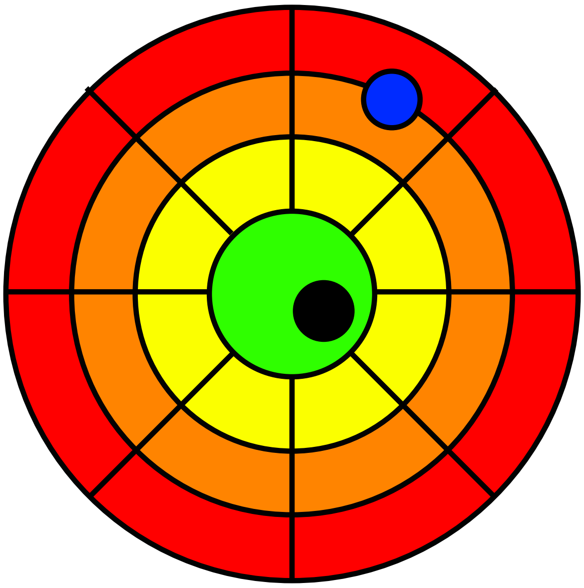
Propeller Balancer App
User Manual

Smart Avionics Ltd.



Propeller Balancer App: User Manual

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Chapter 1. Introduction

The Propeller Balancer app (hereafter referred to as “the app”) provides the user interface for the PB-3 propeller balancer system manufactured by Smart Avionics Ltd. The app aims to be compatible with any Android™ smartphone or tablet that supports Bluetooth® wireless connectivity and is running at least Android version 2.1. The PB-3 system can also be used to balance Gyroplane and Helicopter rotors.

Version 3.1 onwards of the app can also be used with the PB-4. This device uses Wi-Fi to communicate rather than Bluetooth. Unless indicated otherwise, all references in this manual to the PB-3 also apply to the PB-4.

1.1. Obtaining and Installing the App

Note

Before you can install the app, you need to tell your Android device that it's OK to install non-Market applications.

Go to **Menu > Settings > applications** and make sure that the **Unknown Sources** checkbox is checked.

The latest revisions of the app and this documentation can be found at the Smart Avionics website, www.smartavionics.com.

If you have a barcode scanning app, you can download the files directly to your Android device using these QR codes:

PropellerBalancer.apk

PropellerBalancerManual.pdf

When the app has been downloaded, select it and you will be prompted to accept these permissions:

Requested Permission	Why Permission is Required
Storage	To export images and data to the Android device's external storage (SD card).
Network communications	To communicate with the PB-3.

Requested Permission	Why Permission is Required
System tools	To request enabling of Bluetooth and adjustment of screen timeout.

Accept the permissions and the app will be installed.

1.2. Balancing System Overview

The propeller/rotor balancing system has these main components:

Accelerometer	This is mounted near the propeller/rotor to detect the vibration caused by any imbalance.
Optical tachometer	A strip of reflective tape is attached to one propeller/rotor blade and an optical sensor detects the tape as it passes and generates the tachometer signal required by the balancer. For propeller balancing, the PB-3's built in optical tachometer would normally be used. For rotor balancing, an external tachometer must be used.
Signal processor	This digitises the vibration signal and sends the resulting data to an Android device using Bluetooth® wireless communications.
Android device	This provides the interface through which the user interacts with the PB-3.

For details of how the sensors are attached and other hardware related information, please refer to the PB-3 Propeller Balancer User Manual.

1.3. App Overview

1.3.1. Title bar

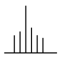
The app's title bar displays the application name (Propeller Balancer). If the height of your Android device's display is limited, you can set a preference to hide the title bar.

1.3.2. Tabbed views

The app has a tabbed interface that provides 4 top-level views:

	The **polar chart view** shows a *polar chart* on which the data points captured during balancing are plotted – it is the primary view used when balancing a propeller/rotor
RPM IPS DEG	The **data view** shows an easy to read numeric display of the current vibration data.

The **graph view** shows a graphical display of the vibration waveform – very much like a simple oscilloscope.



The **spectrum view** shows the vibration spectrum – it can be a very useful aid when diagnosing vibration related problems.

The desired view is selected by pressing the associated tab.

If the height of your Android device's display is limited, you can set a preference to automatically hide the tabs once you have pressed one. When the tabs are hidden, the first item in the option menu makes them visible again.

1.3.3. Quitting the app

To quit the app from a top-level view, press the Android device's back button. Alternatively, you can use the **Quit App** option menu item from any view. A dialog will pop up to confirm the action. If you would rather not have the confirmation dialog, there is a preference to suppress the quit dialog.

1.3.4. Jobs

The app provides a means of keeping the data associated with each balancing session you carry out separate. A “job” is just a named collection of captured data items (polar points and spectra) along with a few values that configure the PB-3's behaviour. The most important configuration value is the job's *mode* which can be either **Propeller** or **Rotor**.

1.3.5. Status bar

The status bar is displayed at the top of each tabbed view. It contains a number of fields separated by '|'. Most of the fields consist of a field name and value separated with '='. The fields are:

Job	*String*	The name [a] of the current job. All data (captured polar points and spectra, exported images, etc.) will be associated with this job. An obvious value for a job name would be the registration letters of the aircraft whose propeller/rotor is being balanced. Job names are case insensitive and are always displayed using upper-case letters.
Locked		This field doesn't have a value and it is only shown when the current job is “locked”.
Axis	**X** or **Y** or *Alias*	The accelerometer axis currently selected. If the currently selected axis has been given an alias, that will be displayed instead of **X** or **Y**.

PSRU	*Number*	The ratio of the PSRU (Propeller Speed Reduction Unit) fitted to the engine.
Mode	**Prop** or **Rotor**	The current job's mode.
Tacho	**Int** or **Ext**	The tachometer currently selected (internal or external).
Log	**On** or **Off**	Indicates whether the Logger is enabled or not. If the Logger has logged some data, the field will be displayed in green.
Bat	*Percentage*	The remaining capacity of the PB-3's battery. If the value is less than 20%, the field is displayed in red.

[a]Previous versions of this app labelled data items with a “job tag”, job names are now used instead.

When the app is connecting to the PB-3, progress messages are appended to the status bar.

If the height of your Android device's display is limited, you can set a preference to hide the status bar.

1.3.6. Menus

View-specific options are accessed through context menus (menu pops up when view is long-pressed).

Common options are accessible via the options menu that pops up when the Android device's menu button is pressed. Devices that run the more recent versions of Android (Honeycomb or later) generally don't have a menu button. Instead, the options menu is accessed via the device's Action Bar. If the width of the display allows, some of the option menu items (**Job**, **List Points**, **List Spectra**, etc.) will be shown in the Action Bar rather than in the option menu.

1.3.7. Exporting images

At any time, a snapshot of the current top-level view can be exported as a JPEG or PNG image by selecting **Export Image** from the options menu. The images are saved into a directory called **Pictures/PB** on the Android device's external storage (SD card). The image format used is determined by the exported image format preference.

After an image has been saved, an image viewing app is invoked to display the image. Typically, Android image viewers provide (menu) options to share the displayed image using Bluetooth, email, etc. Pressing the back button in the image viewer should return you to the Propeller Balancer app. There are many Android image viewer apps that provide a variety of features. A free one that works extremely well for our purposes is “QuickPic” which can be installed via Google Play.

1.3.8. Vibration level colours

The background of the polar chart can optionally be coloured to give an indication of the level of vibration. The same colours are also used for the background of the text wherever the vibration level is displayed textually. The vibration level is expressed in units of *Inches Per Second* (IPS).

Here is a summary of the vibration levels along with their descriptions and colours:

Colour	IPS	Description
	≥ 1.0	Very rough
	< 1.0	Rough
	< 0.5	Slightly rough
	< 0.25	Fair
	< 0.15	Good
	< 0.07	Very good
	< 0.04	Extremely good

1.4. Bluetooth Setup (PB-3)

The PB-3 and the Android device communicate using Bluetooth and they have to be *paired* before communication can take place. To pair the devices, do the following:

1. Turn on the PB-3 and check that its status LED is flashing regularly.
2. On the Android device, go to **Menu > Settings > Wireless & networks > Bluetooth settings** – if Bluetooth is not yet enabled, enable it now using the checkbox on that page.
3. Press **Scan for devices** – after a few seconds the PB-3 should appear in the list of Bluetooth devices displayed lower down on the screen (you may need to scroll down to find it if the list contains several items).

Now pair with the PB-3 by pressing its entry in the list – a dialog should appear inviting you to enter the security code which is **0000**. The PB-3 should now be paired and its entry in list should say “Paired but not connected”.

The Android device and the PB-3 will remain paired until you unpair them by long-pressing the PB-3 list entry and then selecting the **Unpair** option.

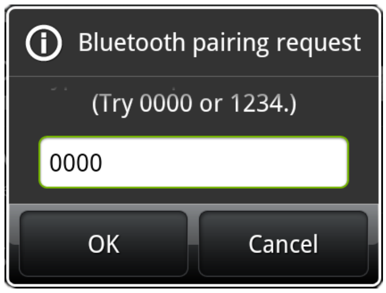


Fig 1.1. PB-3 Pairing

If you turn off the Bluetooth on the Android device, when you next start the Propeller Balancer app it will ask you if you want to turn the Bluetooth on.

1.5. Bluetooth Remote Capture Button

Remote camera shutter release devices that use the Bluetooth HID protocol can be used as a remote capture button. This is particularly useful for capturing polar points and spectra when flying a gyroplane or helicopter as the pilot does not have to hold the Android device or use the on-screen controls at all. The app has been tested with a device called the iKey3 but any device that behaves like a HID keyboard, and sends an Enter key when its button is pressed, should be compatible.

1.6. Wi-Fi Setup (PB-4)

To communicate with the PB-4, both the Android device and the PB-4 need to be talking to the same *access point* (AP). If you are in range of your home/office/workshop AP, the PB-4 and the Android device can both be set up to use that AP.

At the airfield, you normally do not have an AP but the PB-4 can be the AP (see PB-4 HW manual for details). In this case, you need to go into the Wi-Fi setup for your Android device and make it use the PB-4 AP (it will be called PB4-*XX* where *XX* are two letters/digits).

You also need to set the data source preference to **PB-4**.

Chapter 2. Polar Chart View

The polar chart view displays vibration readings plotted in a polar format. Each plotted polar point has a vibration level and a phase angle. The vibration level is zero at centre of the chart. The phase angle is zero at the top of the chart and increases clockwise (0-360°). The background colour of the chart makes it easy to determine the quality (vibration level) of a plotted point. When balancing the propeller/rotor, the aim is to get the polar point as close to the centre of the chart as possible.

The *current polar point* is displayed as either a black filled circle (X axis points) or diamond (Y axis points). If the job has been set up to capture data from both axes and the “Plot All Axes” menu option is selected, both points will be displayed. Otherwise, only one of them (from the *primary axis*) will be displayed. A summary of the polar point's most important attributes is shown in a “bubble” above the point. The format is **RPM/IPS@DEG**. If the show solution option is enabled, a terse description of what should be done to improve the state of balance is displayed below the point.

A grey “standard deviation ellipse” is drawn around the current polar point. The size of the ellipse grows and shrinks depending on the variation in values of the vibration level and phase angle. This provides a useful visual indication of how steady the readings are.

At the bottom of the display is the **Capture** button. Pressing this “captures” the current polar point(s) and, optionally, the current spectra too.

When a point is captured, its details are stored in the app's database. Optionally, a captured point dialog will open to display the point's details.

Each captured point is plotted on the chart as an unfilled circle/diamond so you can see how the points are clustering. When zoomed in sufficiently, each captured point is numbered with its position in the polar point list.

Long-pressing the capture button pops up a dialog that lets you choose the size of that button. So if you find the standard button too small you can make it bigger.

The chart can be panned by dragging it with a finger.

The chart can be zoomed using the zoom control buttons that appear when the chart is panned or by using “pinch-zoom” gestures if your Android device supports them. The visibility of the zoom controls is determined by the show zoom controls preference. You can also use the Android device's volume up/down buttons to adjust the zoom.

Long-pressing the polar chart pops up the polar chart context menu.

