**CU InSpace**

# Radio Packet Format

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# Contents

# 1 Introduction

In order to efficiently communicate telemetry data between various devices, Carleton University InSpace has devised its own unique packet format for transmission over LoRa radio. The packet format is not only used for radio communications, but also for logging telemetry data in-flight.

This packet format is made publicly available via the MIT license.

The packet format which follows is made to efficiently transmit flight data recorded by sensors alongside their measurement times. LoRa is a low bandwidth protocol, so it is critical to minimize any unnecessary control information where possible.

# 2 Packet Layout

CU InSpace's radio packets consist of a packet header followed by one or more segments called blocks. Each block has its own header followed by a variable amount of data determined by the block type. The layout of a packet is shown in figure 2.1.

**All fields in this specification are little endian.**

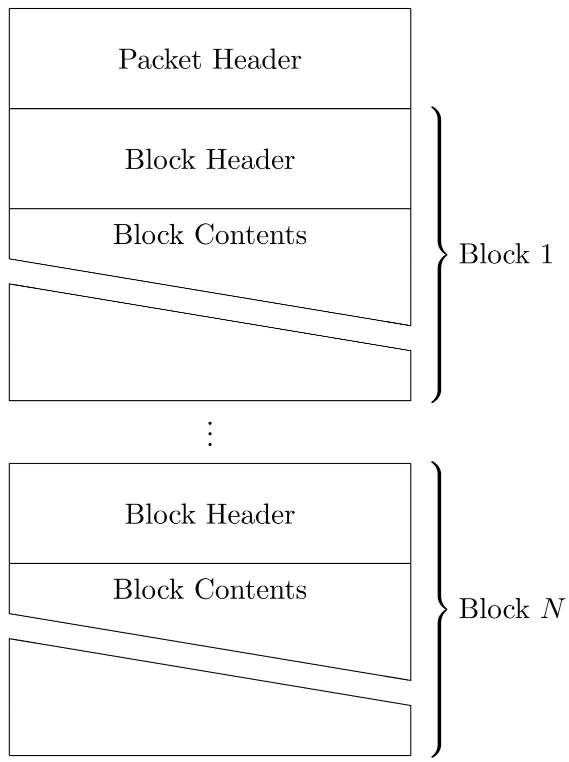


Figure 2.1: Layout of radio packet

## 2.1 Packet Header

Every packet is preceded by a 13 byte header. The header contains an amateur radio call sign and other information which describes the packet as a whole. The packet header follows the format described in figure 2.2.

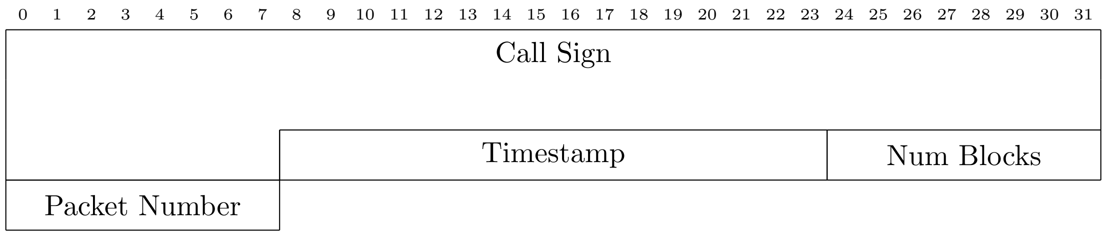


Figure 2.2: Packet header format

**Call Sign** The first 9 bytes of the packet must contain an amateur radio call sign in ASCII. If the call sign being used is less than 9 bytes long, the call sign will be padded with NULL characters at the end.

The call sign field is 9 bytes long because this field is required to accommodate more than just a single Canadian call sign of maximum 6 characters, but also Canadian call signs being used in the United States. Such call signs must be suffixed with the call zone in which they are being used. [1]

For example, the Canadian amateur call sign of `VA3INI` would become `VA3INI/W5`, where `W5` is the 5th call zone (coincidentally the call zone for the location where Spaceport America Cup is hosted).

There are 10 call zones in the United States, represented using digits 0-9. [2] The digit is preceded by a forward slash and a capital 'W', for a total of three additional characters on top of the original 6 for a Canadian HAM radio call sign.

