FM transceiver to minimize DC distortion[1].

For best performance, it is recommended an FM transceiver with good audio low frequency (30 Hz or less) response be used for the ALERT2™ modulation.

[1] Most COTS FM transceivers' audio inputs are already AC coupled.

3 Forward Error Correction, Blocking and Scrambling

The ALERT2™ AirLink Protocol transforms the AirLink PDU to improve the BER and PER performance. It uses a concatenated forward error correction code to provide the equivalent of RF signal gain, called "coding gain". Additionally, to prevent bias in the data stream, the bit stream is "pseudo randomized" to decrease the probability of excessively long runs of '1' or '0' bits in the data.

Since block FEC codes process fixed length blocks, the AirLink PDU is divided into blocks. In order to provide length flexibility, all the block lengths are not equal. The first block transmitted is optimized in length to contain a large percentage of the typical ALERT2™ radio network traffic. The first block also carries the critical AirLink Header, necessary for frame reconstruction. Additional blocks are added when the payload is larger.

3.1 Configurable Forward Error Correction Modes

AirLink version 1.2 supports three levels of forward error correction, each providing a different balance of throughput vs coding gain. Mode 0 provides the highest level of error correction, while Mode 2 provides the greatest throughput. The different modes are summarized in the table below:

Mode	Max MANT Data per Slot Duration (bytes), (35 ms AGC, 1 ms tail, 23 ms pad)			Block Size (first / add'l)	Convolutional Coding	RS Parity Symbols	RX Sensitivity (relative)
	250 ms	500 ms	2000 ms				
0	22	77	377	24 / 32	k=7, r=1/2	16	0dB
1	42	111	523	44 / 44	k=9, r=2/3	20	-1.5dB
2	52	133	625	54 / 54	k=9, r=3/4	20	-2.5dB

Figure 3-1 Forward Error Correction Mode Summary

3.2 AirLink Header

The AirLink header is composed of two control bytes. It is defined in Figure 2.1. The header bytes must be pre-pended before, and must be included in, the FEC encoding process. The bit order is that the most significant bit of the Version is the most significant bit of the most significant byte, and the last bit of the least significant bit of the least significant byte must be the least significant bit of the length field.

The maximum AirLink Payload is 1023 bytes.

Field	Bytes	Bits	Purpose	Notes
Control	2			
		2	Version	Current version is 0
		4	Reserved	Defined as 0000
		10	Length	AirLink Payload Length

Figure 3-2 Control Byte Definition

The value of the Length field must be the count of bytes in the AirLink Payload before any FEC encoding is performed, which is equal to the AirLink PDU minus the AirLink Header length, excluding any "pad bytes" (see below).

3.3 AirLink PDU

The AirLink Payload contains one or more concatenated MANT PDUs. The MANT PDUs must be ordered oldest (first received by the AirLink layer) transmitted first to youngest transmitted last in the AirLink Payload. If the concatenation of the MANT PDUs creates an AirLink Payload greater than the maximum AirLink Payload, the AirLink device shall remove, and not transmit, MANT PDUs from the AirLink Payload, the oldest MANT PDU first, until the payload no longer exceeds the maximum size.

The AirLink PDU shall be formed by pre-pending the AirLink Header to the AirLink Payload. This AirLink PDU must be divided into appropriate data blocks for block FEC encoding and decoding.

The size of the first block and the maximum size of subsequent blocks is determined based on the FEC mode, as follows:

FEC Mode	First Block	Additional Blocks
0	24	32
1	44	44
2	54	54

Figure 3-3 AirLink Block Sizes

The first block must be a fixed length and must include the two AirLink header bytes at the start.

If the length of the AirLink PDU is less than the specified length of the first block, the encoding IND must append "pad bytes" having a value of 0x55 until the first block length matches the specified length.

For AirLink PDUs too large to fit in a single block, follow-on blocks must be formed and must be transmitted in order, following the first block. The maximum size of a follow-on block depends on the FEC mode and is specified in the table above. Each follow-on block must be filled to maximum capacity before appending the next follow-on block. The final follow-on block may be variable length.

