

*Overview & Operating Instructions*  
Preliminary. May 2009

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## 1. Overview

The EzAntennaTracker system, is the first commercially available antenna tracker designed for FPV/UAV flight.

It operates by sending a digital telemetry stream down one of the audio channels of an A/V link, via the EzOSD module. This telemetry stream contains information on the plane's GPS location, and other information available to the EzOSD.

This telemetry stream then exits from the audio jack of the ground-based receiver, and can be used for various purposes.

- 1) It can be simply recorded to the audio/video recorder, and 're-played' through Google Earth™ to show the path that the model took during the flight/drive/sail. This case requires no additional hardware.
- 2) It can be recorded, as above, but used to find a lost plane in the event of a distant crash. The gps coordinates of the last packet sent should indicate roughly (or best case, exactly) where the plane crashed. Again, no additional hardware required.
- 3) It can be fed to an antenna tracker, which is driving a pan/tilt mount. This can aim a directional antenna at the plane during the entire flight, greatly reducing dropouts (and with the added bonus that the antenna points to where the plane landed/crashed in the event of a 'problem'.

This manual is dedicated to the third purpose, the use of the telemetry stream to drive an antenna tracker.



Figure 1: The ImmersionRC Antenna Tracker

## 1.1.Revisions

Two revisions of the Antenna tracker exist, with relatively minor differences.

The first includes a back-lit display, and a 4x3 connector block for the servo and BEC connections. The second includes a reflective (non-back-lit) display, and a different layout for the servo and BEC connections.

## 2. Installation

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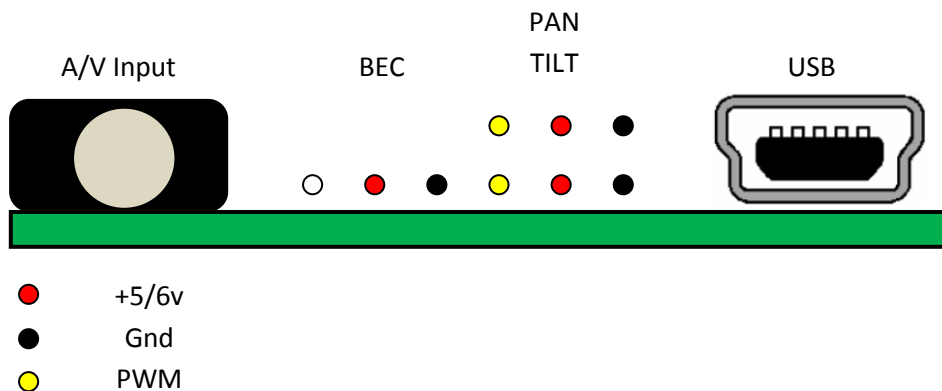
### 2.1.Airborne Electronics

Not much to do on this side, the EzOSD is equipped to transmit telemetry data down the right audio channel.

Ensure that the cable running between the EzOSD and the transmitter is cabled correctly for video and stereo audio (for LawMate systems, take the right channel of the stereo pair from the EzOSD, and route that to the mono audio input of the Lawmate transmitter).

### 2.2.Ground Station Electronics

The EzAntennaTracker -Lite module requires the following connections:



#### 1. Audio Input

The audio input is supplied via a 4-Pole, 3.5mm jack, with the same pinout used for other Fat Shark, and ImmersionRC equipment.

Only the AUDR (Audio, Right), and Ground pins are connected on this connector.

#### 2. Servo Power

Power for the servos, and the EzAntennaTracker module itself, must be supplied through a standard 3-pin servo connector (with only two of the pins used).

Looking at the front of the module, power must be provided through either of the lower two connectors (these are paralleled, and may be use to daisy-chain power to other devices).

Power the EzAntennaTracker unit the same way you would power a R/C receiver. 5v or 6v depending upon servo requirements, sourced from either a 'Rx Battery Pack', or a 5v/6v BEC.

