Review Comments on:
ALERT2 AirLink Protocol Specification
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1. Introduction

This document contains the author's review comments for the *ALERT2 AirLink Protocol Specification*, Version 1.0, dated May 2010, published by the National Hydrologic Warning Council (NHWC). The primary intent of these comments is twofold: to improve the quality of the specification and to highlight specific technical issues that may warrant additional consideration

This document is organized as follows:

- "General Comments" contains just that: comments that aren't clearly associated with specific sections of the specification.
- "Technical Comments" focuses on the technical aspect of the specification, including instances where the specification appears to be unclear or incomplete, and design decisions that may warrant reexamination.
- "Editorial Comments" includes comments that may help improve the readability and understandability of the specification.
- "Conclusions and Recommendations" contains broad conclusions and recommendations about the specification.

[1] This work was supported by National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Office of Climate, Water and Weather Services under Order Number DG133W10SE3038.
[2] The opinions expressed here are those of the author, and do not necessarily reflect those of any other individual or organization, including those that have funded, are funding, or may in the future fund the author's employer, Salo IT Solutions, Inc.

2. General Comments

The comments in this section relate to the specification as a whole

2.1. Protocol Specifications and Interoperability

These review comments assume that the AirLink protocol specification is intended to ensure interoperability among independent implementations of the specification. That is, if a customer acquires from two different vendors, modems that both conform to the AirLink specification, then the customer can reasonably expect that the modems will operate with each other – the customer can "mix and match" equipment from two or more vendors. A good protocol specification, by this measure, is one that has the technical detail and clarity necessary to ensure that *any* device that conforms to the specification is assured of interoperating with *every* other device that also conforms to the specification. An experienced engineer should be able, based only on the information contained in the protocol specification, to develop a conforming and interoperable implementation.

In practice, writing a good protocol specification is difficult. Based on its experience developing specifications for the Internet protocols, the Internet Engineering Task Force (IETF) requires that at least two independent implementations of important specifications be shown to interoperate before those documents may become "Internet Standards".

2.2. System-Level Description

The AirLink specification would benefit considerably from a more detailed description of what is being specified. In particular, the subsystems and interfaces that the specification describes should be clearly identified. One or more diagrams are probably required.

This reviewer's best guess of the system being described is shown in Figure 1. The specification appears to describe, or in some cases assume, as many as six interfaces.

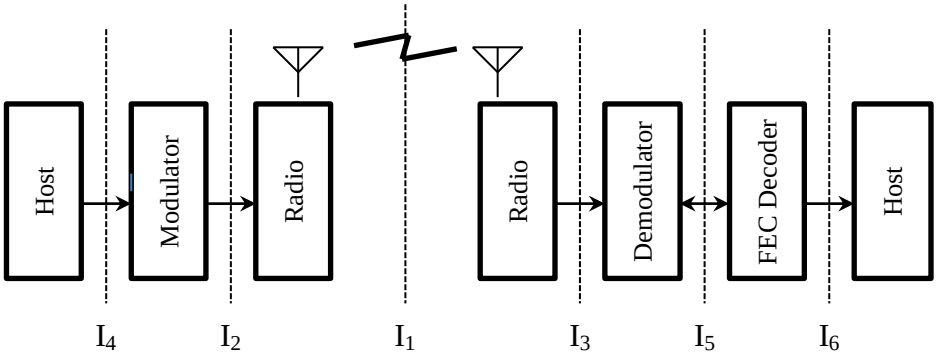

Figure 1. Reviewer's View of AirLink System Components

- I_1 is the AirLink on-the-air protocol, the focus of this specification.

- I_2 and I_3 are physically the audio input and output, respectively, for a voice-grade radio. The AirLink protocol imposes some requirements on these interfaces.

- I_4 is the format of AirLink frames that are transferred across a serial link between a host (e.g., a personal computer) and an AirLink modulator. It appears that neither the format of the AirLink frames nor the requirements of the serial interface are specified.