Since the first block is of fixed length, any AirLink PDU with length fewer than or equal to the specified length will have the same ‘over-the-air” packet time (and Frame Payload byte length). Also, due to the Reed-Solomon parity bytes appended to each follow-on block regardless of size, a follow-on block carrying a single byte of Payload will have a Frame Payload length of 17 bytes (mode 0) or 21 bytes (mode 1 or 2) prior to convolutional encoding.

3.4 Scrambling

Bit scrambling is used to improve the bit transition density, i.e. to decrease the probability of long strings of ‘0’ or ‘1’ bits which would detrimentally affect the RF modulation. Bit scrambling is done with a recursive Maximal Length Sequence (MLS) encoder - decoder.[2]

Scrambling must be done on each block prior to Reed-Solomon FEC encoding when encoding and the identical specified MLS decoder must be used to de-scramble after FEC decoding. The MLS encoder – decoder must be reinitialized with its preload bit value prior to each block’s encoding and decoding.

The AirLink shall use a 17 bit MLS encoder with a tap polynomial of:

```
X^17 + X^3 + 1
```

to scramble each block prior to any FEC. The shift register shall be preloaded with a starting bit sequence of 00000000000000001b, i.e. where X_1 is set to ‘1’ and all other shift register stages are cleared to ‘0’.

[2] A characteristic of an MLS sequence scrambler is that it will propagate single bit errors into following bits (e.g. increase bit errors), so it is done prior to FEC encoding. Bit scrambling adds no additional overhead and is therefore size neutral.

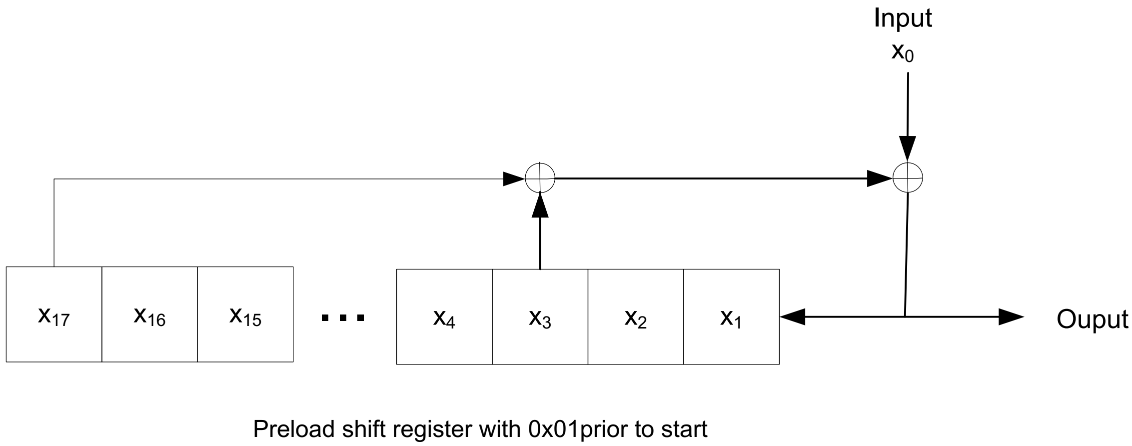

Figure 3-4 Maximal Length Sequence Encoder

3.5 Forward Error Correction

Forward error correction adds significant overhead but provides the coding gain necessary to achieve, at the higher "over-the-air" bit rate, the bit error rates (BER) and packet error rates (PER) comparable to legacy 300 bps ALERT. The scrambled Block Payload is FEC encoded using a concatenated code: a Reed Solomon (R-S) block code followed by a convolutional Code (CC). Three different levels of Forward Error Correction are selectable.

3.5.1 Reed-Solomon Coding

The R-S encoding uses an 8 bit symbol size and corrects up to *t/2* symbol errors per block where *t* is the number of parity symbols. To enhance the coding gain, in FEC mode 0 the ALERT2™ AirLink specifies that all blocks will contain 16 parity symbols and that at most 32 bytes of payload are carried in any block. Mode 0 further limits the size of the critical first block to 24 bytes. In FEC modes 1 and 2, the block size is increased relative to mode 0 and the number of parity symbols is increased from 16 to 20.

