

AUTOMATION SERIAL PROTOCOL ASP

RF System Level Requirements - Physical Layer -

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1.0 Overview

This document outlines a method by which users can implement and field RF based Industrial Control Systems which allow primarily for non-interfering co-existence and secondarily the option for interoperability between multiple users and applications.

The document describes the properties of the multi-channel RF scheme to be used as well as the on-air format of the data messages.

2.0 RF Modulation Characteristics

The external physical properties of the RF data link are described in the following sections.

2.1. Center Frequencies, f_c

Eight RF channels shall be supported, each spaced 3 MHz apart, from 905.58 MHz to 926.58 MHz.

Channel	Frequency f_c (MHz)
1	905.58
2	908.58
3	911.58
4	914.58
5	917.58
6	920.58
7	923.58
8	926.58

2.2 Spread Spectrum Modulation

RF messages shall be spread using Direct Sequence, Binary Phase Shift Keying (BPSK) modulation, with 63 chip linear maximal length pseudo-random sequences.

2.3 On-Air Data Modulation

Data shall be modulated using On-Off Keying (OOK) or BPSK.

OOK messages shall have 30 dB min. key off attenuation. OOK data modulation is limited to 19.4 Kb/s.

BPSK will be available as an upward-compatible data modulation form. Detection of data modulation type will be accomplished automatically by monitoring the Sync byte.

Future BPSK data products may operate at 19.4 Kb/s, 58.2 Kb/s, and/or 116 Kb/s depending on application requirement. BPSK transceivers shall be backward compatible with OOK data modulation devices. The AX-602 Transmitter ASIC supports both OOK and BPSK data modulation.

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2.4. Chip Rate, Transmit-Only

The chipping rate for transmit only devices shall be $f_c \div 9 \div 7 \div 12$, f_c is set to single frequency, transmit only device operation at 923.58 MHz, yielding a chipping rate of 1.2217 MHz.

2.5. Chip Rate, Transceiver

All Primary power Operated Remote Transceivers (PORTs) shall have a chip rate based on 923.58 MHz so that they can receive transmit-only devices, and so that PORTs can transmit supervisory messages which can be received by the same system receiver that is monitoring transmit only devices. PORTs can transmit or receive on any frequency.

2.6. On-Air Data Rate

Three on-air data rates shall be supported:

- a) Standard Rate – OOK or BPSK
Approximately 19.4 Kb/s
Specifically: chip rate $\div 63$
- b) High Rate – BPSK only
Approximately 58.2 Kb/s
Specifically: chip rate $\div 63 \times 3$
- c) Maximum Data Rate – BPSK only
Approximately 116 Kb/s
Specifically: chip rate $\div 63 \times 6$

2.7 Direct Sequencing Synchronization Preamble

All on-air messages shall contain a leader 92 bit times long, although future DSP transceivers may allow shorter preambles but shall remain backward compatible.

Preamble (non data bearing time): 4.74ms

For DSSS acquisition, correlation optimization, antenna diversity optimization, frequency channel search when in frequency agile mode, crystal frequency error removal, impulse noise rejection, data bit sample synchronization.

2.8 Code Division Multiple Access

Six Orthogonal Code Division Multiple Access (CDMA) code channels are available. Applications will be assigned specific CDMA channels in order to help isolate them from one another. Axonn will provide the feedback taps.

2.9 Carrier Sense Multiple Access

Before initiating a transmission, transceivers on shared frequency channels shall verify that a message is not being received before a transmission. If the frequency band is in use by the same CDMA channel, then the transmission shall be delayed until reception is complete plus a random amount of time (up to maximum of 10 msec). If after the delay another message is being received, the delay process is repeated again, but with a new random amount of delay (up to double the previous maximum time).

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2.10 FCC Part 15 Multilateration restrictions apply to:

Outdoor antennas only, which are above 5 meters at 905.58, 908.58, 920.58, 923.58, 926.58 MHz; in such a case the device may still operate but power output and antenna gain must be reduced per an FCC formula.

No restrictions apply to indoor use in any channel. Furthermore, the 911.58, 914.58, and 917.58 MHz channels are not restricted for indoor or outdoor use.

2.11 Antenna Remoting

Antennae are typically integral to transceiver devices but, as an option, may be remoted away with the addition of optional connectors.

2.12 Repeater Provision

Repeaters shall be provided for 920.58, 923.58, 926.58 MHz transmit-only devices. The repeater will repeat all messages received from one of the 3 frequency channels, providing the CDMA channel, Vendor code, Application code and Property code matches.

The repeater shall send a burst of no more than 6 redundant repeated transmissions over pseudo random time slots. The repeater shall store a list of the last 5 seconds worth of repeated messages. If an identical message is received, it will be discarded if it is in the 5 second queue. A repeat level embedded in the message header prevents "repeat loops".