2.1. Propeller Mode Polar Chart

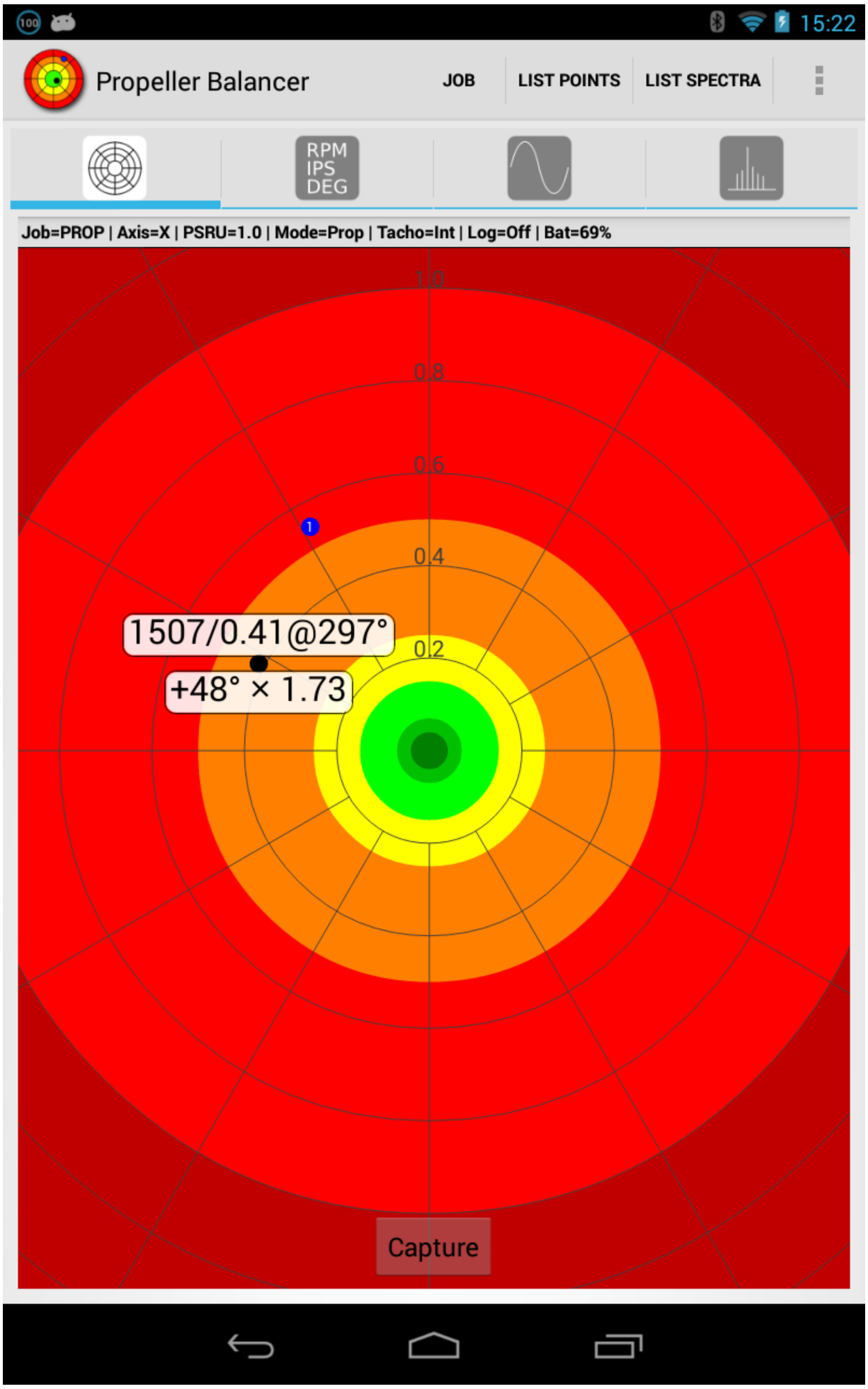
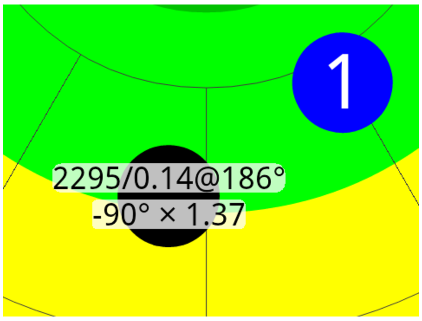


Fig 2.1. Propeller Mode Polar Chart

When balancing a propeller, all adjustments (weight added and/or moved) are determined by comparing the current polar point with the *start point*. A start point is simply a polar point that was captured before any weights were added. Start points are plotted as filled blue circles. Any point can be specified to be the start point.

2.1.1. Propeller mode solution

The propeller mode solution bubble contains a terse description of how the weight needs to be adjusted to achieve the best balance.



If the RPM of the current point is within ±5% of the start point's RPM, a solution of the form **ANGLE** × **SCALE** will be shown. **ANGLE** is signed; a positive value means move the weight forward (in the direction of propeller rotation) that many degrees and a negative value means move the weight backward (opposite to the direction of propeller rotation). **SCALE** is a multiplier that specifies the required change in weight; e.g. a value of 1.2 means increase the weight by 20%, a value of 0.5 means halve the weight.

If the current point's RPM is not close enough to the start point's RPM to calculate a solution, the bubble will indicate how much the RPM needs to be altered.

2.2. Rotor Mode Polar Chart

The polar chart provides a plan view of the aircraft's rotor with the front of the aircraft assumed to be in the 12 o'clock position (the *datum* position). With the rotor blades aligned in the 12 o'clock - 6 o'clock position (fore-aft) the blade at the front (at the datum) is the *master blade*. It should be marked in some way to distinguish it from the other blade.

The accelerometer measures acceleration in two axes. To balance a rotor you only need to use a single axis which is typically orientated to the side-to-side (roll) axis of the aircraft. The job has an option that lets you specify the *primary axis* which is the accelerometer axis to use during the balancing process. You may also be interested in measuring the acceleration in the vertical axis and so the app is capable of capturing data (points and spectra) for both X and Y axes simultaneously and there is a job option to enable that.

The rotor mode polar chart displays 3 markers. Two of the markers are square and they indicate the orientation of the X and Y accelerometer axes. The other marker is arrow shaped and it indicates the position of the master blade at the point when the tachometer is triggered. The arrow points in the direction that the rotor rotates when viewed from above.

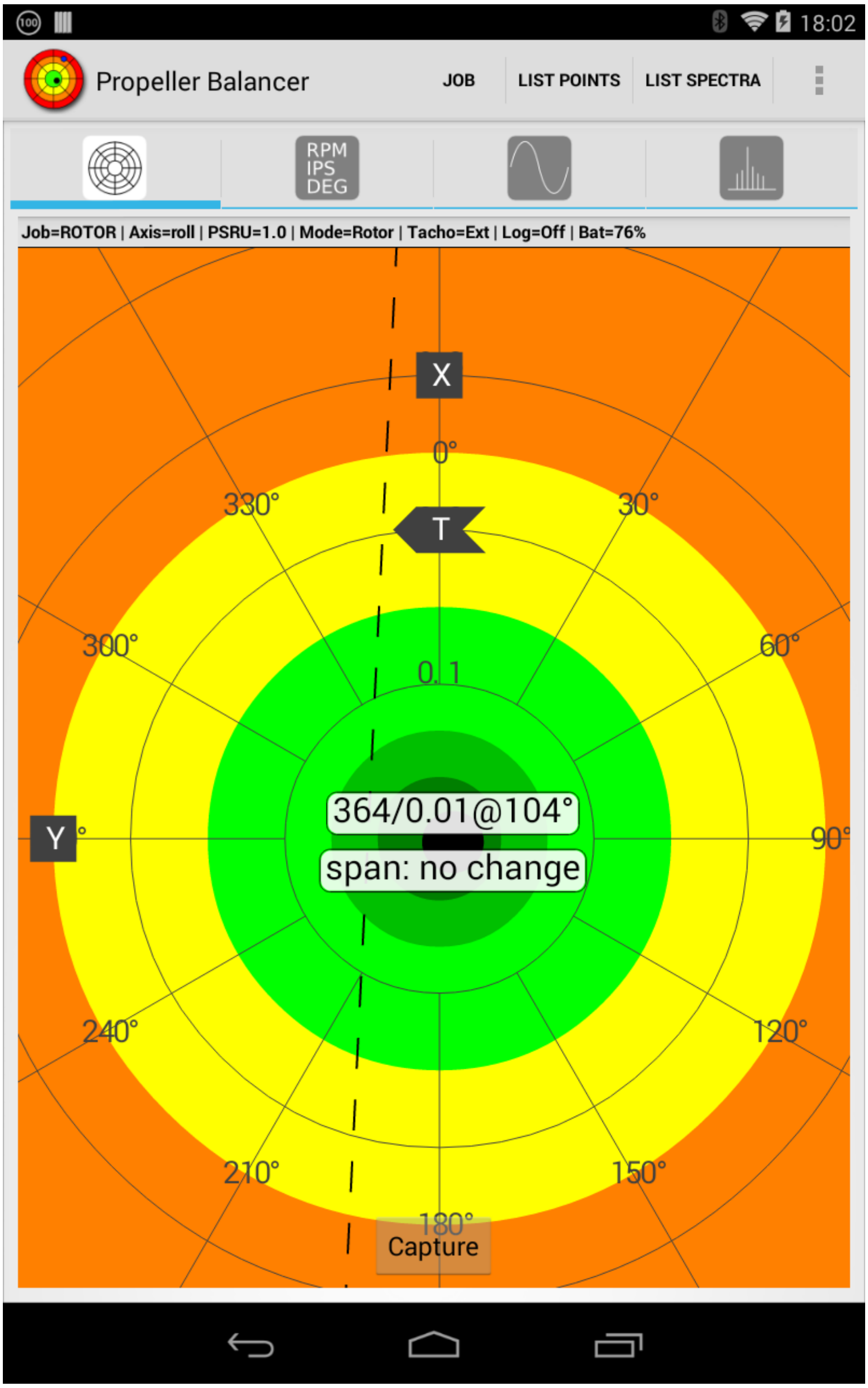


Fig 2.2. Rotor Mode Polar Chart

When balancing a rotor, adjustments are determined by the relationship between the current polar point and one or more *move lines*. Move lines are shown on the chart as dashed[1] black[2] lines. A move line shows on the polar chart the direction the current polar point would move in when a particular adjustment is carried out. For example, there would normally be a move line

[1]Style configurable, default is dashed.
[2]Colour configurable, default is black.

associated with adding weight to either tip of the rotor blades to adjust the spanwise balance. Adding weight to one tip would move the current polar point parallel to that move line in one direction and adding weight to the other tip would move the polar point parallel to that move line in the opposite direction. Another common move line is associated with shifting the mass of the rotor system in a chordwise direction. The move lines are not required to be orthogonal (at 90°) to each other. Each axis (X and Y) can have any number of move lines defined and they will all be shown on the chart. At any one time, a maximum of 2 move lines may be selected to be used in the solution calculation. Each job has its own move lines.

2.2.1. Rotor Mode Markers

The rotor mode markers show you how the accelerometer axes are aligned with the aircraft structure and also where the master blade is positioned at the time the tachometer is triggered. Once defined, you should not need to alter the position of the markers again unless you change the orientation of the accelerometer or the positions of the tachometer sensor and/or the retroreflective tape. With the markers correctly set, the angles reported by the app can be related to the rotor when it is positioned with the master blade pointing forward (the datum position).