The specifications for the AirLink shortened block R-S encoding and decoding for FEC mode 0 are those contained in Section 3.2 of the CCSDS Blue Book (Consultative Committee for Space Data Systems, June, 2001). This reference also contains valuable informative material on the implementation of R-S coding and decoding.[3] One variation from the exact specification provided in the Section 3.2 of the NASA Blue Book is that symbol interleaving shall not be

[3] An Open Source implementation of the R-S encoder and decoder is available from Phil Karn, at http://www.ka9q.net/code/fec/.

performed when performing the AirLink R-S encoding. It is unnecessary because MLS bit scrambling has already been applied.

The AirLink PDU structure and lengths after R-S FEC coding must be:

AirLink Frame Payload Blocking after R-S FEC coding	FEC Mode 0 bytes	FEC Mode 1 bytes	FEC Mode 2 bytes
Fixed first block			
AirLink Header	2	2	2
MANT PDU Data	22	42	52
RS symbols	16	20	20
Total	*40*	*64*	*74*
Follow-On Block			
MANT PDU Data	32	44	54
RS Symbols	16	20	20
Total	*48*	*64*	*74*
Final Block			
MANT PDU Data	1-32	1-44	1-54
RS Symbols	16	20	20
Total	*17-48*	*21-64*	*21-74*

Figure 3-5 AirLink Frame Payload Lengths

3.5.2 Convolutional Coding

In FEC Mode 0, the first block and combined follow-on blocks shall be convolutionally encoded using the NASA standard rate one-half (r = ½), constraint length seven (k=7) code. (Consultative Committee for Space Data Systems, June, 2001) The two encoding patterns used must be 0x6D and 0x4F as shown in Figure 3-6. In FEC Modes 1 and 2, the constraint length is increased to nine (k=9) and the encoding patterns are changed to 0x1AF and 0x11D.

Note that, for consistency with the diagram, the encoding patterns are written reversed from their description in this document.

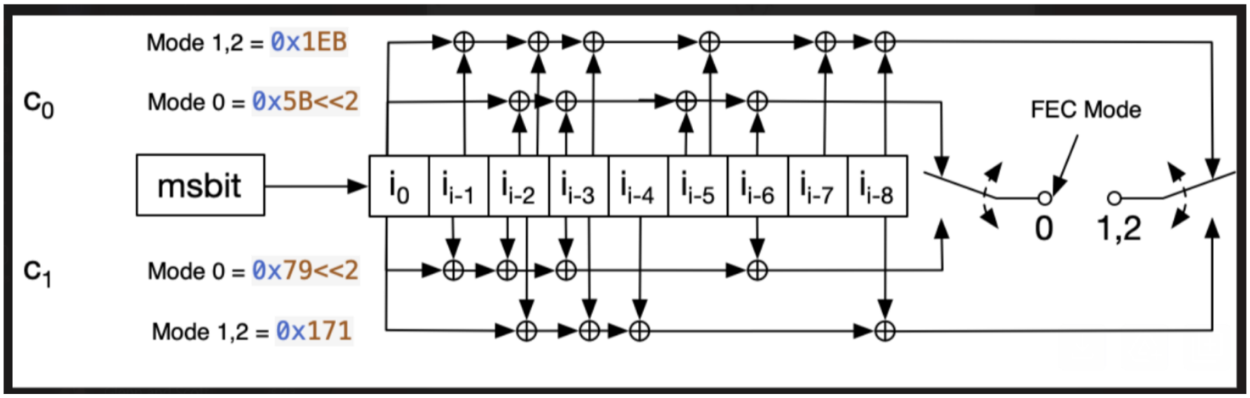

Figure 3-6 Block Diagram Showing Convolutional Encoding

The only variation from the exact NASA specification is that the second output bit must not be inverted. It is not necessary, since bit scrambling was performed prior to CC encoding.