2.13 Fallback Frequency Usage, Transceiver

PORT: If supervision handshake fails after retry, the next fallback channel will be switched to.

2.14 Future Enhancements: Redundant Frequency Channels for Transmit-Only Devices

Three frequency channels are reserved for transmit-only devices. This provision allows for frequency agility at both the transmit and receive ends (recommended channels 923.58, 914.58, 905.58). Future frequency agile transmitters and receivers shall use the same preamble length and shall be backward compatible with initial transmit-only hardware. This future method will enhance:

- a) spectrum use by reducing the number of collisions
- b) anti-jam performance and co-existence of multiple devices
- c) fading resistance as a result of the additional frequency diversity

2.15 Transmit-only Device Density per Receiver

In the case of a data collision (CLASH), the ABORT feature allows a stronger received transmission to be successfully decoded by a receiver. This allows performance to approach that of slotted ALOHA instead of non-slotted ALOHA. Collision performance can be maintained by ensuring that a transceiver is placed within nearest proximity to the transmitters which it is targeted to receive. The total number of receivers in a system must also be appropriate for the total number of transmitters in a system. For example: If 1000 transmitters are to be monitored within a building and the ALOHA formula yields a 100 transmitter- to-receiver result (based on message length and transmission separation), then 10 receivers will be adequate in an evenly distributed installation. Software will be provided by Axonn to readily compute these results based upon individual user needs.

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2.16 Receiver Redundancy

Life safety and critical applications should use receiver redundancy. A redundancy factor of two is required (but it is recommended that every transceiver connected to an application be allowed to contribute). Redundant messages are automatically eliminated by requiring transceivers on the same serial bus to listen to the messages reported by other transceivers on the same serial bus. If a transceiver hears a message which is in its memory queue, that message is eliminated. This technique reduces loading on the serial bus and at the panel level.

Redundant receivers should both be verified for the required minimum SNR required during installation. This is accomplished by ensuring every transmit-only device is adequately received by at least two receivers.

Exception for small systems and RF add-ons to larger hardwired systems:

If the received SNR of the desired transmission exceeds the Minimum Acceptable SNR by 12 dB and there are no more than 10 transmitters, then one receiver may be utilized.

2.17 Minimum Acceptable SNR

During installation, SNR from every device shall be tested automatically, or by a field measurement tool. Once the transmitters and receivers are in place, the test is initiated. RF Signals fade a predictable amount off of the strongest possible received level. RF messages shall therefore be monitored and the highest Signal to Noise Ratio (SNR) from each transmitter shall be stored. Once the required SNR level is exceeded, the transmitter is flagged as OK. The test is complete when all the transmitters have been flagged as OK, or after the expiration of a maximum test time limit as set by the OEM. Any non-complying transmitters can then be dealt with by moving them, adding an additional receiver or adding a repeater.

The highest received SNR shall be large enough to provide adequate operation margin under simultaneous worst case conditions:

Fading Margin (with diversity)	10 dB
Minimum Required Carrier to Noise Ratio (CNR) (@10 ⁻³ BER with 1 bit Error Correction)	10 dB
UL NFPA required additional Margin	<u>3 dB</u> 23 dB

All implementation losses must be added to this figure such as:

Received Signal Strength Indicator (RSSI) Linearity
Correlation function smearing

2.18 Maximum Transmit Message Duration

On-air message length shall be minimized to meet ALOHA requirements. This minimization may be accomplished by:

- a) restricting the information sent to only that which is necessary
- b) breaking long data strings (greater than 31 bytes) into multiple messages
- c) utilizing higher data rates

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3.0 On – Air Message Format

Each RF message transmitted on-air shall conform to a pre-defined format consisting of 10 fields as shown below.

Leader	Sync	Reposition	Vendor Code	Vendor Code /Priority	Property Code	Control	Length	Payload	CRC
11.5 Bytes	1 Byte	1 Byte	1 Byte	1 Byte	2 Bytes	1 Byte	1 Byte	0-240 Bytes (0-31 typical)	2/4 Bytes

On – Air Message Fields

3.1 Leader Field

The Leader Field shall be 92 bits in length and is used to provide time for receivers to synchronize to the chipping sequence of the incoming message.

3.2 Sync Field

The Sync Field shall be 8 bits in length and allows the receiver a way to determine the start of a message data. It is also used to provide a way to distinguish between OOK data messages and BPSK data messages, and whether or not the reposition feature is in use by the message.

3.3 Reposition Field

The Reposition Field shall be 8 bits in length and is used to by the receiver to correct for chipping code synchronization lock drift when the transmitter and receiver chipping frequencies are not exactly the same. This allows for greater transmitter crystal error tolerance by the receiver therefore allowing for lower cost transmitter crystals. Depending upon the length of the Payload Field, one or more reposition bytes may be inserted into the body of the message to allow for crystal tracking. Note that this process is transparent to the user, since all reposition bytes are removed before the received message is delivered through the serial interface.