### 3. Pan Servo

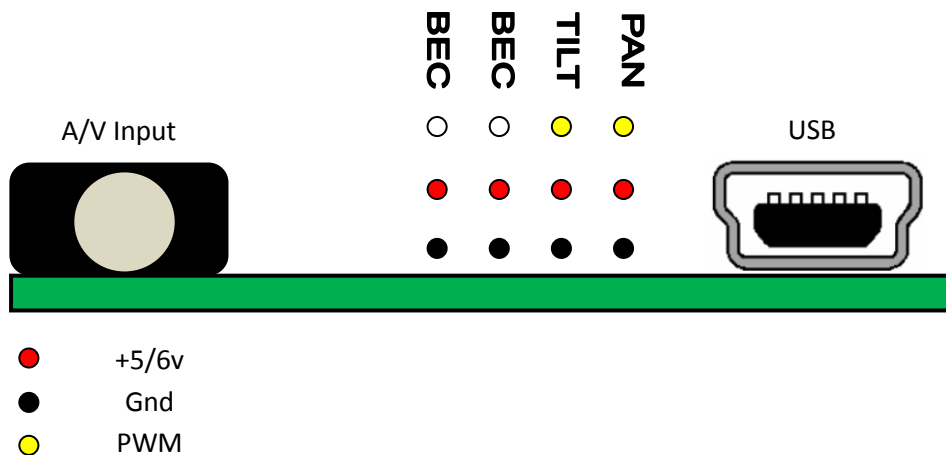
The upper of the 4 connectors is the Pan Servo connection. Connect any R/C servo to this connector. See elsewhere in this document for servo recommendations.

### 4. Tilt servo

The connector below the Pan Servo connector is for the Tilt servo.

Note that the USB connection is currently used primarily for upgrading flash firmware, and may be left disconnected in normal use.

*Note: First revision of the antenna tracker has the following pinout.*



## 2.3.Cabling, Getting the Correct Audio Channel

There are two fundamental types of A/V Tx/Rx equipment being used for FPV, those with a mono audio link, and those with a stereo link.

The 'Lawmate' equipment, and clones, used primarily for law-enforcement, transmits only (relatively low bandwidth) mono audio (one channel). This equipment will function correctly with the EzOSD telemetry link, but note that the only audio channel will be dedicated to telemetry, and cannot be used for an onboard microphone.

The 'Airwave' equipment, and clones, provides a high-bandwidth stereo audio link. One of the two channels may be used for telemetry (generally, the Right-Channel), while the other (Left) may be used for an onboard microphone.

One of the most common problems experienced when setting up an antenna tracking system is to ensure the audio is correctly cabled both in the plane (Tx-end), and on the ground (Rx-end).

Additional care must be taken if Lawmate transmitters are used with Airwave receivers (or vice-versa). These cases will be covered below.

## 2.4.Transmitter Audio Connection

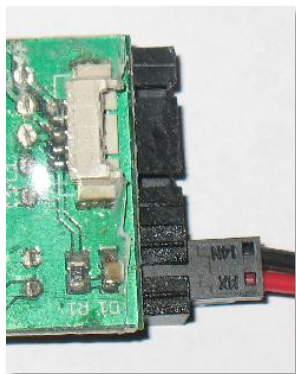
### 2.4.1. ImmersionRC/Airwave Transmitter

If ImmersionRC (Airwave) transmitters are used, there are two A/V connectors supplied on the transmitter board.

One is the 5-pin Molex-SL connector, which is used to interconnect ImmersionRC cameras, Transmitters, and OSDs. This will be the standard method for connecting the audio channels, and requires no additional effort (assuming standard cables are used, with all 5 pins connected).



An additional connector is supplied on ImmersionRC transmitters, for future expansion. This is a 5-pin JST (small white connector), with the same pinout as the larger 5-pin Molex.



### 2.4.2. Lawmate Transmitter

For Lawmate transmitters, a 4-pin connector is supplied, with the following pinout. The telemetry signal from the EzOSD must be routed to the white cable (Audio) .