FEC Modes 1 and 2 both use a punctured convolutional code to achieve a lower coding rate than Mode 0. In Mode 0, two bits of output are generated for every bit of input. Mode 1 generates three bits of output for every two bits of input, while Mode 2 generates four bits of output for every three bits of input. Because the puncturing removes some of the bits from the output, it is desirable to use a larger constraint length (sliding window size) of k=9 and a different polynomial. The table below specifies the polynomials and the puncturing matrix used in each FEC mode.

FEC Mode	Polynomial A	Polynomial B	Code Rate	Puncturing Matrix
0	0x6d	0x4f	1/2	1 1
1	0x1af	0x11d	2/3	1 0 1 1
2	0x1af	0x11d	3/4	1 0 1 1 1 0

Figure 3-7 Convolutional Coding Parameters

The puncturing matrix is applied starting with the most significant bit of the transmission, column down then row across. For Mode 1, this results in the removal of the third bit of every four-bit sequence. For Mode 2, the third and sixth bits of every six-bit sequence are removed.

In FEC Modes 1 and 2, if the output of the convolutional coding is not byte aligned, padding bits should be appended in the same manner that they are appended in Mode 0.

The AirLink fixed length first block shall be CC encoded and decoded separately from all the other combined follow-on blocks. When encoding, the convolutional coding tail must be appended to the first block as two bytes, using the most significant bits and with any extra bits cleared. Separate CC encoding of the first block allows real-time decoding of the first block and extracting the AirLink Header. The AirLink Payload length may then be used to control the demodulation process.

All follow-on blocks must be CC encoded and decoded in a single stream, and the CC tail must be appended as the last two bytes of the Frame Payload, where the least significant bits are the unused bits and are cleared.

The AirLink PDU structure and lengths after R-S and Convolutional FEC coding must be:

AirLink Frame Payload Blocking After R-S & Convolutional FEC coding[4]	FEC Mode 0 bytes	FEC Mode 1 bytes	FEC Mode 2 bytes
Fixed first block			
Header	2	2	2
MANT PDU Data	22	42	52
RS symbols	16	20	20
Convolutional code (bytes added)	40	32	24
CC Tail	2	2	2
Total Block Length	*82*	*98*	*100*
Follow-On Block			
MANT PDU Data	32	44	54
RS Symbols	16	20	20
Convolutional code (bytes added)	48	32	24
Total Block Length	*96*	*96*	*98*
Final Block			
MANT PDU Data	1-32	1-44	1-54
RS Symbols	16	20	20
Convolutional code (bytes added)	17-48	11-32	7-24
CC Tail	2	2	2
Total Block Length	*36-98*	*34-98*	*30-100*

Figure 3-8 AirLink Frame Payload Lengths

[4] The Convolutional Code length is useful for discussing the overall payload length, but it should be remembered that there are no separate “convolutional” bytes. The convolutional encoding process transforms a single data bit into multiple bits based on the past history of bits in the payload; the data bits are no longer individually identifiable.

4 Media Access

The ALERT2™ radio network architecture allows for two methods of radio media access: the traditional ALERT ALOHA method and a Time Division Multiple Access (TDMA) method. The recommended access method is TDMA in order to provide a contentionless radio network. It is possible to mix access methods on a single channel, but doing so will reduce the benefits of TDMA.

4.1 ALOHA Method

When configured to provide ALOHA media access, the AirLink Protocol device must initiate the creation of an AirLink Frame upon receipt of a MANT PDU, and must transmit the frame as soon as possible.

After a transmission, another frame must not be transmitted until a 10 second "hold off" time has expired. The hold off time must be measured from the end of the tail of the preceding transmission.

MANT PDUs received during the hold off time, or received after a transmission has begun, must be buffered for transmission at the end of the hold off time.

The AirLink layer device must be capable of buffering MANT PDUs for aggregation and transmission at the end of the hold off time. The buffered MANT PDU must be aggregated and transmitted oldest (first received) first.