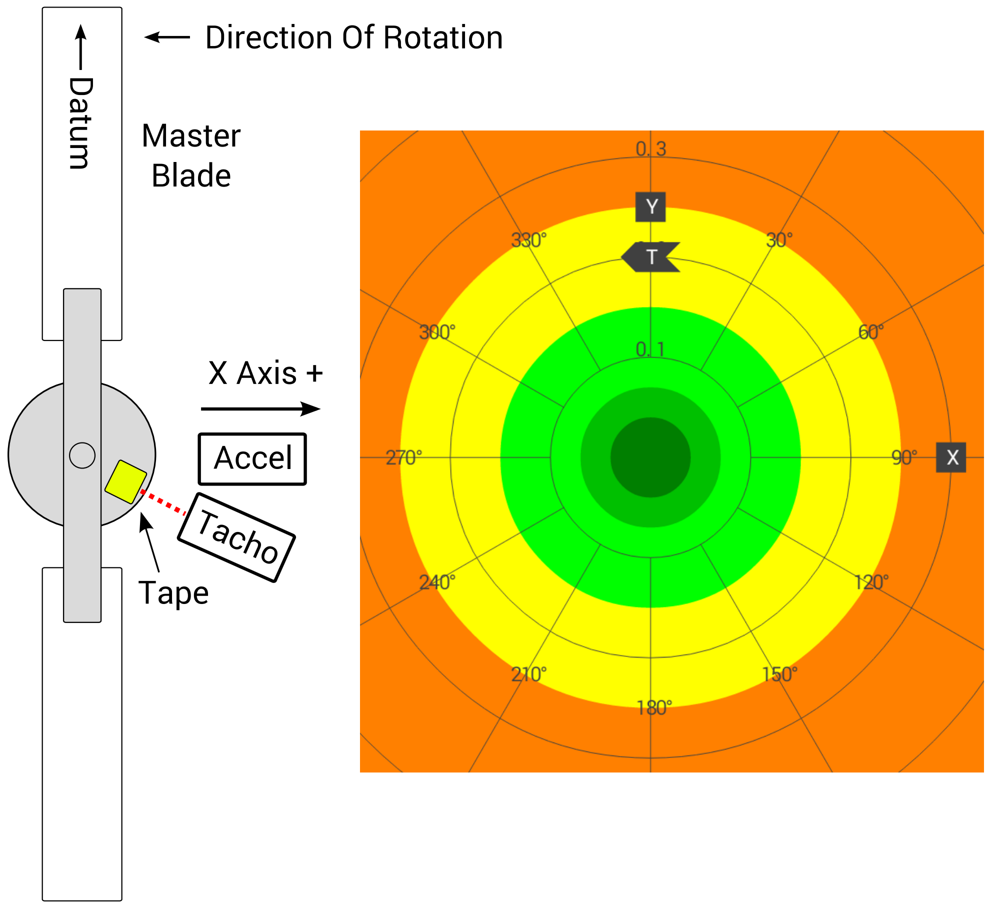


Fig 2.3. Marker Positions When Tape Aligned With Tacho

The positions of the markers that are labelled **X** and **Y** indicate the directions of the positive accelerometer axes when the accelerometer is mounted such that its axes are parallel with the rotor's plane of rotation. For example, consider a machine whose rotor rotates anti-clockwise when viewed from above. If the accelerometer is mounted so that the positive X axis is pointing away from the rotor's axis of rotation in the 3 o'clock direction (i.e. pointing to the right when viewed from above), the **X** marker should be in the 3 o'clock (90°) position as shown in Fig 2.3.

When an accelerometer axis is perpendicular to the plane of rotation (i.e. the axis is pointing vertically upwards), its marker should be set to 0 degrees.

The marker that is labelled **T** indicates the *position of the master blade at the point where the tachometer triggers*. To determine the position for this marker, move the rotor until the retroreflective tape is illuminated by the beam from the tacho sensor and then measure (or estimate) the angle from the master blade to the datum position in the direction of rotation. Often, the tape can be positioned in front of the tacho sensor with the master blade at the datum position, in which case, the **T** marker should be positioned at 0 degrees as shown in the previous figure.

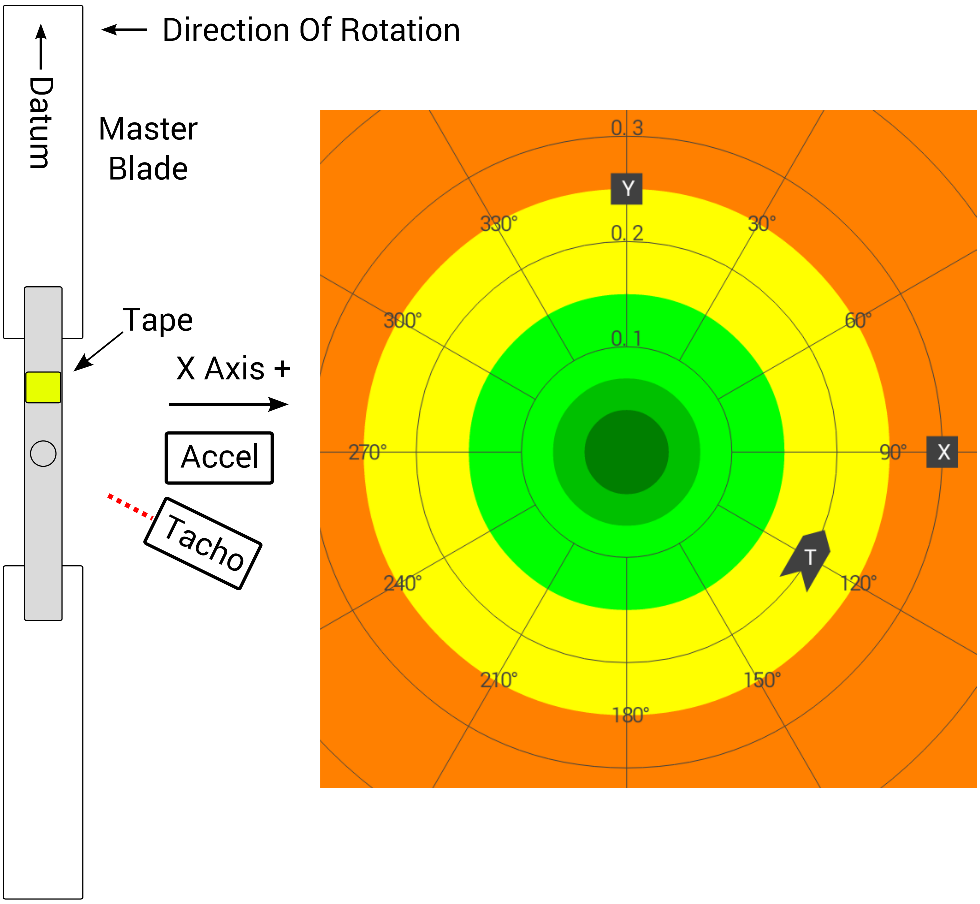


Fig 2.4. Marker Positions When Tape Aligned With Master Blade

Alternatively, if the retroreflective tape is attached to the master blade such that when that blade is at the datum, the tape is also lined up with the datum, then the **T** marker's position must coincide with the actual position of the tachometer on the aircraft. In Fig 2.4, the tachometer is mounted in the 4 o'clock position and so that's where the **T** marker is placed.

The markers can be moved by selecting the **Move Markers** item from the polar chart context menu. Alternatively, the markers can be positioned by entering the required angles into the job setup dialog.

2.2.2. Defining move lines

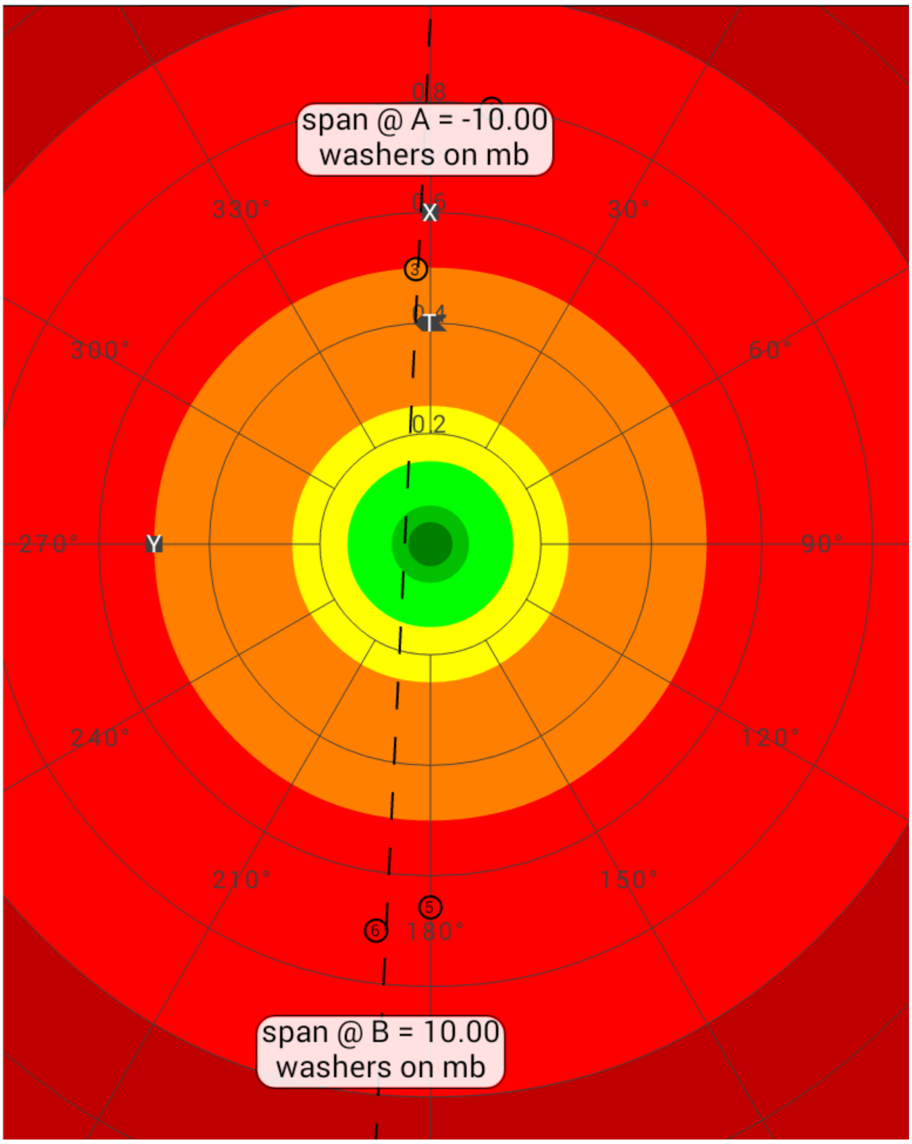


Fig 2.5. Moving A Move Line

The orientation of a move line is defined by positioning on the polar chart two *nodes* (node A and node B) that the line passes through. A move line's orientation is adjusted by dragging its nodes to positions on the chart that correspond to known conditions.

For example, to set up the spanwise move line, weight is first added to one tip and one or more polar points are captured in that condition. Then the weight is moved to the opposite tip and more polar points are captured. The move line's nodes are then positioned on the polar chart above the two groups of points.

The amount of weight added to each tip (grams, number of washers, etc.) is entered into the move line setup dialog along with an optional name ('span', 'chord', etc.) and units ('grams', 'washers', 'inches of tape', etc.). Once the move line is set up, the “solution” for the current polar point will contain a suggested adjustment derived from the position of that point along the move line. In “move move lines mode” the move line nodes are shown as white bubbles containing text.

2.2.3. Move line setup dialog

The move line setup dialog is used to configure a single move line. It contains these items:

Name	The move line's name. It is simply used as a label and it doesn't have to be unique or defined at all if you don't want to name the move line.
Applies To Axis	The name (X, Y or axis alias) of the accelerometer axis that this move line is associated with. Each move line can only be associated with one axis.
Units	The units of adjustment for this move line. Typical move line units are “grams”, “washers”, “inches of tape”, “degrees clockwise”, etc.
Value @ A **Value @ B**	The number of units of adjustment that correspond to the positions of the move line's nodes. For example, one node could correspond to the condition of 10 washers being attached to the tip of the master blade and the other node for the opposite condition of 10 washers being attached to the tip of the non-master blade. These two values must be different in either magnitude or sign, i.e. they can't both be 10 (but one can be 10 and the other -10).
Increment	When the adjustment is calculated, the resulting value will be a multiple of this increment. So if you only have washers of one size, then an increment of 1 would be appropriate but if you also had some washers that weighed half as much, then an increment of 0.5 would be appropriate because then the suggested amount of adjustment would be to the nearest 1/2 washer.

Move Line Colour The move line's colour. Supported colours are black, red, green, blue, magenta and orange.

Move Line Style The move line's style. Supported styles are dashes, arrows, solid and dots.

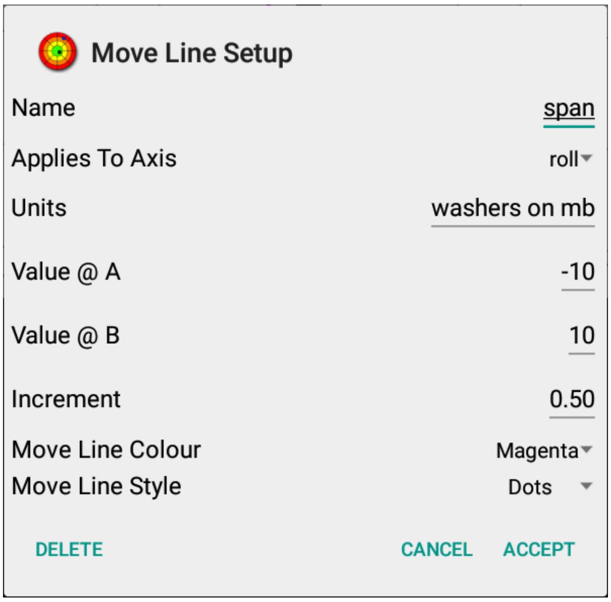
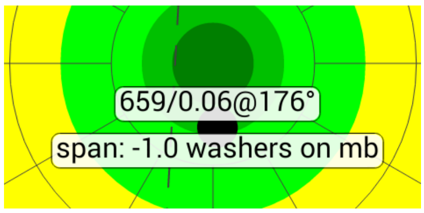


Fig 2.6. Move Line Setup

2.2.4. Rotor mode solution

The rotor mode solution bubble contains one or two suggestions for adjustments to be made to achieve the best balance. Each move line provides one suggestion. The format of the suggestions is "*name*: *amount units*" where *name* is the move line's name (if it has one), *amount* is the amount of adjustment required and *units* are the units of adjustment (if they were defined for the move line).