Yellow	Composite Video
White	Audio (Mono)
Black	Ground
Red	+5v/+12v

## 2.5.Receiver Audio Connection

### 2.5.1. ImmersionRC/Airwave receivers

ImmersionRC receivers, including the Duo2400, and the Fat Shark RCV922 LCD glasses, all use a standard 4-pole 3.5mm jack. For reasons which are not immediately obvious, manufacturers of equipment using these connectors do not always follow the same pinout. The 4 most common are shown below:



	1	2	3	4
Fat Shark, Archos, Gigabeat, Creative Zen Vision Series, Cown iAudio, Apple iBook	Ground	Video	Right	Left
Standard Camcorder Cable	Right	Ground	Video	Left
iPod Video	Video	Ground	Left	Right
Zune	Video	Ground	Right	Left

The pinout used by the ImmersionRC/FatShark equipment is shown, and is shared with other common consumer equipment (Archos, Creative Labs, Apple, etc.)

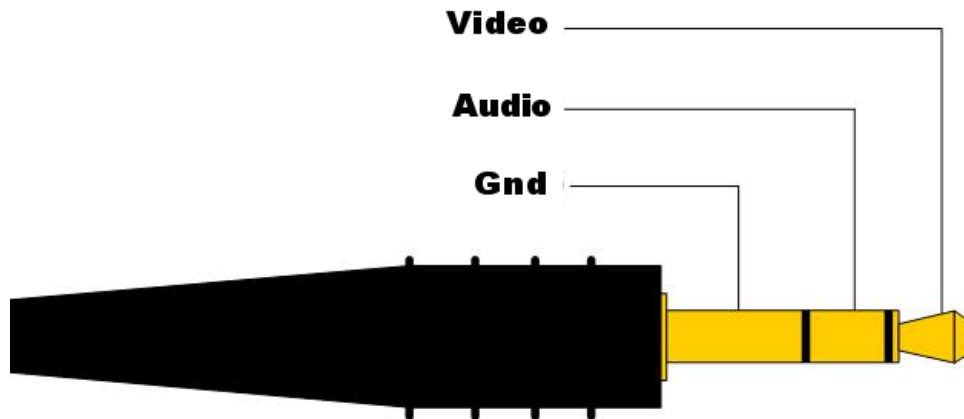
When an ImmersionRC transmitter is used, the telemetry signal will appear on the Right audio channel, pin 3.



Typically, when a 4-pole 3.5mm cable is terminated with Phono/Cinch/RCA connectors on the other end, the colors are Yellow for video, Red for Audio-Right, and White for Audio-Left. (*Note: This is typical, but cannot be guaranteed*).

### 2.5.2. Lawmate Receivers

Lawmate receivers use a stereo 3.5mm jack. With the following pinout:



Cables commonly used to interface to Lawmate receivers have a 3.5mm stereo jack on one end, and two Phono/Cinch/RCA connectors on the other. These connectors are typically Red & White, with audio emitted on the red connector, and video on the white.

Mixed Equipment

### 2.6.Lawmate Transmitter, Airwave Receiver

In the case where a lawmate transmitter is coupled to an airwave receiver, for example, the ImmersionRC Duo 2400, the mono audio from the lawmate transmitter will be emitted on both audio outputs. Note however that the Right channel (Red connector usually) is generally 'cleaner', and contains less interference from the video channel.

## 2.7. Checking, and Debugging Audio Issues

There are two useful tools in the EzAntennaTracker –Lite for debugging audio issues.

The first is the audio level tool. This is accessed by cycling through the status screens using the up/down buttons. The indicator shows the ‘volume’ detected on the audio right-channel input.