- I_5 is the bidirectional interface between the AirLink demodulator and the forward error correction (FEC) decoder. The specification of this interface appears to be incomplete. Furthermore, this interface appears to reflect a particular implementation strategy, an issue that is discussed in more detail below.

- I_6 is the interface that passes received AirLink frames to a host. The specification is not clear whether this is a physical interface or a software interface.

I recommend that the AirLink specification contains a system-level overview that clearly describes and delineates the subsystems and interfaces that are part of an AirLink system.

It is important that the boundaries of an AirLink device be clearly specified. For example, the specification should be clear whether, for example, a conformant AirLink device must implement I_5, the interface between the AirLink demodulator and the AirLink FEC decoder. Requiring conformant devices to implement I_5 may, for example, discourage a vendor from combining a demodulator and the FEC decoding functionality into a single device. On the other hand, customers would undoubtedly benefit from a single integrated device. Conversely, not specifying I_5 may reduce interoperability and require customers to purchase a demodulator and a FEC decoder from the same vendor, if the demodulator and FEC decoder must be separate physical devices.

The architecture of AirLink devices described in the specification appears to be somewhat unwieldy. The simplified architecture illustrated in Figure 2 suggests that the modulator, demodulator, and FEC correction functionality should all be combined into one physical device. This would simplify the customers' acquisition, installation, and operation of AirLink devices. Furthermore, this simplified architecture would permit a broader range of implementation approaches.

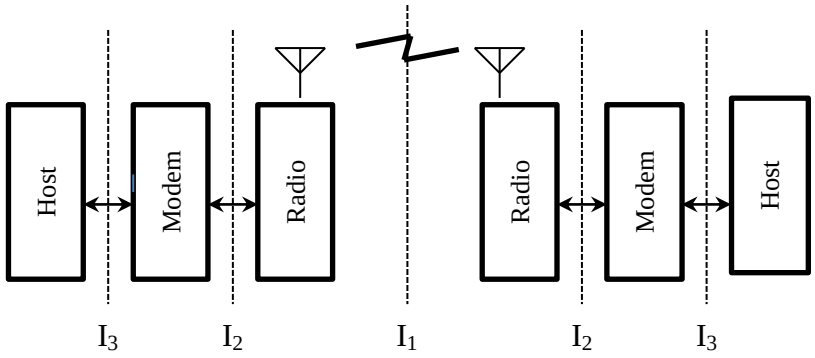

Figure 2. Suggested Hypothetical AirLink Device Architecture.

I suggest that the ALERT2 Protocol Technical Working Group consider specifying the boundaries of AirLink devices such that one device must implement all AirLink functionality, including modulation, demodulation, and FEC decoding. Alternatively, if a conformant AirLink device could implement only modulation, but not demodulation, or the converse, this should be stated explicitly (since is it rather unusual).

2.3. Relationship to Other ALERT2 Specifications

This specification might benefit from referring to, and describing its relationship with, the other ALERT2 protocol specifications. A detailed description of the ALERT2 system architecture would also be beneficial. This overview should identify all of the major subsystems, protocols, and interfaces that are part of the ALERT2 system architecture. A separate, stand-along system overview document might be worthwhile. The AirLink specification should reference the other ALERT2 protocol specifications. It should also describe the relationship between the specifications, using diagrams as necessary.

I recommend that the ALERT2 Protocol Technical Working Group consider writing an ALERT2 architecture document that provides an overview of the ALERT2 system architecture and explains how the various ALERT2 devices and protocols fit into the ALERT2 architecture.

2.4. Missing ALERT2 TDMA Specification

The ALERT2 time division, multiple access (TDMA) protocol is not documented in this specification and does not appear to be documented in any of the currently available ALERT2 protocol specifications. The ALERT2 TDMA protocol is a key component of the ALERT2 architecture – interoperability cannot be assured unless and until it is fully documented. It is particularly important that the ALERT2 TDMA protocol be fully specified, because this protocol will permit an RF channel to be shared between AirLink modems and future, yet-to-be-developed modems, thereby providing a graceful migration path to future technologies. For example, a well-specified TDMA protocol may allow an AirLink network to share an RF channel with 6.25 kHz very narrowband modems or modems that support two-way communications.