If more than one suggestion is shown, they are ordered with the largest adjustment shown above the smaller adjustment[3].



2.3. Polar Chart Context Menu

The polar chart context menu contains these items:

[3]The ordering is done by comparing the distances along the respective move lines that the polar point would need to move to reach the centre of the chart so the move lines' units do not have to be the same.

Plot All Jobs	A checkbox that controls whether captured points from other jobs are plotted along with the current job's points or not.
Plot All Axes	A checkbox that controls whether captured points whose axis differs from the current axis are plotted or not.
Track Current Point	A checkbox that controls whether the chart is to be automatically panned so that the current polar point is always displayed near to the centre of the screen.
Keep Centre Visible	A checkbox that controls whether the chart is to be automatically zoomed so that the centre of the chart is always visible when tracking the current point.
Colour Background	A checkbox that controls whether the chart's background will be coloured or not.
Show Solution	A checkbox that controls whether a “solution bubble” will be shown below the current point's summary or not. The solution bubble content is different for propeller and rotor modes.
Pan & Zoom Chart[a]	Enters the legacy pan-zoom mode. You can also use the Android device's volume up/down buttons to adjust the zoom.

[a]Only available if the legacy modal pan-zoom behaviour is enabled.

In rotor mode, the context menu also includes these items:

Rotor Rotates Clockwise	A checkbox that, when checked, specifies that the rotor rotates in a clockwise direction when viewed from above. The **T** marker shows the direction of rotor rotation.
Move Markers	Normally, the positions of the **X**, **Y** and **T** markers are fixed. This menu item enables “move markers mode” which allows you to reposition the markers by simply dragging them with your finger to the required positions. The markers become blue when move markers mode is active. To fix the markers again use the (now visible) **Fix Markers** menu item or just wait a short while and the markers will become fixed again automatically. As you move the **T** marker, all of the polar points on the chart move with it. Moving one of the accelerometer axis markers (**X** or **Y**) just moves the points associated with that axis.
Move Move Lines	Selecting this item enables “move move lines mode” which allows you to adjust the positions of the existing move lines by dragging the lines' nodes. The positions of the lines' nodes is shown by “bubbles” that are displayed while this mode is active. Drag the nodes so that they lie on top of the polar point(s) that correspond

	to a particular state of imbalance (weight on one tip or the other, etc.) To fix the move lines again use the (now visible) **Fix Move Lines** menu item or just wait a short while and the move lines will become fixed again automatically.
Setup Move Line	This item lets you select one move line to be configured. For a short while, the move lines' node information is displayed so that you can identify the move lines. Touch the move line that is to be configured and the move line setup dialog will appear.
Select Move Lines To Use	Pops up a dialog containing a list of check boxes, one for each defined move line. You can select which of the move lines will be used to calculate the rotor mode solutions. No more than 2 move lines can be selected at any one time.
Add Move Line	Adding the move line involves setting up its parameters and positioning the line on the chart. Selecting this item firstly pops up the move line setup dialog and when that dialog is dismissed using the **Accept** button, move move line mode is entered so that the new move line's nodes can be positioned.
Show Move Line Names	A checkbox that enables the display of the move line names. When enabled, the name of each move line will be displayed in a “bubble” positioned on the appropriate line.

2.4. Panning and Zooming the Polar Chart

Only available if the legacy modal pan-zoom behaviour is enabled.

In *pan-zoom mode* the **Capture** button is hidden and two new buttons appear at the top of the view and (optionally) zoom control buttons appear at the bottom of the view.

The chart can be panned by dragging it with a finger.

The chart can be zoomed by using the zoom control buttons or by using “pinch-zoom” gestures if your Android device supports them. The visibility of the zoom controls is determined by the show zoom controls preference. The new buttons are:

Reset – centres the chart in the view and zooms out so that the whole chart is visible.

Cancel – exits pan-zoom mode without saving any changes.

To save the changes you have made and exit pan-zoom mode, press the Android device's back button.

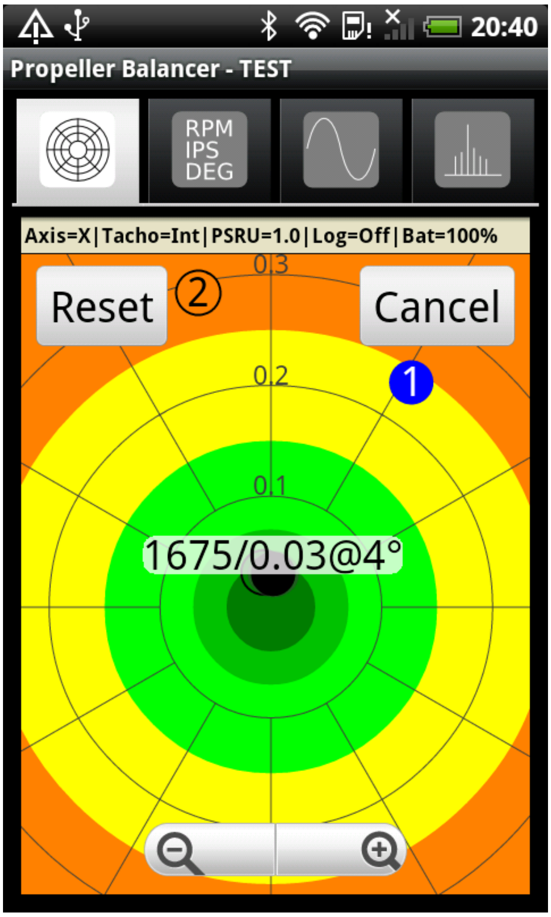


Fig 2.7. Polar Chart Pan & Zoom

While in pan-zoom mode, current point tracking is temporarily disabled.

Chapter 3. Data View

The data view provides a numeric display of the current vibration data values.

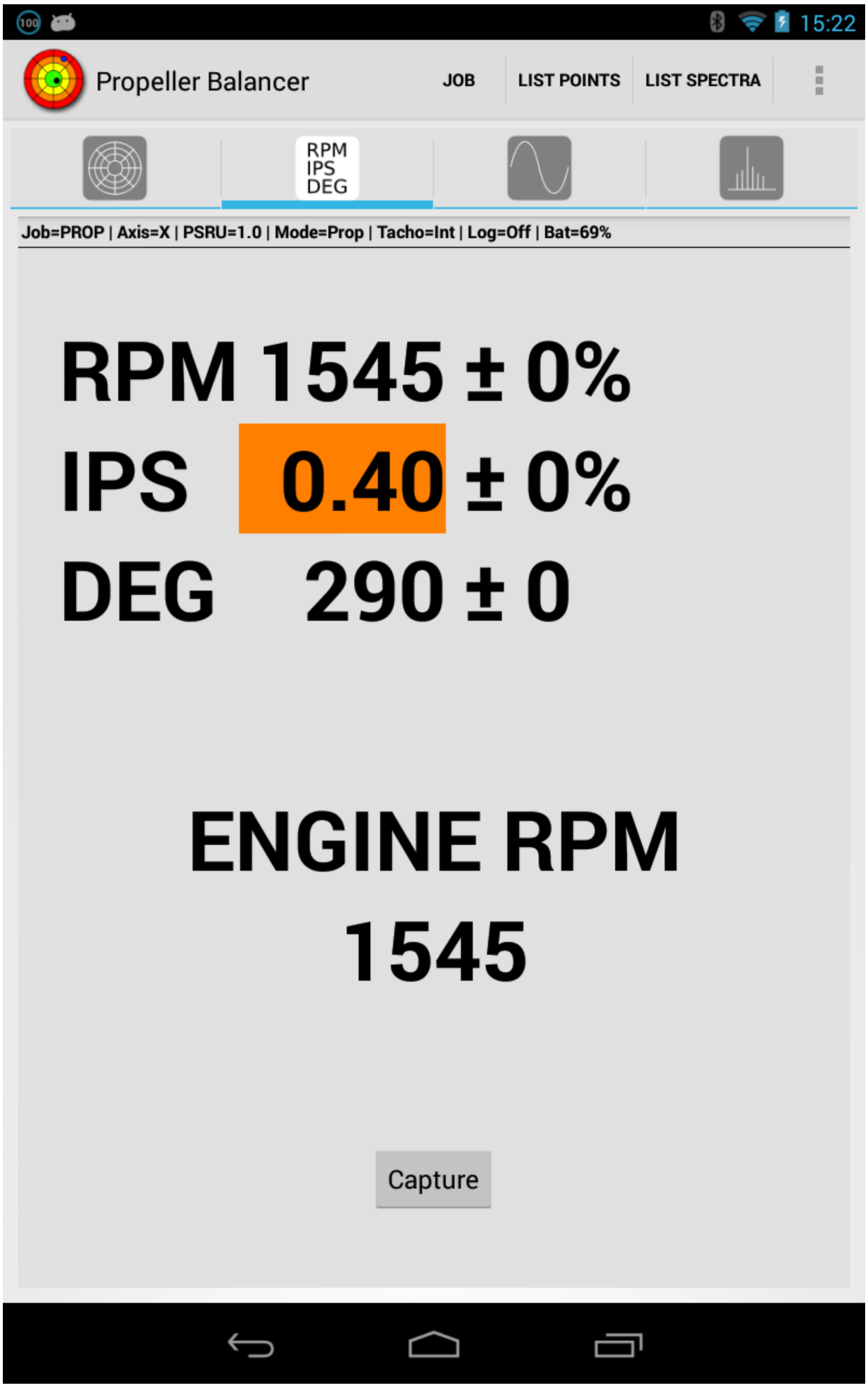


Fig 3.1. Data View

The data values displayed are:

RPM – the propeller RPM and associated percentage standard deviation.

IPS – the vibration level and associated percentage standard deviation.

DEG – the phase angle of the vibration (in degrees) and associated standard deviation (the standard deviation is limited to a maximum of 90).

ENGINE RPM - this is simply the propeller RPM multiplied by the PSRU ratio.

Below the data values is the **Capture** button. Pressing this “captures” the current polar point(s) and, optionally, the current spectra too.

When a point is captured, its details are stored in the app's database. Optionally, a captured point dialog will open to display the point's details.

Chapter 4. Graph View

The graph view displays the time domain vibration waveforms (acceleration, velocity or displacement plotted against time) for one revolution of the propeller/rotor. The waveform may be plotted using either Cartesian or Polar coordinates. Alternatively, if data is captured from both X and Y axes, it may be plotted as a 2 dimensional graph.

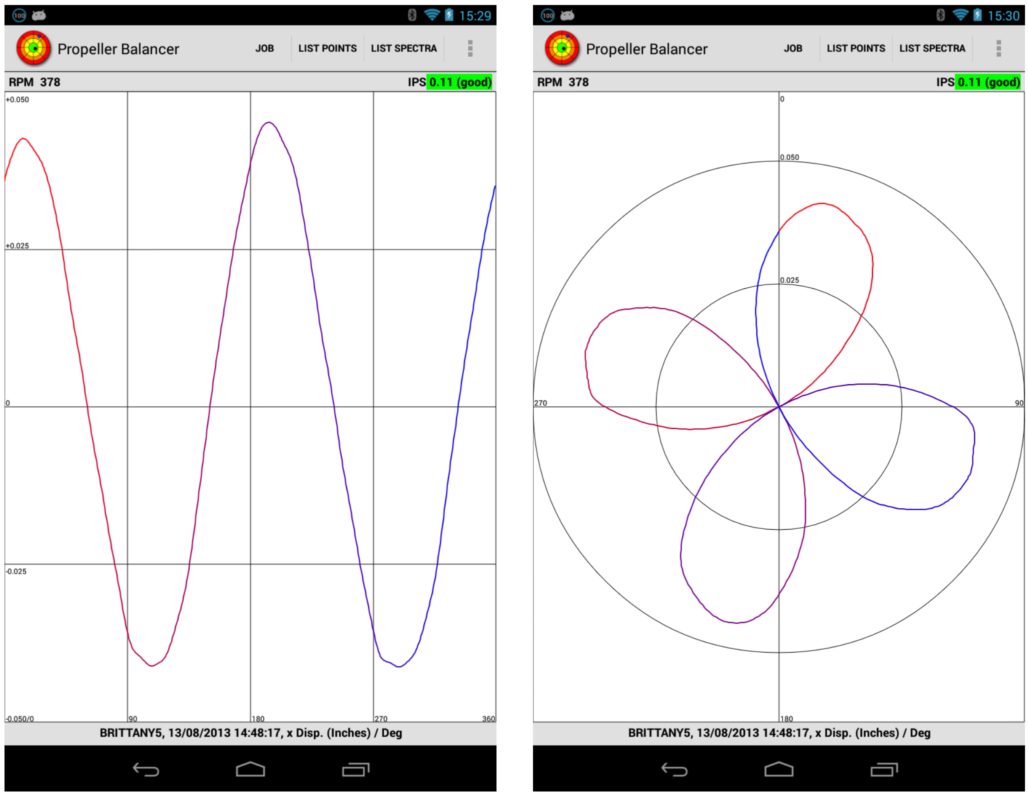


Fig 4.1. Graph View (Cartesian and Polar Formats)

If the **Colour Waveform** context menu option is selected, the waveform is coloured red at the start of the cycle and blue at the end.