**Timestamp** This field is an unsigned 16 bit integer representing a number of half-minutes since power on. This timestamp serves as a base timestamp to which measurement timestamp offsets are added to.

For instance, the packet header may contain a value of 1 in this field, indicating the base timestamp is 30 seconds since power on. A subsequent block may be a temperature block with a measurement timestamp field containing the value of +12 milliseconds. This value is to be added to the packet header field, meaning that the temperature measurement was taken at 30 seconds and 12 milliseconds after power on.

This schema allows millisecond resolution on measurement time, while preserving a maximum mission duration of around 546 hours, as seen in equation 1

$$\frac{2^{16}-1}{2*60} = 546.125 \tag{1}$$

**Num Blocks** This field is an unsigned 8 bit integer that contains the total number of blocks in the packet.

**Packet Number** This field is an unsigned 8 bit integer. It is a rolling counter of the packet sequence number, starting at 0 and increasing until 255 before rolling over again.

Reading this field off of received packets should give an indication of whether any packets were lost in transmission.

## 2.2 Block Header

Every block starts with a block header. This header indicates the type of information contained in the subsequent block, which allows for parsing of the received data. The block header is formatted as described in Figure 2.3.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Type | | | | | | | |

Figure 2.3: Block header format

**Type** The block type field indicates the information contained in the block. Possible values are listed in table 2.1. Block types are discussed in more detail in section 3.

| Block type | Value |
|---|---|
| Altitude above sea level | 0x00 |
| Altitude above launch level | 0x01 |
| Temperature | 0x02 |
| Pressure | 0x03 |
| Linear acceleration | 0x04 |
| Angular velocity | 0x06 |
| Humidity | 0x07 |
| Coordinates (latitude and longitude) | 0x08 |
| Voltage | 0x09 |
| Reserved for future use | 0x0A through 0xFF |

Table 2.1: Block types

# 3 Block Formats

Blocks have a type which indicates their contents. The possible block types are listed in table 2.1. This section describes the possible block types and their associated data formats.

## 3.1 Altitude

The altitude block is used to convey the altitude of the rocket. The format of the altitude block payload is described in Figure 3.1.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measurement Time | | | | | | | | | | | | | | | |
| Altitude | | | | | | | | | | | | | | | |

Figure 3.1: Altitude Data Payload Format

**Measurement Time** A signed 16 bit integer in units of milliseconds. This timestamp is meant to be added as an offset to the base timestamp in the packet header. This is explained in section 2.1.

**Altitude** The calculated altitude in units of millimetres. This field is a signed 32 bit integer in two's complement format.

If the block header specifies the type for altitude above sea level, this measurement should be interpreted as millimetres above sea level.

If the block header specifies the type for altitude above launch height (ground level), this measurement should be interpreted as millimetres from the starting height of the rocket.

See Table 2.1 for the different altitude types.

## 3.2 Linear Acceleration

The linear acceleration block is used to convey generic 3-axis accelerometer data. This block is intended to abstract over the details of any individual accelerometer. The format of the acceleration block payload is described in figure 3.2.

| 0–15 |
|---|
| Measurement Time |
| X-Axis |
| Y-Axis |
| Z-Axis |

Figure 3.2: Acceleration Data Payload Format

**Measurement Time** A signed 16 bit integer in units of milliseconds. This timestamp is meant to be added as an offset to the base timestamp in the packet header. This is explained in section 2.1.

***-Axis** These fields represent the acceleration measurements for each axis. These fields are signed integers in two's complement format.

The unit of measurement for each axis is measured in centimetres per second squared. That is, dividing the value in each axis field by 100 will give the standard acceleration unit of metres per second squared.

The acceleration measurements are relative to the rocket's heading. If the IMU Z-axis is in parallel with the rocket, then the acceleration in the z-axis is also a parallel vector.

## 3.3 Angular Velocity

The angular velocity block is used to convey generic 3-axis gyroscope data. This block is intended to abstract over the details of any individual gyroscope. The format of the acceleration block payload is described in figure 3.3.

| 0–15 |
|---|
| Measurement Time |
| X-Axis |
| Y-Axis |
| Z-Axis |

Figure 3.3: Angular Velocity Data Payload Format

**Measurement Time** A signed 16 bit integer in units of milliseconds. This timestamp is meant to be added as an offset to the base timestamp in the packet header. This is explained in section 2.1.