3.4 Vendor Code Field

The Vendor Code Field shall be 12 bits in length and represents a unique value assigned to each vendor by Axonn. The byte immediately following the Reposition Field shall contain the least significant 8 bits of the Vendor Code, the most significant 4 bits of the Vendor Code are located in the Vendor Code / Priority Field. The Vendor Code Field shall act as a filter to block messages which do not contain an exact match with the receiver's vendor value. This provides a hardware means to isolate vendor applications from one another. Alternately, generic Vendor Code values will be reserved for vendors who alternatively or additionally wish to allow for interoperability between their systems and other vendors.

Vendor Code Field Value	Property
0	(illegal)
1-4079	Allocated by Axonn
4080-4095	(reserved for testing)

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3.5 Vendor Code / Priority Field

The Application/Priority Field shall be 8 bits in length and contains two sub-fields, The Vendor Code MS Nibble Field and the Priority Level Field.

Bits	Application/Priority Sub-Field
0-3	Vendor Code MS Nibble
4-7	Priority Level

The Priority Level field is used to meet UL requirements and is used by the vendors network layer to handle expedited routing of life-safety and/or security alarm messages. The Priority Levels are defined below.

Priority Field Value	Priority Level
0	(reserved)
1 - 15	Lowest - Highest

3.6 Property Code Field

The Property Code Field shall be 16 bits in length and contains a value which is assigned by a vendor at installation time and logically relates all RF equipment to a particular installation. The Property Code Field shall act as a filter to block messages which do not contain an exact match with the receiver's set Property Code Field.

Property Field Value	Property
0	(illegal)
1-64999	Normal usage
65000-65533	(reserved)
65534-65535	(reserved for testing)

3.7 Control Field

The Control Field shall be 8 bits in length and contains four sub-fields, The Sequence Number Field, the CRC Control Field, the Repeat Flag Field, and a Reserved Field.

Bits	Control Sub-Field
0-3	Sequence Number
4	CRC 16/32 Bits Flag
5	Repeat Flag
6	Transmitter Battery Low
7	(reserved for future use)

The Sequence Number Field shall act as a simple one-up counter that is incremented by the transmitter with each successive message and which rolls over to zero after reaching a count of 15. This allows the system the capability to determine when a transmitted message is not received and can be used to provide link quality indicator (percent message throughput).

The Cyclical Redundancy Check (CRC) Control Field is used to determine whether the message contains a 16 or 32 bit CRC value at the end of the message. 16 bit CRC values are adequate for most applications, but for applications requiring an extremely high level of message integrity, a 32 bit CRC value can be used at the cost of approximately .8 msec of on-air time and an additional 2 msec of calculation time.

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CRC Control Field Value	CRC Mode
0	16 Bit
1	32 Bit

The Repeat Level Field is used to indicate that a message is a repeated message from a repeater device.

Repeat Field Value	Repeated Message
0	No
1	Yes

The Transmitter Battery Low Field is used by the device transmitting the message to report current battery status. A device reporting a battery low condition has a battery at or near it's specified end of life.

Transmitter Battery Low Field Value	Battery Level Low
0	No
1	Yes

The Reserved Field is reserved for future use and shall be set to zero until a use is determined.

3.8 Length Field

The Length Field shall contain 8 bits, the value of which shall be equal to the number of bytes in the Payload Field. The valid range of values for the Length Field is from 0-240. ****Note**** Although large Payload Fields are allowed in the protocol, initial Axonn product offerings only support payloads up to 31 bytes.

3.9 Payload Field

The Payload Field shall be a variable length in bytes the format of which is definable by the user. As a general rule, users should strive to keep the size of the Payload Field to a minimum in order to minimize on-air time as well as maximize battery life.

3.10 CRC Field

The CRC Field shall be 16 or 32 bits in length depending on the value of the CRC Control Field. It shall contain a standard CCITT 16 or 32 bit CRC calculation based upon the bytes in the transmitted message from the Vendor Field through and inclusive of the Payload Field. Any added reposition bytes are not included in the CRC calculation.

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4.0 Glossary of Terms

Abort – If, during the time in which a RF message is being demodulated, a stronger power RF message starts which will cause reception of the first message to be jammed, the Abort feature causes the receiver to stop demodulation of the first message and attempt to synchronize to the second, stronger message.