When acceleration is being displayed using the polar format, the display also shows (with a small red cross) the position of the average of the plotted polar coordinates. This gives you a visual indication of the vibration waveform's phase angle.

The waveforms' size may be scaled manually using either the context menu or the Android device's volume controls or automatic scaling can be enabled. At the top of the view, the current RPM and IPS are shown and at the bottom status information that shows when the waveform was captured and what is being displayed.

Long-pressing the view pops up a context menu.

4.1. Graph View Context Menu

The graph view context menu contains these items:

Cartesian Plot A checkbox that selects a Cartesian plot of the data.

Polar Plot A checkbox that selects a Polar plot of the data.

2 Axis Plot A checkbox that selects a 2 dimensional plot using data from both axes. The primary axis data is used for the vertical direction and the secondary axis data is used for the horizontal direction. To give you an idea of how the waveform progresses through the cycle, a label is displayed every 15 degrees.

Set Full Scale Pops up a list of full scale magnitudes for you to select from. The first item in the list is **Auto** which automatically scales the waveform so that it fits the display.

Plot Acceleration A checkbox that selects display of acceleration. This is the raw data coming from the accelerometer.

Plot Velocity A checkbox that selects display of velocity. This waveform is obtained by integrating the acceleration data.

Plot Displacement A checkbox that selects display of displacement. This waveform is obtained by integrating the velocity data.

Colour Waveform A checkbox that enables the colouring of the displayed waveform. The beginning of the waveform is coloured red and the end of the waveform is coloured blue.

Draw Graticule A checkbox that enables the display of the graticule and axis values.

Chapter 5. Spectrum View

The spectrum view shows the vibration data in the frequency domain – each spectral line represents the vibration level at a given RPM.

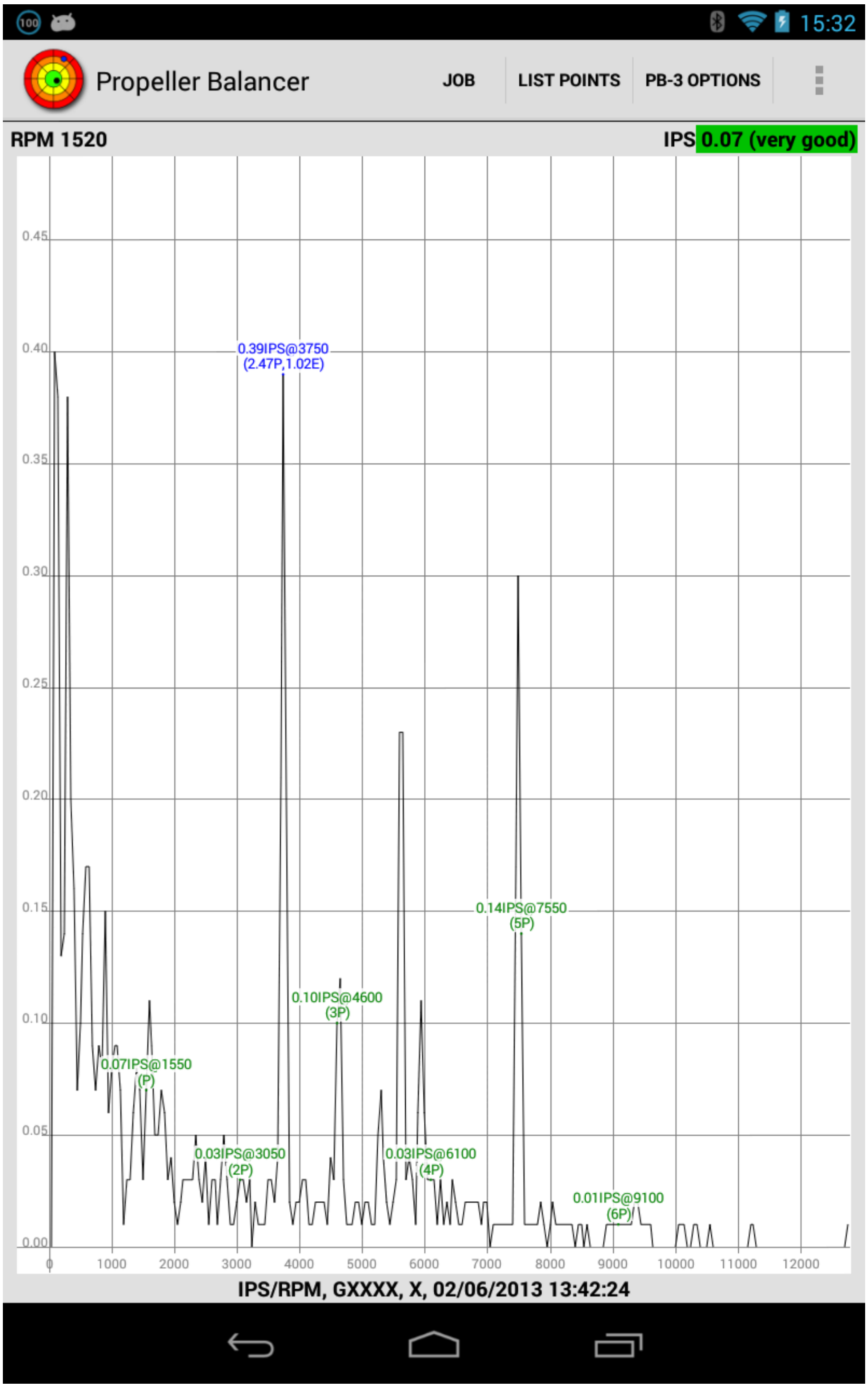


Fig 5.1. Spectrum View

The spectrum view is extremely useful for helping to diagnose vibration problems as it allows you to determine how much vibration is occurring at each of the frequencies of interest (prop frequency, blade pass frequency[1], engine crank and half-crank frequencies, etc.)

By default, the plot's vertical axis represents velocity (in IPS). Alternatively, the vertical axis can represent acceleration (in G).

The display can be scrolled left and right by simply dragging the white area in the required direction.

Optionally, a graticule can be displayed and “interesting” spectral lines can be labelled.

The horizontal and vertical scaling and the “width” of each of the spectral lines may be altered using the context menu.

The width of the spectral lines is specified in RPM per line. Note that the display update rate is influenced by the width: the narrower the width, the slower the update rate.

If labels are being displayed, they are positioned at the top of their respective spectral lines.

At the top of the view, the current RPM and IPS are displayed.

Long-pressing the view pops up a context menu.

5.1. Spectrum View Context Menu

The spectrum view context menu contains these items:

Capture Spectrum	Captures the current spectrum and stores it in a database on the Android device. The list of captured spectra is accessible through the options menu. This menu item is not shown when a previously captured spectrum is being viewed or when the **Capture** button (see below) is displayed.
Analyse Spectrum	Opens an analysis dialog that describes the current spectrum.
Set RPM Per Line	Opens a dialog that lets you choose between 10, 20, 50 & 100 RPM per spectral line. This menu item is not shown when displaying a previously captured spectrum.
Set RPM Axis Zoom	Opens a dialog that lets you choose a scaling value of 1, 2, 5, or 10 for the RPM (horizontal) axis. You can also use the Android device's volume up/down buttons to adjust the RPM axis zoom.

[1]Blade pass frequency is the prop frequency × number of propeller blades.

Set IPS Axis Zoom	Opens a dialog that lets you choose a scaling value of Auto, 1, 2, 5, 10, 20 or 50 for the IPS (vertical) axis. When set to **Auto**, the scaling is automatically adjusted so that the tallest line uses 80% of the available display height.
Set FFT Window	Opens a dialog that lets you choose the type of *FFT window* to use. This menu item is not shown when displaying a previously captured spectrum. The available window types are: **None** — No window is used so the display will show artifacts due to the “spectral leakage” that occurs when a periodic waveform is processed by a discrete Fourier transform. **Hann** — The Hann window reduces the spectral leakage and produces a display with fewer artifacts and better frequency resolution. This is the default window type. **Flat Top** — The Flat Top window reduces the spectral leakage and produces the most accurate magnitudes.
Set Auto-Pause IPS Level	Opens a dialog that lets you choose one of Off, 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2 or 5 for the auto-pause IPS level. If the spectrum contains a line whose IPS value exceeds the selected level, the display will be paused. The display can be un-paused using the options menu. Selecting **Off** disables the auto-pause feature. This menu item is not shown when displaying a previously captured spectrum.
Plot Acceleration	A checkbox that controls whether the spectrum is plotted as acceleration (G) rather than velocity (IPS).
Plot As Curve	A checkbox that controls whether the spectrum is plotted as a continuous curve or as individual vertical lines.
Draw Graticule	A checkbox that controls whether a graticule is displayed or not.
Label Prop Lines	A checkbox that controls whether the spectral lines that correspond to integer multiples of the propeller/rotor RPM are labelled or not. If enabled, each spectral line whose RPM is an integer multiple of the propeller/rotor RPM has a green label showing the IPS and RPM values along with the appropriate multiplier (P, 2P, 3P, ..., 6P for propellers) or (R, 2R, 3R, ..., 6R for rotors)
Label Engine Lines	A checkbox that controls whether the spectral lines that correspond to integer multiples (and also 1/2) of the engine crankshaft RPM are labelled or not. If enabled,

those spectral lines will have a red label showing the IPS and RPM values along with the appropriate multiplier (E/2, E, 2E, 3E, ..., 6E).

Label Cursor Line A checkbox that controls whether a user selectable peak, the “cursor line ”, is labelled or not. If enabled, the line will have a blue label showing its IPS and RPM values along with the multiples of the propeller and engine RPMs (xP,yE) or multiple of the rotor RPM (xR). The current cursor line is selected by tapping the desired peak in the lower half of the spectrum display. Tapping the upper half of the spectrum display moves the cursor to the next peak (to the left or right depending on which side of the display is tapped).

Show Capture Button A checkbox that controls whether the **Capture** button is displayed in the top-right corner or not. Pressing that button captures the current spectrum and stores it in a database on the Android device. The list of captured spectra is accessible through the options menu.

Share CSV Data Shares this spectrum as CSV data.

Note

It is possible to use the spectrum view without a tachometer but, in that case, no analysis is possible and no propeller or engine lines will be labelled.

5.2. Spectrum Analysis Dialog

The spectrum analysis dialog displays text that describes the current spectrum. To be able to do this, the propeller/rotor RPM must be known so you need to have a working tachometer.

You can export an image of the analysis by long-pressing the dialog and pressing the **Export Image** context menu item.

The figure on the right shows a typical analysis exported image.

The analysis compares the vibration levels of the spectra at integer multiples of the propeller RPM to try to determine the number of propeller blades and if a plausible number is determined[2] it is shown along with level of the blade pass vibration.

Likewise, if the vibration level at the crankshaft and half-crankshaft RPMs are significant compared to the vibration at propeller RPM, they are shown.

Analysis: GXXXX
2 Jun 2013 13:42:31

The vibration due to imbalance is 0.13 IPS.

It looks like you have a 3 bladed propeller.

The blade pass vibration (0.16 IPS) is greater than the vibration due to imbalance.

The vibration at crankshaft RPM (0.34 IPS) is greater than the vibration due to imbalance (0.13 IPS).