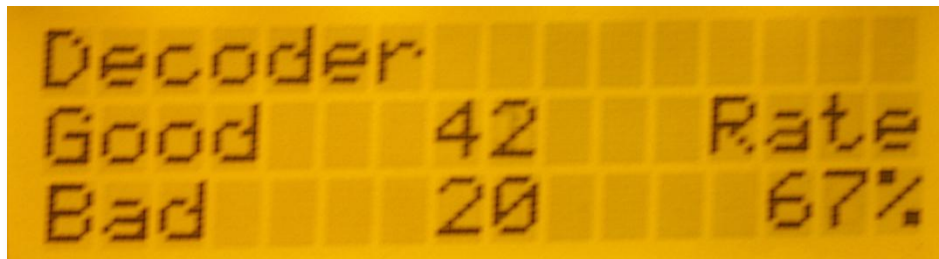
The status in the lower-left corner will show ‘Low’, ‘OK’, or ‘High’, depending upon the suitability of the audio signal for telemetry use.



The second tool is the Decoder status screen, which shows the number of packets successfully decoded, along with the bad packet count, and the ratio between good/bad packets.

*Note: In most cases, there is no cause for alarm if the bad packet rate is relatively high. The telemetry protocol used by the EzTelemetry system sends several updates per second, and the antenna tracker (especially when the plane is a long distance out) requires very few for a successful track.*

*If the bad packet count is high when the plane is close to the Rx then it may indicate a problem.*



## 2.8. Recording telemetry

Not much to do here either, just ensure that the output from the audio/video receiver is correctly cabled to the recording device (avoiding swapping the left and right audio channels if possible).

Try to use a fairly high bitrate for recording the audio (DV Camcorder users don't need to worry, its plenty high enough).

## 2.9. Suitable Pan/Tilt mounts

Some antenna pan/tilt mounts that have been used successfully with the EzAntennaTracker system are listed below. The SPG785/DDT500H combination has been used by the designers of the EzAntennaTracker for several months, and has proven to be a reliable, robust solution.

### 2.9.1. ServoCity Medium-Duty

SPG785 Pan, 2:1 ratio option (630 degrees)

DDT500H Tilt

This combination works well, and gives a full 360 degree pan rotation with plenty of torque (especially on the Pan axis) for larger patch antennas.



Figure 4: ServoCity mount with 8dBi 2.4GHz antenna installed



Figure 3: The SPG785 Pan mount



Figure 2: The DDT500H Tilt mount

The SPG785 includes the highly recommended HS-785 HB sail winch servo. The specifications for this servo may be found here: [http://www.hitecrcd.com/product\\_file/file/35/HS-785HB.pdf](http://www.hitecrcd.com/product_file/file/35/HS-785HB.pdf)

This is a high-torque servo, which provides 1260 degrees of rotation, straight out of the box.

## 2.10. Low cost alternatives

The 'GWS 125' 360 degree servo, is a reasonable low-cost alternative for the pan servo, at least for light-weight antennas. This is also sold under the SuperTec brand, as the S125.

This servo is available from various online retailers, including [www.servocity.com](http://www.servocity.com) in the USA, and <http://www.activerobots.co.uk> , or <http://www.servoshop.co.uk> in the UK.

Note that with any of these 360 degree servos it is highly advisable to support a heavy antenna with an external bearing, and not rely only on the servo's output shaft.

### **2.11. Do I really need a Tilt axis?**

Not in all cases. For example, when using the pan/tilt mount for long distance flight, at safe altitudes, the tilt angle is generally only a few degrees from horizontal, pointing just above the horizon.

In this case, a patch, or yagi antenna, on a pan-only mount, should suffice.

To improve this solution further, use a diversity receiver, with a second omnidirectional antenna, or low-gain patch (with the patch facing straight up). When flying closer to the antenna, the diversity will prefer the omni, or low-gain patch. When flying long-range the pan-mounted antenna, with its narrower radiation pattern, will be preferred.

### **2.12. Servo Splines**

One last point on pan servos, there appear to be two common spline sizes used for the output shafts of standard-size servos. The Futaba, and the Hitec standard. The GWS/SuperTec servo uses a Futaba standard spline.