Aloha – A radio network scheme developed at the University of Hawaii in which several transmitters transmit finite length packets at random time intervals to a single receiver. Aloha provides a mathematical means of determining statistically how often on-air collisions will occur between transmitted messages. Slotted Aloha is a network scheme in which messages are transmitted in discrete time slots instead of at random times. Messages in Slotted Aloha networks collide either 0% (if no other messages are broadcast in that time slot), or 100% (if another message is broadcast in the same time-slot). Slotted Aloha networks provide lower probabilities of collision than standard Aloha networks by eliminating collision cases in which two messages only partially collide causing the loss of both messages. Axonn wireless RF systems are designed to function as a standard Aloha radio networks, but approach Slotted Aloha statistical collision performance because the Abort feature (see *Abort*). The Abort feature is designed so that, in the event of a collision between two messages, most of the time at least one of the messages will be correctly received.

Anti-Jam – The amount of resistance a receiver has against non-desired radio energy in the same frequency band as desired radio messages.

ASIC - Application Specific Integrated Circuit.

AX-602 ASIC – A Spread Spectrum Communication ASIC chip designed by Axonn, which among other functions, provides for very efficient low current battery powered transmitter operation, spread spectrum pseudo-random code generation, DC to DC voltage conversion, real time external event detection while operating in low current sleep mode, and low battery energy detection.

BPSK - Binary Phase Shift Keying. A data modulation technique in which the phase of a carrier signal is switched between two settings separated by 180°, depending upon whether or not a binary 1 or 0 is to be transmitted.

CCTV - Closed Circuit Television

CDMA - Code Division Multiple Access. Direct Sequence Spread Spectrum systems spread their messages by mixing the data with a pseudo random sequence or “Code”. CDMA systems allow multiple channels of information to be transmitted simultaneously on the same RF frequency provided they each use different pseudo random codes.

Chip Rate – The bit rate of the pseudo random sequence used to spread the information bit signals. Each bit of the sequence is called a Chip, and there are many Chips in each information bit.

CRC - Cyclical Redundancy Check. A method used to detect and potentially correct errors in bits of a message demodulated by a receiver. Transmitters create a 16 or 32 bit value which is a polynomial transformation of the data message to be broadcast, and appends it to the end of the message. The receiver performs the same calculation on the message when it is received, and if the CRC value sent by the transmitter does not match the receiver calculated value, an error is detected.

CSMA - Carrier Sense Multiple Access. When a transceiver device needs to transmit a message, the CSMA function will check to make sure no other device is transmitting before it begins its broadcast.

Data Collision – When all or a portion of transmitted messages from different devices overlap in time on the same RF frequency and CDMA (see *CDMA*) channel.

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Direct Sequence Spread Spectrum – A method by which a narrow band data signal is mixed with a much higher rate pseudo random data pattern causing the resulting message to take on the bandwidth of the pseudo random data pattern.

FCC – Federal Communications Commission

Leader – (See *Synchronization Preamble*)

Minimum Detectable Signal (MDS) - $KT_b + NF + CNR$ (at 10^{-3} BER) + 10 Log BW
(BW includes data detection BW and guard band for Monte Carlo and temperature drifts)

Minimum Required CNR (with 1 bit Error Correction) - Carrier to Noise Ratio – The minimum amount that a received signal level must be above the mean level of receiver band limited noise in order to acceptably demodulate an incoming message.

NFPA – National Fire Protection Agency

On Air Data Rate – The rate at which data message bits are transmitted.

OOK - On Off Keying – A data modulation technique in which RF energy is transmitted during '1' bit times, and no RF energy is transmitted during '0' bit times.

Part 15 – A set of rules enforced by the FCC, which allow for unlicensed RF transmission of signals, provided that the signals meet a strict set of guidelines. Axonn devices are designed to adhere to the FCC Part 15.247 guidelines.

PORT - Primary power Operated Remote Transceiver

Reposition – A technique patented by Axonn which allows receivers to re-achieve fine chip synchronization with an incoming message during the body of a transmitted message.

RF – Radio Frequency

SNR - Signal to Noise Ratio. The ratio of a desired signal level to that of the noise present in the same bandwidth.

Sync Byte – A byte of data with a special pattern of ones and zeros which is transmitted immediately following the Synchronization Preamble and allows the receiver to achieve data frame synchronization with the incoming message.

Synchronization Lock Drift – If the crystal frequency which generates the chipping rate for the transmitter is different from the crystal frequency which generates the chipping rate on the receiver, the chipping sequence alignment achieved by the receiver during initial signal correlation will drift over time. This drift causes the receiver to slowly lose correlated signal strength as a message is demodulated. Axonn devices automatically correct for Synchronization Lock Drift by means of the Reposition (*see Reposition*) feature.

Synchronization Preamble – Each Axonn on air message begins with a 92 bit long Synchronization Preamble which provides time for the receiver to search through different combinations of chip code alignment, frequency offset, and antenna selection, and achieve correlation with the incoming message.

System Transceiver – A line powered transceiver or network of transceivers which are hardwired and serially communicate with the application software or panel.

UL – Underwriters Laboratories