***-Axis** These fields represent the angular velocity measurements for each axis. These fields are signed integers in two's complement format.

Each field describes angular velocity in tenths of degrees per second. In other words, dividing this field by 10 will give you angular rotation in a standard unit of degrees per second.

## 3.4 Coordinates

The coordinates block is used to convey the geographical (latitude and longitude) coordinates of the rocket. The format of the coordinates block is described in figure 3.4.

<table>
<tr><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th></tr>
<tr><td colspan="16">Measurement Time</td></tr>
<tr><td colspan="16">Latitude</td></tr>
<tr><td colspan="16">Longitude</td></tr>
</table>

Figure 3.4: Coordinate Data Payload Format

**Measurement Time** A signed 16 bit integer in units of milliseconds. This timestamp is meant to be added as an offset to the base timestamp in the packet header. This is explained in section 2.1.

**Latitude** Measured in tenths of micro-degrees. This field is a signed 32 bit integer. To convert to degrees, divide by $10^7$.

**Longitude** Measured in tenths of micro-degrees. This field is a signed 32 bit integer. To convert to degrees, divide by $10^7$.

## 3.5 Humidity

The humidity block is used to convey the relative humidity inside of the rocket. The format of the humidity block is described in figure 3.5.

<table>
<tr><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th></tr>
<tr><td colspan="16">Measurement Time</td></tr>
<tr><td colspan="16">Humidity</td></tr>
</table>

Figure 3.5: Humidity Data Payload Format

**Measurement Time** A signed 16 bit integer in units of milliseconds. This timestamp is meant to be added as an offset to the base timestamp in the packet header. This is explained in section 2.1.

**Humidity** The calculated relative humidity in ten thousandths of a percent (i.e 1% is 100). This field is an unsigned 32 bit integer.

## 3.6 Pressure

The pressure data block reports the pressure detected from within the rocket in Pascals. The format of the pressure block payload is described in figure 3.6.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measurement Time | | | | | | | | | | | | | | | |
| Pressure | | | | | | | | | | | | | | | |

Figure 3.6: Pressure data block format

**Measurement Time** A signed 16 bit integer in units of milliseconds. This timestamp is meant to be added as an offset to the base timestamp in the packet header. This is explained in section 2.1.

**Pressure** The measured pressure in units of Pascals. This field is an unsigned 32 bit integer.

## 3.7 Temperature

The temperature data block reports the temperature detected from within the rocket in millidegrees Celsius. The format of the temperature block payload is described in figure 3.7.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measurement Time | | | | | | | | | | | | | | | |
| Temperature | | | | | | | | | | | | | | | |

Figure 3.7: Temperature data block format

**Measurement Time** A signed 16 bit integer in units of milliseconds. This timestamp is meant to be added as an offset to the base timestamp in the packet header. This is explained in section 2.1.

**Temperature** The measured temperature in units of millidegrees Celsius. This field is a signed 32 bit integer in two's complement format.

## 3.8 Voltage

The voltage data block reports the voltage measured on a specific electrical trace within the rocket. The measurement is associated with a generic numerical ID for identification by the receiver. This allows multiple voltage points to be measured within the rocket. The format of the voltage block payload is described in figure 3.8.

<table>
<tr><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th></tr>
<tr><td colspan="16">Measurement Time</td></tr>
<tr><td colspan="16">Voltage</td></tr>
<tr><td colspan="8">ID</td></tr>
</table>

Figure 3.8: Voltage data block format

**Measurement Time** A signed 16 bit integer in units of milliseconds. This timestamp is meant to be added as an offset to the base timestamp in the packet header. This is explained in section 2.1.

**Voltage** The measured voltage in units of millivolts. This field is a signed 16 bit integer.

**ID** A numerical identifier associated with the voltage measurement for identification by the receiver. This field is an unsigned 8 bit integer, allowing for up to 255 unique identifiers.

## References


[1] S. Bertuzzo. "Operating amateur radio in foreign countries," Accessed: Feb. 11, 2024. [Online]. Available: https://www.rac.ca/operating/operation-in-foreign-countries/.

[2] S. Stroobandt. "Us call areas & zones by state," Accessed: Feb. 11, 2024. [Online]. Available: https://hamwaves.com/map.us/en/index.html.