Hitec standard-sized servos use a 24-tooth spline, and Futaba, a 25-tooth spline.

ServoCity offers a wide variety of adapters for these standard splines, which are interesting for use in building an antenna pan/tilt mount.

## Configuration

The setup menu is available by pressing the center menu button. The menu contains a long list (18 at the current count) of controls, some of which must be configured correctly when setting up the pan/tilt mount, and some before a flight may start.

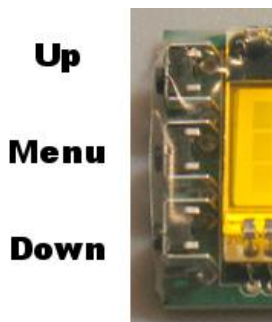


Figure 5: Antenna Tracker Controls

### 2.13. Setup Menu

Once the setup menu is displayed, the Up and Down menu buttons will scroll through the list of controls. A Carat will show the currently selected control.

To toggle the state of a two-state control, just press the center (Menu) button when the control is selected with the carat.

To set the value of a numeric field, select the field, press the menu button, and then use the up/down buttons to adjust the value. A second carat will appear beside the numeric value during its adjustment.

#### 2.13.1. Description of Controls

Each of the controls is described below:



**Set Home:** Press when the GPS-equipped plane is located beside the antenna. This will give the antenna tracker one of the references that it needs, before flight.

Note that this occurs automatically the first time that the antenna tracker 'sees' 6 satellites or greater reported by the plane's GPS. For a more precise fix, wait until the GPS lock is better (9 satellites or more), and press 'Set Home' again.

**Calibrate, Bear(ing) Cal(ibration):** Press the Calibrate button to teach the antenna tracker the second reference that it requires, the direction in which the antenna mount is pointing.

See the Calibration section in this manual for a complete description of how this functions.

```
>Servo Set no
Pan Deg 0°
Tilt Deg 0°
```

**Servo Set(up):** Enable the servo setup control in order to take manual control of the pan and tilt servos. This is useful during initial setup of the pan/tilt mount, and also when using the same antenna mount (un-guided) to fly with a plane not equipped with an ImmersionRC telemetry system.

**Pan Deg, Tilt Deg:** Once servo setup mode is enabled, these controls define the pan and tilt servo angle respectively.

```
>Pan us/360 470
Til us/360 4000
Tilt max 90°
```

**Pan us/360, Til(t) us/360:** These are essentially the relationship between angle, and the width of the servo pulse required to move the servo to that angle. These controls only need to be setup once, during the construction of the antenna pan/tilt mount.

See the 'Setting Up The Servos' section of this manual for an explanation of how to set these up, along with example settings for common pan/tilt mounts.

```
>Tilt min 0°
Pan min -180
Pan max 180°
```

**Tilt max, Tilt min, Pan max, Pan min:** Use to limit servo movement to avoid mechanical constraints .

```
>Pan offset 0°
Til offset 5°
Pan Rev. yes
```

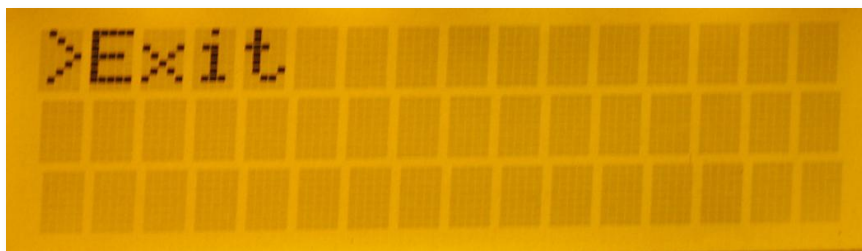
**Pan offset, Til(t) offset:** Use to correct for mechanical offsets. For example, the tilt offset is used to define the offset in degrees between 'zero tilt' (looking at the horizon), and the servo neutral position.