I recommend that the ALERT2 TDMA protocol be fully specified, either in the AirLink specification or in a stand-alone specification. Because most devices that implement the AirLink protocol will or should also implement the ALERT2 TDMA protocol, I suggest that the AirLink and ALERT2 TDMA specifications progress through the NHWC standardization process in tandem.

2.5. AirLink Design Objectives

It may be beneficial to summarize the design objectives for the AirLink protocol in this specification. My probably incomplete understanding is that the AirLink design objectives include:

- Bit error rates and/or frame error rates comparable with the original, 300 bits-per-second (bps) ALERT protocol, with no change to the other elements in the RF path (e.g., no increase in antenna gain, transmit power, or receive gain).
- Operation with low-end, voice-grade FM radios.
- Operation with 12.5 kHz channels.
- Avoidance of a need for FCC certification of AirLink modems as intentional radiators (devices such as radio transmitters that are designed to emit RF energy).

If the AirLink protocol is not required to operate with 6.25 kHz, very narrowband channels, or if it is technically infeasible for the AirLink protocol to operate with 6.25 kHz channels, the specification should state as much.

A summary of why commercial, off-the-shelf (COTS) equipment does not meet the needs of the hydrologic warning community might be included.

2.6. Normative versus Informative Language

The AirLink specification should clearly differentiate between normative requirements (requirements that a device *must* meet in order to conform to the specification) and informative descriptions (descriptions that provide background information or suggest implementation strategies, but don't specify requirements). Careful use of terms such as "must" and "shall" is often beneficial.

2.7. Citations and References

This document ought to include the appropriate citations and references. Some indication should be provided as to whether a reference is normative or informative. Documents written by members of the hydrologic warning community should probably be made permanently available on the NHWC website.

2.8. Performance Requirements

Performance requirements ought to be included. Failing to clearly specify performance requirements can lead to interoperability problems. A few of the many performance requirements that ought to be considered include:

- Is there some minimum inter-frame time that a transmitter must ensure between successive frames? Or, must a receiver be able to correctly receive back-to-back frames that are transmitted by the same or different transmitters? Must the FEC decoder be able to decode a long stream of back-to-back frames without dropping any (i.e., must the FEC decoder operate, on average, in real time)? It would be nice to avoid a situation where a customer must manually tune a minimum inter-frame time to avoid overrunning a receiver.

- What speeds must the host-to-modulator, demodulator-to-FEC decoder, and FEC decoder-to-host interfaces support? Must all of these interfaces transparently support 8-bit binary transfers?

- Radio receive-to-transmit turnaround times can have a significant effect on system performance. Should the AirLink specification express an opinion on the desired performance of the transmitter used? (This may requirement may be more appropriate for the TDMA specification.)

2.9. Technical Maturity

Collectively, the three available specifications (ALERT2 AirLink Protocol Specification, ALERT2 MANT Layer Protocol Specification, and ALERT2 Application Layer Protocol Specification) leave the impression that they *may* be snapshots of an evolving system design, rather than a consistent set of specifications. For example, the application-layer protocol specification states that the address of the source node is contained in the *application-layer* protocol, and the MANT specification states that the modem inserts the source address in the *link-layer* header (which presumably the application-layer protocol could use), but the AirLink specification omits any mention of this requirement.

2.10. Alternative Implementation Strategies

This specification explicitly assumes that AirLink modulators and demodulators will be implemented using digital signal processors (DSPs). However, alternative implementation strategies may exist, and may offer the prospect of much less expensive AirLink devices. In particular, at one point, a vendor of modem chips expressed an interest in configuring a modem chip to support the AirLink protocol. The AirLink specification ought to avoid requirements that unnecessarily prevent alternative implementation strategies, such as configuring a modem chip.