4.2 TDMA Method

The AirLink Protocol only specifies a few requirements for the TDMA access method, allowing it to be used effectively for ALERT2™ networks of dramatically differently sizes. Conceptually, a network of transmitters is divided into repeating time frames consisting of time slots, where specific time slots are allocated to transmitters. The frame definition and allocation of slot assignments are not dictated by specification; they depend primarily on the desired latency, number of sensing sites, number of data elements, number of repeaters and expected peak traffic load. By not specifying a defined structure, the AirLink Protocol allows the network designer to utilize sub-framing and varying slot sizes to maximize flexibility.

The AirLink TDMA access method is statically configured; devices' time slot allocations are invariant, unless reconfigured. As with other IND configurations, TDMA reconfiguration may be done by network communication using the MANT Control Protocol.

When configured to provide TDMA media access, the AirLink Protocol device must be capable of buffering MANT PDUs for aggregation and must initiate the creation of an AirLink Frame at its assigned slot time, as specified below.

4.2.1 Slot assignment

It shall be possible to assign an AirLink device a period of time it may initiate a transmission (a slot), and it shall be possible to assign a time interval between the AirLink device's recurring slots (a frame time).

The minimum slot time shall be 250 milliseconds, variable in increments of 250 milliseconds.

The maximum slot time is defined by the maximum AirLink Payload size specification and air interface bit rate.

An individual AirLink device may be assigned multiple slots in a frame, either contiguous or distributed across the frame.

The figure below illustrates these possibilities. It represents a single TDMA 10 second frame with a slot size of 500 msec. Site A is assigned two slots 5 seconds apart, Site N has a 1 second window and Site O has a 2 second window. Twelve other sites have single 500 msec slots each.

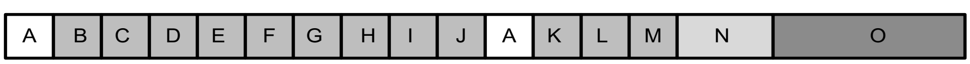

Figure 4-1 Illustration of slot assignments

4.3 Timekeeping

UTC time shall be used. Developers should be aware of the implications of the occurrence of leap seconds. A transmission must not occur on a leap second. In order not to violate the slot occupancy specification, it is incumbent on vendors who time the AirLink device with GPS to prevent any transmission until after a time fix has been obtained at those times a leap second can possibly occur.

4.4 Slot Occupancy

A complete ALERT2 solution must provide mechanisms to ensure that transmissions do not violate slot boundaries. This involves both the AirLink device and the associated APD:

- From the assigned slot duration and the required time buffer size, an APD submitting data to an AirLink device must request or compute the maximum AirLink PDU size and refrain from submitting a PDU that is too large to fit in the allowed transmission period.
- From internal information of expected drift rates and a configurable padding duration that is applied to the beginning and end of the TDMA slot, the AirLink device must compute the maximum time allowable between successful clock updates that will keep messages within the slot boundaries, and if this time is exceeded, the IND must switch to a time of transmission that is randomized across the TDMA frame.

Figure 4-2 illustrates slot occupancy.

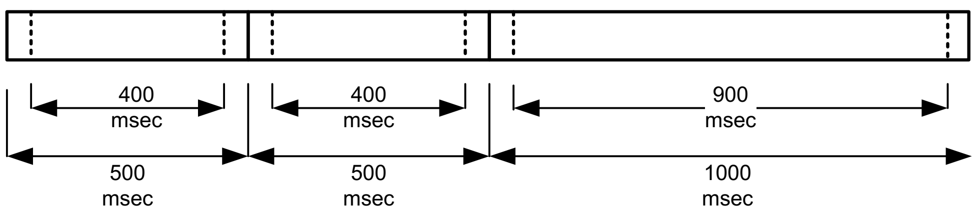

Figure 4-2 Example of slot occupancy

5 Demodulation

There are multiple means to accomplish demodulation, decoding and the reconstruction of the MANT PDUs.