**Pan Rev(erse), Tilt Rev(erse):** Allows the pan/tilt axes to be reversed, to adapt to different servo, and mechanical linkage requirements.

**Servo T(e)st:** Start a servo test, this will walk the mount around its extremes, in both axes.

**Servo Spd:** Servo speed, 1 = fastest, 10 = slowest. Normally, the default setting of 1) is appropriate. Use higher settings only with large, heavy antennas.



**Exit:** Exit the setup menu, and return to the previously displayed status menu.



## 2.14. Setting up the servos

The antenna tracker firmware has several parameters, which are stored in non-volatile memory (i.e. preserved when not powered up).

These parameters allow the characteristics of the servos, and mount, to be defined, and include:

<b>Pan Reverse</b>	no/yes
<b>Tilt Reverse</b>	no/yes
<b>Pan us/360</b>	300-2000us in 10us steps
<b>Tilt us/360</b>	200-4000us in 20us steps
<b>Tilt min</b>	-90 to +90 degrees in 10 degree steps
<b>Tilt max</b>	-90 to +90 degrees in 10 degree steps

To help with the configuration of the mount, a servo setup mode is provided. Once enabled, using the **Servo Setup** entry in the menu, the **Pan Deg**, and **Tilt Deg**, options may be used to manually move the servos.

### 2.14.1. Servo Setup Step #1: Defining the zero position

Use the **Servo Setup** mode to set both servos to zero degrees (centered). When in this mode, mechanically adjust the pan/tilt mount configuration until the antenna is pointing 'straight ahead', with zero tilt (pointing at the horizon).

This generally involves simply removing the screw from each servo's horn, and rotating the horn until the antenna is in its zero-pan, zero-tilt position;

### 2.14.2. Servo Setup Step #2: Setting up servo reverses

Once zero has been defined, set each axis to a setting of +20 degrees, and ensure that the servos move in the correct direction. For Pan, +20 degrees = 20 degrees right of center. For Tilt, +20 degrees = 20 degrees up from level.

If either servo is backwards, change its reverse setting to compensate.

### 2.14.3. Servo Setup Step #3: Setting up servo gains

Next step is to teach the antenna tracker how many microseconds of servo drive pulse width are required to rotate through 360 degrees.

To do this, remain in servo setup mode, and set the pan servo manually to a setting of +90 degrees. Adjust the **Pan us/360** control until the pan axis is rotated 90 degrees to the right of center.

Repeat this for the tilt axis.

### 2.14.4. Servo Setup Step #4: Setting up tilt servo limits

Again, using the **Servo Setup** mode, manually change the tilt angle to each of its mechanical limits in turn, then back off by one 'click'. Note down these values, and enter them into the **Tilt min/Tilt max**



controls.

That's it, the mount should now be setup correctly.

## 2.15. Example settings

### ServoCity pan/tilt mount , SPG785 Pan (2:1, 630 degree option), DDT500H Tilt

<b>Pan Reverse</b>	Yes
<b>Tilt Reverse</b>	No
<b>Pan us/360</b>	450us
<b>Tilt us/360</b>	4000us
<b>Tilt min</b> degrees)	10 degrees (or zero if possible without the tilt servo binding at 0
<b>Tilt max</b>	90 degrees

### GWS/SuperTec S125 (for pan axis only)

<b>Pan Reverse</b>	Yes
<b>Tilt Reverse</b>	---
<b>Pan us/360</b>	990us
<b>Tilt us/360</b>	---
<b>Tilt min</b>	---
<b>Tilt max</b>	---

## 3. Flight

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### 3.1. Status Pages

Four status pages are available, and may be accessed using the up/down buttons while not in the setup menu.

The default page shows the plane's current (or last-known) GPS coordinates. This includes Longitude, Latitude, and Altitude (Above Launch Point). The number of satellites currently locked is also shown, in the lower right corner.



The second page shows the audio levels currently being received, along with an indicator showing 'Low', 'OK', or 'High'.