The RMS acceleration is 0.85 G.

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Fig 5.2. Spectrum Analysis (prop)

The rotor mode spectrum analysis is similar except that it doesn't report the crankshaft related vibrations.

Analysis: BRITTANY5
13 Aug 2013 14:47:28

The vibration due to imbalance is 0.06 IPS.

It looks like you have a 2 bladed rotor.

The blade pass vibration (2.93 IPS) is much greater than the vibration due to imbalance.

The RMS acceleration is 1.81 G.

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Fig 5.3. Spectrum Analysis (rotor)

[2]It's just an estimate so don't panic if it reports the wrong number of blades!

Chapter 6. Polar Point List

The polar point list is a scrollable list of the current job's captured points. It is invoked via the options menu.

The list's bold title will be one of the following:

All Points, if the **Show All Jobs** context menu item is checked.

***Job name* Points**, if the current job has a non-empty name.

Anonymous Points, when the current job's name is empty.

Each point's IPS@DEG and RPM values are shown along with the date and time of capture and the accelerometer axis used. If the list is showing points for all jobs, each point's job name is displayed below the axis name. If a point has notes associated with it, they are also displayed below the axis name.

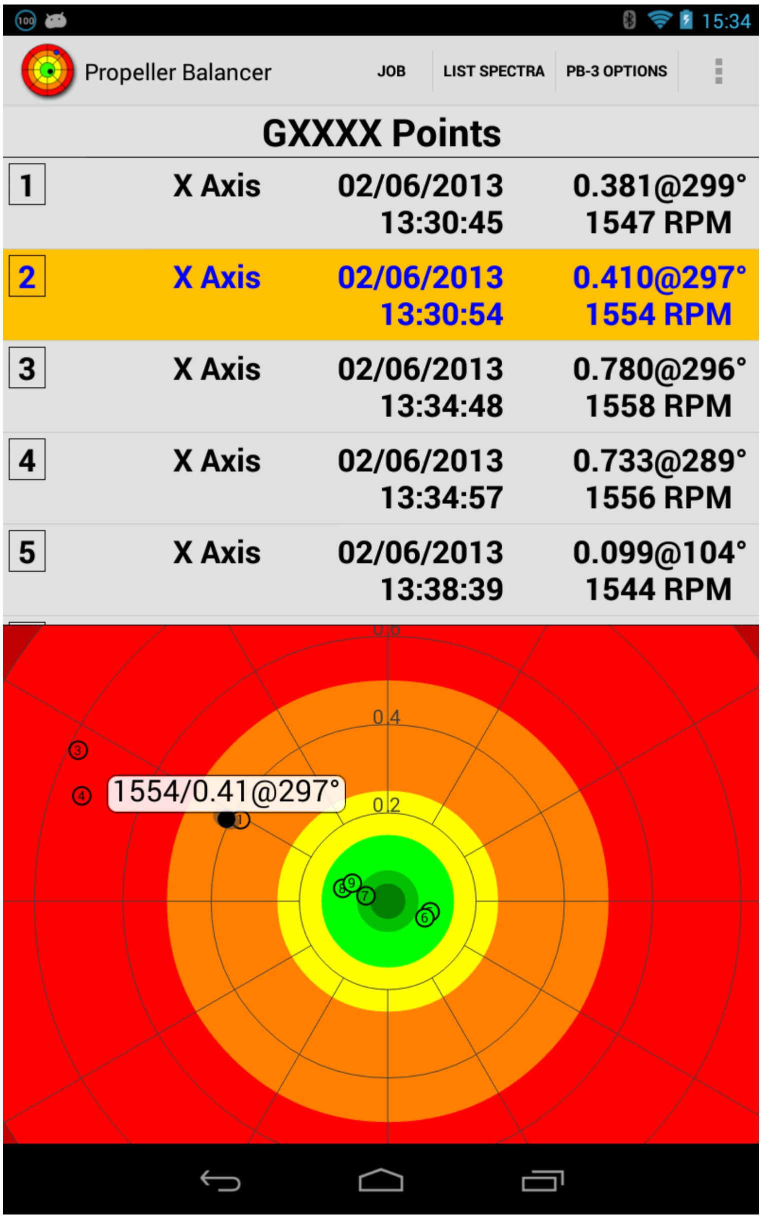


Fig 6.1. Polar Point List

If a point has been designated as a *Start Point*, its summary will be displayed in blue, otherwise, its summary will be displayed in black. If a point was captured today, its background will be white, otherwise, its background will be grey.

Pressing the Android device's back button will return you to the previous screen.

If the divide screen preference is enabled, the screen will be divided into two halves: one half will contain the polar point list and the other half will contain a polar chart. Otherwise, the screen will just show the polar point list.

To select a point, short press (tap) its entry in the list. The list entry will be highlighted and, if the polar chart is being displayed, the point will be displayed as a filled circle. If the polar chart is not being displayed, selecting a point will immediately pop up the point's captured point dialog which will display the point's details. When the polar chart is being displayed next to the list, you need to press the selected point's list entry a second time to pop up that dialog.

Long-pressing the point list pops up a context menu.

When the screen is divided to show both the polar point list and the polar chart, you may press a point on the chart to select it. If more than one point is a possible candidate for selection, you will be shown a list of the candidates so you may choose the point to be selected.

6.1. Polar Point List Context Menu

The polar point list context menu contains these items:

Show Point's Details
Pop up the captured point dialog for the currently selected point.

Change Point's Job
Pops up a list of the currently known unlocked jobs so you can choose the job that the currently selected point will be moved to. This menu item is not shown when the current job is locked.

Edit Point's Notes
Pops up a dialog that displays the notes for the currently selected point which you can then edit. Previously used notes (history) can be selected from a drop-down list which makes it very easy to reuse common phrases (e.g. “added washer”, “moved washer forward”, etc.) This menu item is not shown when the current job is locked.

Delete Points
Pops up the delete points submenu that lets you delete groups of points from the database. This menu item is not shown when the current job is locked.

> **Note**
>
> An individual point can also be deleted using the captured point dialog context menu.

Show Only Items With Notes
Only polar points that have notes will be displayed in the list.

Show All Jobs A checkbox that controls whether captured points from all known jobs are shown or not.

Show All Axes A checkbox that controls whether captured points whose axis differs from the current job's primary axis are shown or not.

If the polar chart is being displayed, the context menu also contains the **Colour Background** and **Show Solution** items from the polar chart context menu and also (if applicable) the rotor mode context menu items.

6.2. Delete Points Submenu

The delete points submenu lets you choose a group of points to be deleted. You will be asked to confirm the action before any points are really deleted.

Important

All of the points currently shown in the list are possible candidates for deletion – if the **Show All Jobs** option is checked, it is possible to delete all the captured points from all of the unlocked jobs!

The delete points submenu items are:

All Points All points in the list are deleted.

Selected Point The currently selected point is deleted.

All Older Than Today All points in the list that were captured before the current day are deleted.

All Captured Today All points in the list that were captured today are deleted.

All Without Notes All points in the list that don't have notes are deleted.

The following items are only shown when the **Show All Jobs** option is not checked and when the current job is using propeller mode.

All Before Start Point All points in the list that were captured before the start point are deleted.

All After Start Point All points in the list that were captured after the start point are deleted.

The following items are only shown when the **Show All Jobs** option is checked.

All In Job A dialog opens to let you select a job and all points in the list from the selected job are deleted.

All Not In Job A dialog opens to let you select a job and all points in the list that are not from the selected job are deleted.

6.3. Captured Point Dialog

This dialog is displayed when a captured point is selected – a point can be selected by short-pressing its polar point list entry. Also, when a point is first captured by pressing the **Capture** button, it will be automatically selected if the show point details after capture option is enabled in the job setup dialog.

The dialog is titled with the point's IPS & DEG values. For propeller mode jobs, if the point is a *start point*, that will be indicated in the dialog's title.

The dialog displays the point's details and a short description of the vibration level.

Use the Android device's back button to dismiss the dialog.

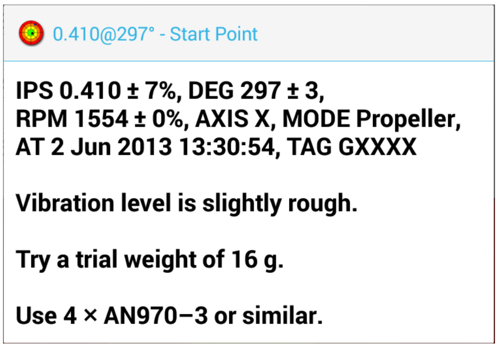


Fig 6.2. Point Details

A short press on the dialog will display the point on a polar chart as a filled circle (X axis point) or diamond (Y axis point). Other points from the same job are shown unfilled. Press the Android device's back button to dismiss the chart. Long pressing the dialog will display the captured point context menu.

6.3.1. Propeller mode

If the point is a start point, an estimate of the amount of weight required to correct the imbalance is shown[1].

Otherwise, for non-start points, if a start point has been defined for the job, instructions on how to improve the balance (a "solution") are displayed.

The instructions tell you how the position and mass of the trial weight should be altered to reduce the level of vibration.

Directions are in terms of propeller rotation, forward means in the direction of rotation and backwards means opposite to the direction of rotation.

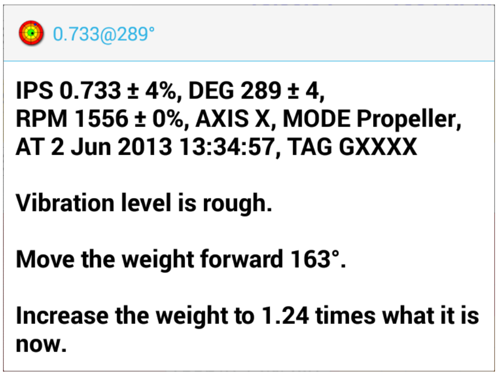


Fig 6.3. Balance Solution

[1]The estimate assumes that the engine is less than 100HP, larger engines and heavier propellers will require more weight (+25% for engines 100-300HP, +200% for engines 300+HP).

6.3.2. Rotor mode

If move lines have been defined for the current job's primary axis, the dialog shows the suggested adjustment for each move line.

6.3.3. Captured point dialog context menu

Long pressing the the captured point dialog pops up a context menu containing these items:

Use As Start Point	Use this point as a start point. This item is only available for propeller mode jobs.
Show Waveform	Opens a graph view to graphically display the acceleration data associated with the current polar point.
Show Related Spectrum	Searches for a related spectrum[a] whose capture time most closely matches the point's capture time. If a spectrum is found that differs in capture time by no more than 30 seconds, it is displayed. Press the Android device's back button to dismiss the spectrum view.
Show On Polar Chart	Displays the point on a polar chart as a filled circle or diamond. Press the Android device's back button to dismiss the chart.
Edit Point's Notes	Opens a dialog so that you can edit the notes associated with this point. This menu item is not shown when the current job is locked.
Change Point's Job	Pops up a list of the currently known unlocked jobs so you can choose the job that the currently selected point will be moved to. This menu item is not shown when the current job is locked.
Export Image	Exports the current view as a JPEG or PNG image.
Delete	After confirmation, the point is deleted from the database. This menu item is not shown when the current job is locked.

[a]A spectrum is related if it has the same job and accelerometer axis as the point.

Chapter 7. Spectrum List

The spectrum list is a scrollable list of the current job's captured spectra. It is invoked via the options menu.

The list's bold title will be one of the following:

All Spectra, if the **Show All Jobs** context menu item is checked.

***Job name* Spectra**, if the curent job has non-empty name.

Anonymous Spectra, when the job's name is empty.

Each line in the list shows the accelerometer axis used and the date and time the spectrum was captured. If the list is showing spectra for all jobs, each spectra's job name is displayed after the axis name. If a spectrum has notes associated with it, they are also displayed after the job name.