I suggest that the AirLink specification be offered for review to a modem chip vendor.

3. Technical Comments

These comments suggest areas where the technical content could be made more complete or clear. In a few instances, these comments suggest specific technical aspects of the proposed technology that may warrant additional examination.

- Page 7. This first section would really benefit from one, or probably several diagrams that illustrate the devices, interfaces, and protocols that are discussed in this specification.

- Page 8. This section doesn't appear to include enough information to ensure interoperability. It is rather confusing and could benefit from reorganization and a rewrite.

- Page 8. I strongly recommend that each field in the AirLink frame be described in a separate paragraph or even a separate section. This format may also highlight missing descriptions.

- Page 8, paragraph 1. "Follow-on blocks are variable length…" seems to conflict with the following sentence.

- Page 8, paragraph 2. With what precision must the transmitter clock the bits? Conversely, how great a clock slew must the receiver be prepared to accept?

- Page 8, Section 2.1. One or more diagrams of the AirLink frame format would considerably enhance the readability of this section.

- Page 8, Section 2.1. Listing the length of frame fields in both time and bits or bytes is fairly distracting. I recommend that field lengths be specified in bytes, except where it is necessary to use some other units (e.g., the RF preamble). From another perspective, I believe that (for the most part) the bit and byte lengths are normative, and the timing information is merely informative.

- Page 8. Please specify what the length field covers. Are only payload bytes included? Is the three-byte AirLink frame header included? Are the forward-error correction (FEC) bytes included? Are the convolutional coding (CC) tail(s) included?

- Page 8. Please describe the AirLink protocol identifier (ALPID). Is this field ignored by the AirLink modem or modulator/demodulator pair? Again, clearly defining the boundaries of the system being specified, and clearly specifying the various interfaces may make it clear whether this field is part of the physical-layer protocol or used by the higher-layer protocols (or, more pedantically, if it is used by a shim between the physical-layer protocol and the higher-layer protocols).

- Page 8. Please specify the status of the reserved bits. Are any of these used currently? Must (or should) the transmitter set them to some value, such as zero? Must (or should) an AirLink 1.0 receiver ignore these bits?

- Page 8, last paragraph. I don't believe that the Reed-Solomon FEC data is properly called "parity".

- Page 8, Section 2.1. The specification of the AGC-lock bit stream is missing.

- Page 9, paragraph 2. What is the relationship between the value of the ALPID field and the length and the size of the follow-on blocks? Must AirLink devices be cognizant of the various ALPID values? If this is the case, this design decision should be revisited. Hardwiring ALPID values within a modem will make it difficult to add new ALPID values. Or, if AirLink modems don't need to be cognizant of ALPID values, the text should be corrected.

- Page 9, last paragraph. Why are these sample on-the-air times for various payload sizes included here? Perhaps, this information would be more appropriate in an informative appendix.

- Page 10. This table tries to do too much and is therefore very confusing. I suggest that this table be replaced by several diagrams and one or more tables. I strongly suggest that the table have separate columns for timing information (msec) and length information (bits or bytes). Some information is better included elsewhere, perhaps as footnotes (e.g., the 4800 bps clock speed, and the parameters for the Reed-Solomon and convolutional coding algorithms). A separate diagram would help communicate how the convolutional coding overhead is spread across the whole block, rather than appended to the end of the block (as the table vaguely suggests).

- Page 11, paragraph 3. A reference, perhaps informative, for maximal length sequence (MLS) encoders would be useful.

- Page 11, paragraph 5. Please provide a normative reference for the NASA Reed-Solomon codes.