The Decoder page shows the number telemetry packets decoded, along with the error rate.



The Tracking Page shows the plane's current altitude (above launch point), distance from the launch point, and the bearing and inclination of the antenna required to point to the plane.



### 3.2. Calibration

The Antenna Tracker has no GPS itself (at least not as a standard feature), nor does it know which way is north, so it needs some help during setup time to let it know where it is, and which direction it faces.

The antenna tracker should be oriented so that most flying will take place in the natural direction that it faces (Pan = 0 degrees), to avoid crossing the -180/+180 degree boundary, and therefore avoiding 360 degree complete rotations as the antenna crosses that boundary.

In order to teach it its GPS position, power up the plane, with onboard EzOSD, and wait for it to get a good satellite fix.

Once it has (and ideally after waiting a couple of minutes for a very precise fix), enter the antenna tracker's menu, and select 'Set Home'.

Next thing to do is teach it which direction is north.

There are a couple of possibilities here:

#### 1) Manually, using a compass.

If a compass is available, then the direction in which the antenna tracking is facing may be directly entered into the menu, into the **Bearing Cal** menu item.

As an example, if the zero-position of the antenna tracker points North-West, enter -45 (degrees) into the **Bearing Cal** menu. *Note that the range of this menu item is -180 thru +180 degrees. Many compasses are marked from 0 thru 360 degrees, so for values between 180 and 360, just subtract the value from 360 degrees. E.g. compass reads 320 degrees,  $360 - 320 = 40$  degrees. Enter this into the menu.*

#### 2) Automatically, using the GPS in the plane

Once the GPS 'home position' has been learned, enter the antenna tracker's menu, and select 'Calibrate'. The text 'CAL' will appear on the display (blinking), and the antenna will move to point to the center position in both axes (pan = 0 degrees, tilt = 0 degrees).

Walk the plane out 20 or 30 paces (the further the better), directly in the axis of the antenna (antenna is pointing directly at the plane).

Walk back to the antenna tracker (leaving the plane where it is), and press the center menu button. The pan (heading) zero position will be stored, and flight can commence!

Explanation: Why 'the further the better'?

When a GPS is powered up, especially in the presence of a high-power video transmitter, the positional errors can be significant until a large number of satellites have been acquired.

For long distance flight, the antenna positioning accuracy is fairly critical, so the calibration of the antenna tracker is also just as critical. If the home location of the antenna tracker is stored when the GPS error is large, and then if the bearing (pan) calibration is performed with the plane close to the antenna tracker, also with its own GPS error, the bearing calibration error can be quite large.

The further the plane is positioned from the antenna tracker when the bearing calibration is performed, the less significant this error will be.

### 3.3.

Tip: If flying often at the same location, mark the position of the antenna mount legs on the ground. The position of the antenna, and the heading calibration, are stored in non-volatile memory, and will be restored when power is next applied. This will avoid the need for any 'home position', or heading calibrations each time you fly.

## 4. Replaying recorded telemetry data

Once a flight has been recorded, it may be replayed in order to test the antenna mount (or just to impress your friends with your NASA-class technology).

When choosing the recording/playback device, and its settings, it is important to remember that the audio channel which contains the telemetry stream must be recorded at a fairly high bitrate, and sample rate, in order for reliable decoding to take place.

Audio compression techniques, such as MP3, distort the audio waveform in ways that the human ear does not detect, but the antenna tracker will be adversely affected.

Some examples of recording/playback devices, and 'decodability' are shown below:

Recorder	Playback	Success
DV Camcorder, 25mbps bitrate, for audio + video	Apple iPhone video, Audio encoded to 128kbps, 48kHz sample rate	Approx. 50% lost packets, quite usable none the less.
DV Camcorder, 25mbps bitrate, for audio + video	Audio: 256 Kbps, 44,100 Hz, 16 Bit, Stereo.	Very good, > 95% good packet rate.

## 5. Frequently Asked Questions

TBD