To maximize the probability of recovering all frames on the RF media, the COTS FM radio may be operated in open squelch. For radios that have a long carrier detect or RSSI time constant, this allows the demodulator to continuously search for the bit synchronization pattern in the audio, independent of the radio's carrier detect or received signal strength indicator (RSSI).

One method to determine the end of the frame uses the embedded AirLink Header, decoded in real time, to determine the length of the received AirLink Frame. This method enables the demodulator to also operate with an open squelch radio. Again, this method has the advantage that frame reception is independent of the radio's carrier detect time constant.

Alternatively, depending on the COTS FM radio in use, utilizing the RSSI or CD is a viable method to determine the end of an AirLink frame.

6 Glossary

Abbreviation	Description
Block	The intermediate structure within an AirLink PDU: three types are defined, a first block, a full follow-on block and a partial block.
AirLink Frame	The complete ALERT2™ transmitted package, from exertion of PTT to its release at the end of the transmission.
AirLink Header	Two control bytes at the beginning of the AirLink PDU. It is added by the AirLink layer and contains control information including the length of AirLink Payload that follows.
AirLink Payload	One or more concatenated MANT PDUs contained in a single frame.
AirLink PDU	The complete (not FEC-encoded) data packet that is transmitted in an AirLink Frame
Application PDU	The protocol data unit that is transferred between the application and MANT layers. It consists of 1 or more data reports preceded by the one-byte application header and two-byte timestamp.
Frame Payload	The FEC-encoded (expanded) AirLink PDU; it includes all of the transmitted bits except for bit and frame synchronization.
MANT PDU	The protocol data unit that is transferred between the AirLink and MANT layers; it consists of the Application PDU and the MANT header.
Preamble	That portion of a Frame that precedes the FEC-encoded PDU. It includes unmodulated RF carrier used to allow the FM transceiver to lock (CO time), tone modulated carrier to permit the audio processor's automatic gain control to lock (AGC time), bit synchronization (sometimes referred to as the correlation) pattern bits and the frame synchronization pattern bits.
Segment	The two units of the AirLink PDU which are FEC encoded separately: the first block containing 24 bytes, and the remainder of the PDU encompassing all follow-on blocks.

7 References

Consultative Committee for Space Data Systems. (2006). *TC Synchronization and Channel Coding - Summary of Concept and Rationale CCSDS 230.1-G-1.* Washington DC: Consultative Committee for Space Data Systems.

Consultative Committee for Space Data Systems. (June, 2001). *Telemetry Channel Coding, CCSDS 101.0-B-5.* Washington, DC: National Aeronautics and Space Administration.

International Telecommunications Union - Radiocommunication Sector. (1990). *Report 903-2 Digital Transmission in the Land Mobile Service.* Geneva, Switzerland: International Telecommunications Union.

Sallen, R., & Key, E. (1955). "A Pratical Method of Designing RC Active Filters". *IRE Transactions on Circuit Theory 2 (1)* , 74-85.

8 Revisions

Beginning with Version 1.2, changes to the specification are detailed here

8.1 Version 1.2

- Add configurable forward error correction levels and decrease the minimum slot size to 250ms. By using a different frame sync header for newer messages with lower forward error correction, compatibility with older versions of the standard is maintained. Receivers implementing the older standard will continue to receive FEC mode 0 messages, but will not receive FEC 1 and 2 messages. Newer receivers will receive messages sent from older transmitters.
- Section 2.1 and 2.2: Allow the unmodulated carrier time and RF tail time to be shorter than 5ms. Decrease the typical RF tail time from 5ms to 1ms, which is sufficient to capture the end of the message on commonly used radios. Allow the unmodulated carrier portion of the AirLink preamble to be omitted entirely.
- Section 4.4: Move the responsibility for ensuring that a message does not violate slot boundaries from the AirLink device to the associated APD. In the event that not all data will fit in a TDMA slot, the APD is better positioned to prioritize which data is sent.

The ALERT Version 2 protocol would not have been possible without the dedication, time and energy of members of ALERT2™ Protocol Technical Working Group. The NHWC would like to thank the member organizations that allowed their people to provide their time.

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