- Page 11, last paragraph. Why does the receiver need to decode the ALPID field in order to properly decode the received frame? This specification contains no information about how the value of the ALPID field is used to decode a frame. In the absence of any information about how the ALPID field is used, I have concerns about the wisdom of having an AirLink modem understand the ALPID field. At a minimum, requiring the receiving modem to understand the ALPID field would appear to make it very difficult to add new ALPID values. If this is actually the case, this specification needs to illuminate this issue and discuss the process by which an existing network would be upgraded to use new ALPID values.

- Page 11, last paragraph. Where are ALPID values documented? What is the process of adding ALPID values? How will deployed AirLink modems be affected by new ALPID values? Will they need to be upgraded? How should an AirLink modulator or demodulator respond if it receives an unknown ALPID value?

- Page 13, paragraph 1. Please provide a reference for the NASA frame synchronization pattern.

- Page 13, paragraph 1. Please provide a reference for CCIR Report 903.

- Page 13, paragraph 2. Will AirLink modems work with *any* voice grade FM radio? Or, does the performance of acceptable radios need to be specified? Or, will it be necessary to identify or certify the radios that have been demonstrated to work with AirLink devices or specific AirLink products? What risk will a customer experience if an AirLink device is used with a new radio?

- Page 13, paragraph 3. I think that a carrier must be transmitted first, and then the AGC lock bits.

- Page 13, paragraph 5. How does a customer know whether a certain radio will work with an AirLink device?

- Page 13, paragraph 6. Again, will the customer know in advance whether a particular FM transmitter meets this requirement? How will the customer know if a particular FM transmitter *doesn't* meet this requirement?

- Page 14, paragraph 2. See earlier comments about the desirability, from the perspective of customers, of a single integrated demodulator/FEC decoder. An integrated radio/demodulator/FEC decoder (i.e., a data radio) may be even more beneficial, particularly if AirLink devices are likely to work poorly with some radios.

- Page 14. This information is useful, but describes one possible implementation, and so should probably be clearly labeled as informative.

- Page 14, paragraph 5. A binary stream would be twice as fast as a hexadecimal stream. Perhaps, this should be considered.

- Page 14, paragraph 6. What is the "'return to search mode' command"? What other commands are supported on this interface? What other commands must the FEC decoder use?

- Page 15. The format of the date and time stamp needs to be specified. Is this a fixed format, or must the receiver be prepared to accept a variety of timestamp formats? Is the timestamp a binary field or an ASCII field?

- Page 15. What is the meaning of this time stamp? For example, does this timestamp indicate when the first bit of the first byte of the frame (the byte containing part of the length field) was received? When the last bit, perhaps the last bit of the convolutional code tail was received? When the frame was queued for transmission across a serial interface between the AirLink demodulator and the host? Or, when transmission of the frame started? Or, do more than one of these approaches conform to the AirLink specification?

- Page 15. What requirements are placed on this timestamp? How closely must it be synchronized with, for example, UTC? Or, does the receiver have no assurance that this is synchronized with UTC?

- Page 15. Overall, this frame structure seems pretty unwieldy and much more suitable for a debugging interface. Why should the host have to parse AirLink blocks? Wouldn't the host software be simplified if this was simply passed as one binary stream of contiguous bytes?

- Page 15. What is the format of the RS and CRC error flags?

- Page 15. This is the first mention of a CRC. Is that a typo?

- Page 15. Speaking of CRC, would the inclusion of a CRC in AirLink frames permit receivers to bypass FEC decoding, and rely of a CRC for error detection? I don't know if this would be useful, but it might permit the development of low-end AirLink devices that can receive FEC-encoded frames, but avoid decoding them (at the obvious risk of higher frame error rates)?

- Page 15. Additional information about the interface over which this message is transmitted may be useful. Is this a physical interface? If so, how are frames delimited? Should it be protected against errors, perhaps by a cyclic redundancy check (CRC) code? Or, is this a software interface? Is support for this interface a required element of the AirLink specification? Or, is this merely a detail of one implementation? Again, this document really needs to specify the boundaries of the AirLink modem or modulator and demodulator.