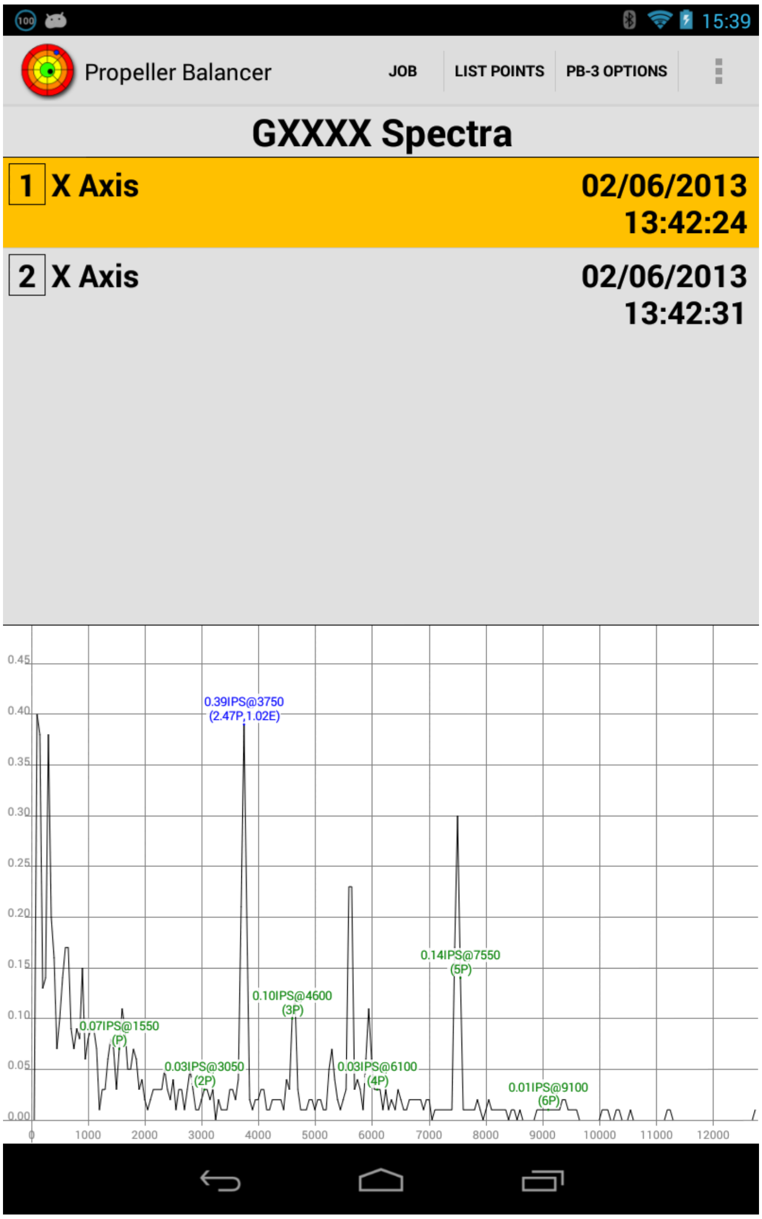


Fig 7.1. Spectrum List

If a spectrum was captured today, the list entry's background will be white, otherwise, grey.

Pressing the Android device's back button will return you to the previous screen.

If the divide screen preference is enabled, the screen will be divided into two halves: one half will contain the spectrum list and the other half will be used to display the selected spectrum. Otherwise, the screen will just show the spectrum list.

To select a spectrum to display, short press its entry in the list. The list entry will be highlighted. If the screen is divided, the selected spectrum will be displayed alongside the list. Otherwise, it will be displayed in a spectrum view. The spectrum view's context menu now has a **Delete Spectra** entry available so you can delete that individual spectrum.

Long-pressing the spectrum list pops up a context menu.

7.1. Spectrum List Context Menu

The spectrum list context menu contains these items:

Delete Spectra
: Pops up the delete spectra submenu that lets you delete groups of spectra from the database.

> **Note**
>
> An individual spectra can also be deleted using the spectrum view context menu.

Change Spectrum's Job
: Pops up a list of the currently known unlocked jobs so you can choose the job that the currently selected spectrum will be moved to. This menu item is not shown when the current job is locked.

Edit Spectrum's Notes
: Pops up a dialog that displays the notes for the currently selected spectrum which you can then edit. Previously used notes (history) can be selected from a drop-down list which makes it very easy to reuse common phrases (e.g. “added washer”, “moved washer forward”, etc.) This menu item is not shown when the current job is locked.

Analyse Spectrum
: If a spectrum is currently selected, this menu item opens an analysis dialog that describes the spectrum.

Show Only Items With Notes
: Only spectra that have notes will be displayed in the list.

Show All Jobs
: A checkbox that controls whether captured spectra from all jobs are shown or not.

Show All Axes
: A checkbox that controls whether captured spectra whose axis differs from the current axis are shown or not.

If a spectrum is being displayed, the context menu will also contain items from the spectrum view context menu.

7.2. Delete Spectra Submenu

The delete spectra submenu lets you choose a group of spectra to be deleted. You will be asked to confirm the action before any spectra are really deleted.

Important

All of the spectra currently shown in the list are possible candidates for deletion – if the **Show All Jobs** option is checked, it is possible to delete all the captured spectra from all of the unlocked jobs!

All Spectra	All spectra in the list are deleted.
Selected Spectrum	The currently selected spectrum is deleted.
All Older Than Today	All spectra in the list that were captured before the current day are deleted.
All Captured Today	All spectra in the list that were captured today are deleted.
All Without Notes	All spectra in the list that don't have notes are deleted.

The following items are only shown when the **Show All Jobs** option is checked.

All In Job	A dialog opens to let you select a job and all spectra in the list from the selected job are deleted.
All Not In Job	A dialog opens to let you select a job and all spectra in the list that are not from the selected job are deleted.

Chapter 8. Big Capture Button View

The “big capture button” view simply contains one big button. It is invoked via the options menu. The button text shows the current RPM and the number of captures completed since starting the view. Touching the button captures the current polar point(s) and, optionally, the spectrum data.

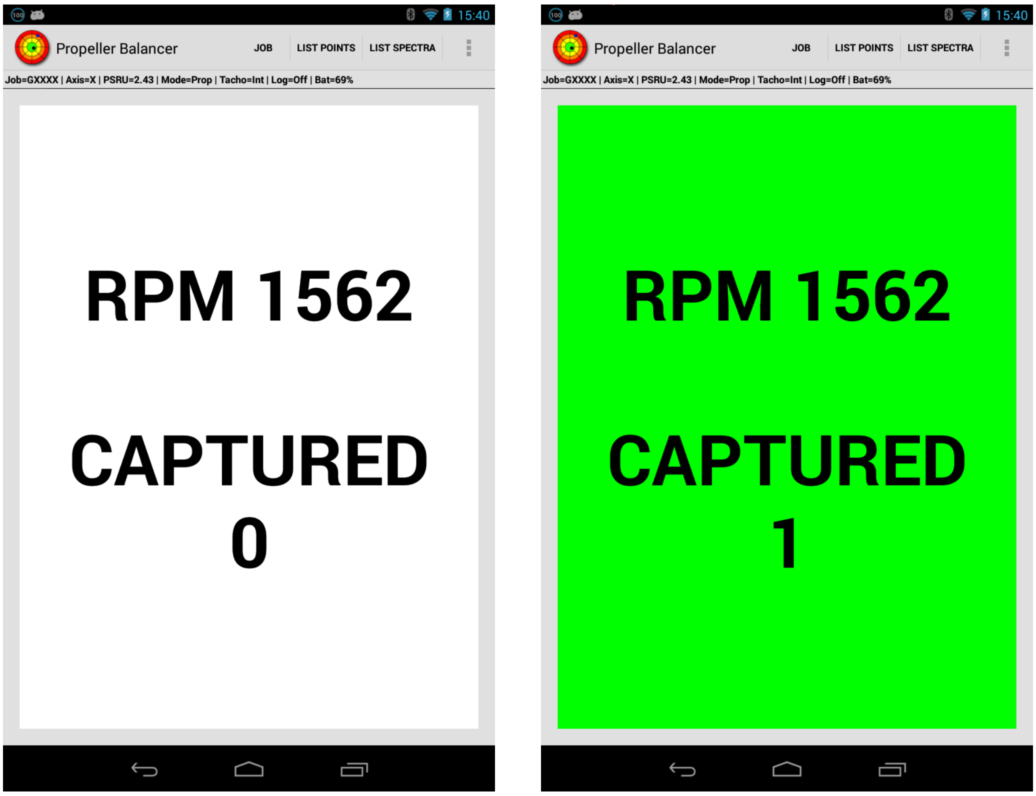


Fig 8.1. Big Capture Button View

Initially, the button's background is white and the RPM is not shown. As soon as the RPM is detected, it will be shown and the button is enabled. When the button is touched, the background becomes orange and when the capture operation is complete, the background becomes green.

If the current job has the **Capture Both Axes** option set, then polar points and spectra from both the X and Y axes will be captured. Otherwise, only points and spectra from the current job's primary axis (X or Y) will be captured.

The current job's **Also Capture Spectra** option must be set to capture the spectra, otherwise just the point(s) will be captured.

Pressing the Android device's back button will return you to the previous screen.

A display preference can be set to automatically open the big capture button view when the app is started.

Chapter 9. Options Menu

Pressing the Android device's menu button pops up an options menu containing these items:

Show Tabs	If the Hide Tabs preference has been set, this menu item is available to make the tabs visible again.
Pause/Continue	Toggles the current view's paused state – when paused, the view is not updated. If your Android device has a hardware keyboard, the space key also toggles the paused state.
Export Image	Exports the current view as a JPEG or PNG image.
Help	Pops up a submenu that let's you choose which manual to view (PB-3 manual or the app manual). If the chosen manual can be found locally[a] on the Android device, it will be displayed using your preferred PDF reader[b]. If the manual cannot be found locally, an attempt will be made to download it from the Smart Avionics website[c].
Job	Pops up the job submenu.
List Points	Displays the polar point list.
List Spectra	Displays the spectrum list.
PB-3/PB-4 Options	Pops up the PB-3/PB-4 options submenu. This menu item is only shown if the **Data Source** preference is set to **PB-3** or **PB-4**.
Dummy Data Options	Pops up a submenu that gives you access to the dummy data setup dialog. This menu item is only shown if the **Data Source** preference is set to **Dummy**.
Big Capture Button	Invokes the big capture button view.
Two Plane Balancing	Invokes the two plane balancing view.
Export Data	Pops up the export data submenu.
Import Data	Pops up the import data submenu.
Database	Pops up the database submenu.
Point Logger	Pops up the point logger submenu.
Preferences	Opens the app's preferences view.
About	Opens a dialog that displays hardware and software revision numbers, copyright information and the PB-3's Bluetooth address. To make it easy to check you are using the latest version of the app, a button is provided that opens the app release history page at www.smartavionics.com in a web browser.

Quit App — Quits the app and returns you to the Android home screen. A dialog will pop up to confirm the action. If you would rather not have the confirmation dialog, there is a preference to suppress the quit dialog.

Back To Top — Returns you to the current top-level view. This menu item is only shown when the current view is not a top-level view.

[a]The following directories located on the Android device's external storage (sdcard) are searched for the manual: `PropellerBalancer`, `download`, `downloads` and `Downloads`.

[b]You need a PDF reader app to be installed on your Android device to be able to read the manuals.

[c]The stock Android browser will not download the PDF files unless a PDF reader app is already installed.

9.1. Job Submenu

This menu contain items related to creating and configuring jobs:

Switch Axes — This item toggles the job's primary axis between the **X** and **Y** axes.

Last Job — Make the previous current job the current job again. Each press of this item toggles between the two most recently used jobs.

Switch Job — This item presents a list of all the known job names so you can select the job that is to become the current job. All new polar points and spectra that are captured will be associated (tagged) with this job. The job names are initially listed in alphabetic order. A dialog button toggles between alphabetic ordering and job age ordering. A job's age is simply the age of the job's last captured point or spectrum.

New Job — Opens a dialog so that you can enter a name for the new job. When the name has been entered, two buttons are enabled that let you choose between creating the new job with default parameters or creating the new job with parameters that are copied from an existing job. When you press the latter button, you will be presented with a list of all the existing jobs and you can select one to copy the parameters from. The new job is created and the job setup dialog is opened so that you can configure the job.

If you enter a name that is already in use, you are given the option to switch to that job and if you decline to do that, the new job name dialog reappears and gives you the chance to enter a new job name.

Setup Job — This item opens the job setup dialog.

Rename Job This item presents a dialog into which you can enter the new name for the current job. It won't let you use a name that is already in use.

View Report This item generates a job report in the form of a page of HTML which you can subsequently export via email, Dropbox, etc. The report shows a simplified polar chart and a table containing the polar point details. You can select from the following options which determine the points to be included in the report:

All Points - all of the job's points are included.

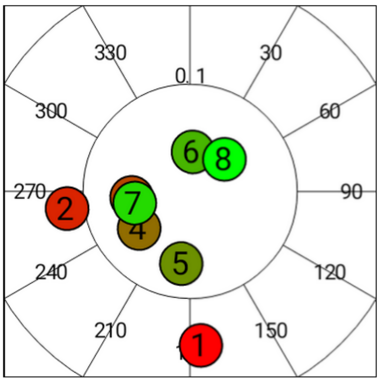
Interesting Points - all "interesting" points are included. Interesting points are those that have notes, the start point, the first and last points and any other point that differs markedly (in terms of the IPS and Deg values) from the previous included point.