- Page 15. What is included in the payload size field? Only the payload bytes? The payload bytes plus the three-byte AirLink frame header? What is the format of the payload size field? Is it a fixed format field?

- Page 15. In general, it would seem preferable to pass the payload as binary bytes. The receiving host will have to convert them to binary anyway, so converting to hex and then back to binary seems redundant. Plus, the hex representation will require roughly twice as long to transfer, if this is a serial link.

- Page 15. It would seem to make more sense to simply pass the payload as one contiguous stream of binary bytes. The receiver ought not to care about blocks; only the AirLink demodulator should have cognizance of blocks. This seems like the demodulator passing work off to the higher layers that really ought to be performed within the AirLink functionality.

4. Editorial Comments

These comments are principally editorial.

4.1. Terminology

The use of standard terminology tends to strengthen the credibility of a document. For example, physical-layer protocol data units (PDUs) are usually referred to as "frames", rather than "packets".

4.2. Detailed Editorial Comments

- Page 5. Please fix.
- Page 6, Paragraph 1. Please delete "This heading appears in the table of contents but has no section number assigned to it.
- Page 6, Paragraph 1. Please provide a permanent URL for the referenced document, preferably on the NHWC website.
- Page 6, Paragraph 2. Please use consistent capitalization for "ALERT2 Protocol Technical Working Group.
- Page 6, Paragraph 2. This list of ALERT2 protocol technical working group differs from the list on page 3. Is that correct?
- Page 7, Paragraph 1. It might be easier if AirLink was referred to as the (or, perhaps a) physical-layer protocol within the ALERT2 protocol *suite*. Trying to refer to ALERT2 as a protocol (singular), rather than as a collection of several protocols, will probably become cumbersome. Technically, ALERT2 is a collection of protocols, not a single protocol.
- Page 7, paragraph 2. I suggest that physical-layer protocol data units (PDUs) be referred to as "frames", rather than "messages".
- Page 11, section 3. Splitting and reorganizing this section into separate subsections for scrambling, Reed-Solomon encoding and convolutional code encoding would enhance its readability.
- Page 13, paragraph 1. I believe that this is more commonly called a "preamble", rather than a "header" (although the term "preamble" has already been used).
- Page 14, paragraph 2. This specification should be more clear about how much of this is information about one implementation and how much is a requirement for conforming AirLink devices. Must the demodulator and FEC processing be implemented in separate devices? If the modulator and FEC processing are implemented in separate devices, must the demodulator/FEC processor interface described in this section be used?

- Page 14, paragraph 2. Is “application software” the correct term? Should this be called something like “FEC decoding software”? Or, is application software actually responsible for FEC decoding?

- Page 14, paragraph 4. This paragraph seems to describe an implementation, rather than specify the AirLink protocol. Perhaps, this and related paragraphs should be clearly labeled as “implement hints”, “reference implementation”, or some such thing.

5. Conclusions and Recommendations

I recommend that the ALERT2 Protocol Technical Working Group consider the review comments contained in this document and update the ALERT2 AirLink Protocol Specification document as it believes is appropriate.

Based on my review, I conclude that Version 1.0 of the ALERT2 AirLink Protocol Specification does *not* provide the detail and clarity necessary to ensure that independent implementations of the AirLink protocol developed based only on the information in this specification will interoperate. I recommend that the ALERT2 AirLink specification be expanded to better ensure interoperability between AirLink implementations.

I recommend that the ALERT2 specifications be adopted by the NHWC as full standards only *after* an independent implementation that was developed using only the information contained in these specifications has been shown to interoperate with the existing ALERT2 prototypes and products. This is perhaps the only way to ensure that the standards adopted by the NHWC are accurate enough and sufficiently detailed enough to permit independent implementations of these protocols to interoperate with each other. In the interim, the NHWC might adopt this specification as a "draft standard" or assign it a similar status that denotes that the NHWC believes that the specification is complete, but that the NHWC is awaiting feedback about implementation experiences before promoting it to full standard status.