First And Last Points - only the first and last points are included.

The report is formatted for a minimum screen width of 800 pixels and it is best viewed using a recent Web Browser (i.e. Chrome, Firefox, IE9) on a PC/laptop. Use the **Export** menu option to export the report from the Android device.

Propeller Balance Report

Job: GTSIM-2
Date: 3 Jun 2015 5:37:38 pm
Mode: Propeller
Axis: X
PSRU Ratio: 2.15



Point	Date/Time	IPS	Deg	Notes
1	20/08/2013 14:37:33	0.144	176	
2	20/08/2013 14:48:17	0.116	262	
3	20/08/2013 14:51:16	0.055	264	
4	20/08/2013 14:54:14	0.059	234	
5	20/08/2013 14:54:28	0.068	187	
6	20/08/2013 14:56:47	0.037	4	
7	20/08/2013 14:56:52	0.053	258	
8	20/08/2013 14:57:01	0.044	47	

Generated by Propeller Balancer 2.6

www.smartavionics.com

Fig 9.1. Propeller Balance Report

9.2. Job Setup Dialog

This dialog provides the means to configure the current job. Some of the configuration values are specific to the job's mode (propeller or rotor). The common values are:

Locked	A checkbox that, when checked, “locks” the job and all of its points and spectra so that it cannot be configured, deleted, renamed, etc.
Mode	The job's mode, **Propeller** or **Rotor**.
Tacho Channel	The tachometer channel to use, **Internal** or **External**.
Primary Axis	The primary accelerometer axis (**X** or **Y**).
Capture Both Axes	A checkbox that, when checked, enables data capture for both accelerometer axes.
Also Capture Spectra	When this checkbox is checked, a spectrum will be captured immediately after a point is captured.
Show Point Details After Capture	When this checkbox is checked, the captured point dialog is displayed automatically after a point is captured.
X Axis Alias	An alternative name for the X axis which will be used in all views.
Y Axis Alias	An alternative name for the Y axis which will be used in all views.

9.2.1. Propeller mode job setup

For propeller mode jobs, this item can be configured:

PSRU Ratio

Here you can specify the gearbox ratio of the engine's *Propeller Speed Reduction Unit* (PSRU). This ratio is used for two purposes:

- In propeller mode, the PB-3 averages multiple propeller cycles for each reading it takes to reduce the effect of engine vibration. The optimal number of propeller cycles to average per reading depends on the PSRU ratio.
- Given the PSRU ratio, the app can determine the engine RPM which is displayed on the data view and also used to label spectra displayed by the spectrum view.

You can specify the PSRU ratio by either selecting one of the known engine types from the **Engine** spinner or by entering the ratio directly into the **Ratio** text field. The known ratios are:

Ratio	Engine type
1.0	No PSRU (direct drive engine or gyroplane rotor)
1.82	Subaru (Eggenfellner)
2.12	Subaru (NSI)
2.27	Rotax 912
2.43	Rotax 912S & 914

9.2.2. Rotor mode job setup

For rotor mode jobs, 3 angles (in degrees) can be entered:

- The directions of the positive X and Y accelerometer axes.
- The direction of the master blade at the point at which the tachometer is triggered.

The angles are measured to the datum in the direction of rotation (the datum is located at the 12 o'clock position on the polar chart).

For example, if the X accelerometer positive axis was orientated in the 3 o'clock direction, the angle from it to the datum would be 90 degrees. Note that it is also possible to configure these angles graphically using the move markers polar chart context menu item.

9.3. Point Logger Submenu

9.3.1. Point logger function (PB-3)

The PB-3 has the capability to autonomously log polar points. Once logging has been configured and enabled, the PB-3 will continue to capture polar points as long as it is switched on. Later, the logged polar points can be fetched from the PB-3 to the Android device.

The point logger works like this: the PB-3 continuously captures polar points (each point is a triple of RPM, IPS, DEG and their associated standard deviations) and accumulates each polar point into a “bucket”. There can be a number of buckets configured and which bucket a particular point is accumulated into depends on the point's RPM. The configuration dialog described below allows you to specify the minimum and maximum RPM values the buckets cover and how wide (in terms of RPM) each bucket is.

9.3.2. Point logger function (PB-4)

The PB-4 point logger is triggered manually using a capture switch operated by the pilot/observer. Points are captured for both the X and Y axes. Later, the logged polar points can be fetched from the PB-4 to the Android device.

9.3.3. Point logger submenu

The point logger submenu contains these items:

Start Logger	Activates the logger – if the logger already has some logged data, you will be asked if you want to clear that data first. Once the logger has been activated, you may quit the app and the logger will continue to log data. If you turn the PB-3 off, the next time you turn it on again it will continue to log data.
Stop Logger	Deactivates the logger.
Get Logged Data	Fetches the logged data from the PB-3 and enters it into the polar point database. The logged data is cleared from the PB-3. You do not need to stop the logger before fetching the data.
Clear Logged Data	Deletes any logged data stored in the PB-3 (does not delete any polar points from the database).
Configure Logger	(PB-3 only) Pops up the logger configuration dialog described next.

9.3.4. Point logger configuration dialog (PB-3 only)

The point logger configuration dialog contains these items:

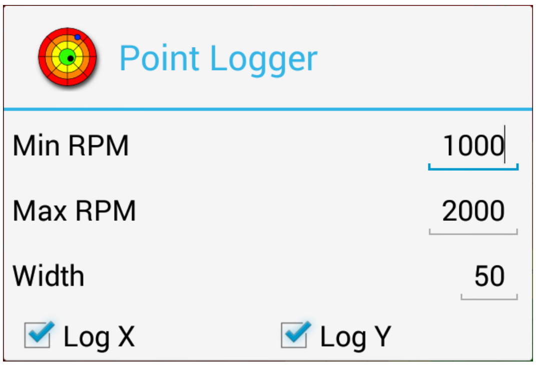


Fig 9.2. Point Logging

Min RPM – the minimum RPM of interest, all polar points that have an RPM less than this will be ignored.

Max RPM – the maximum RPM of interest, all polar points that have an RPM greater or equal to this will be ignored.

Width – the width (in RPM) of a single logger bucket.

Log X & **Log Y** – a pair of checkboxes that determine which axes will be logged.

Use the Android device's back button to dismiss the dialog.

The values shown in the example dialog would produce 20 logger buckets[1] and the RPM ranges of the buckets would be 1000-1049, 1050-1099, 1100-1149 ... 1950-1999. Both the X and Y axes would be logged.

When the logged data is uploaded from the PB-3, each non-empty bucket will provide a single polar point which is an average of the points that were accumulated into the bucket.

9.4. Database Submenu

The database holds all of the polar points and spectra that have been captured. It is stored on the Android device as an sqlite database file that is not directly accessible by other apps. The database submenu provides actions for sharing, saving, loading and clearing the contents of the database.

Note

Two of the actions described below require the user to choose the name of a file located on the Android device's external storage (SD card). Unfortunately, the Android system earlier than version 4.4 (KITKAT) does not provide a file chooser. To obtain that functionality, you need to install a compatible File Manager app. Currently, the only compatible app is the **OI File Manager** which may be installed from the Market or downloaded from `www.openintents.org`.

The database submenu contains these items:

Share Database
: This saves the current database into a temporary sqlite file and then prompts you to select an app to share (export) that file. Most devices should already have an email client (gmail) that can share the database file as an attachment. If you install a cloud storage app like dropbox, you can use that to send the database file directly to other computers.

Save Database
: This invokes a file chooser so that you can specify the name and location of a file to save the database into (sqlite format). A default filename is supplied but you can alter that if you wish.

Load Database
: This menu item invokes a file chooser so that you can select the sqlite file whose contents will be loaded (after confirmation) into the database. **Loading a file into the database will delete all of the existing data in the database so if you want to access that data again, save the database first.**

[1] (2000 - 1000) / 50

Clear Database After confirmation, all of the data in the database is deleted. **Save the database first if you want to access that data again.**

9.5. Export Data Submenu

The export data submenu provides the means to export polar point or spectrum data from the app. You can export the data in either CSV (Comma Separated Values) format which is suitable for importing into spreadsheet applications or as SQL statements that may be imported into the propeller balancer app on another Android device. You can limit the data output to a specific job or you can output data for all jobs.

The submenu provides these items:

Export CSV Data This menu item pops up a dialog that let's you specify which items are to be shared. You can select either polar points or spectra to be output as CSV data which is suitable for importing into a spreadsheet. The spectral line values can be output as velocities (V) or accelerations (A). The CSV data format is described in Appendix A.

Export SQL Data This menu item pops up a dialog that let's you specify which items are to be shared. You can select polar point and/or spectrum data to be output as SQL statements which are suitable for importing into the propeller balancer app (or another sqlite compatible application.)

9.6. Import Data Submenu

The import data submenu provides the means to import data (points and/or spectra) that has previously been exported from the app as SQL statements.

Note

The action described below requires the user to choose the name of a file located on the Android device's external storage (SD card). Unfortunately, the Android system earlier than version 4.4 (KITKAT) does not provide a file chooser. To obtain that functionality, you need to install a compatible File Manager app. Currently, the only compatible app is the **OI File Manager** which may be installed from the Market or downloaded from `www.openintents.org`.

The submenu provides this item:

Import SQL Data This menu item invokes a file chooser so that you can select the file containing SQL statements to be imported.

9.7. Preferences View

This view is accessed through the options menu. It contains these items:

9.7.1. Display Preferences

Screen Orientation A spinner that lets you select one of **Unspecified**, **Portrait** or **Landscape**. Selecting either **Portrait** or **Landscape** will force the app to use that screen orientation irrespective of the orientation of the Android device. Otherwise, the screen orientation will be determined by the Android device's global settings.

Divide Screen A spinner that determines whether the screen should be divided into two areas when displaying lists of points or spectra. The choices are:

- **Yes** Always divide the screen (even when it is small).
- **No** Never divide the screen (even when it is large).
- **Auto** Divide the screen if the largest dimension is at least 480 pixels.

Hide Status Bar A checkbox that, when enabled, hides the Android status bar. If you change this parameter, you will need to exit the app and restart it for the change to have an effect.

Hide Title Bar A checkbox that, when enabled, hides the app's title bar. If you change this parameter, you will need to exit the app and restart it for the change to have an effect.

Hide Tabs A checkbox that enables the hiding of the view select tabs immediately after a view has been selected. When the tabs are hidden, the first item in the options menu will redisplay the tabs so you can then select a different view. If the height of the Android device's screen is limited, enabling this option makes better use of the available screen area.

Show Zoom Controls A checkbox that enables the display of zoom controls when zooming is possible (i.e. when the polar chart view is in pan-zoom mode). If your Android device supports multi-touch, you can hide the zoom controls and use “pinch-zoom” gestures to zoom the display.

Use Legacy Polar Pan & Zoom A checkbox that enables the legacy modal polar pan-zoom behaviour.

Auto-start Big Capture Button Enabling this checkbox will automatically open the big capture button view when the app starts.

User Interface Language	The language to use for all User Interface text (buttons, menus, etc.) Can be set to “System Default”, “English” or “French”. Please note that due to a limitation of the Android system, changing the language here doesn't have an immediate effect. Rotating the screen and selecting the options menu can be sufficient to cause the displayed language to change but you may actually have to completely kill the app and restart it to get the desired result.

9.7.2. General Preferences

Confirm Quit	A checkbox that enables the confirm quit dialog.
Data Source	A spinner that chooses the source of the acceleration and tachometer data used by the app. In normal operation this should be set to **PB-3** or **PB-4** so that you can carry out real propeller balancing but it may be set to **Dummy** in which case the app just uses simulated data. If you change this parameter, you will need to exit the app and restart it for the change to have an effect. When using simulated data, the app no longer shows any PB-3 related menu items or dialogs. Instead, there is a dummy data setup dialog that is accessed through the options menu.
Exported Image Format	A spinner that chooses the format for exported images. The choices are **JPG** and **PNG**.
CSV File Suffix	The file suffix used for exported CSV files (default “csv”).
SQL File Suffix	The file suffix used for exported SQL files (default “sql”).

9.8. Dummy Data Setup Dialog

This dialog features a number of sliders that adjust the parameters used to generate the simulated data values.

If the display is tall enough, the dialog will also contain a polar chart that shows a single polar point that has been generated from the current parameter values.

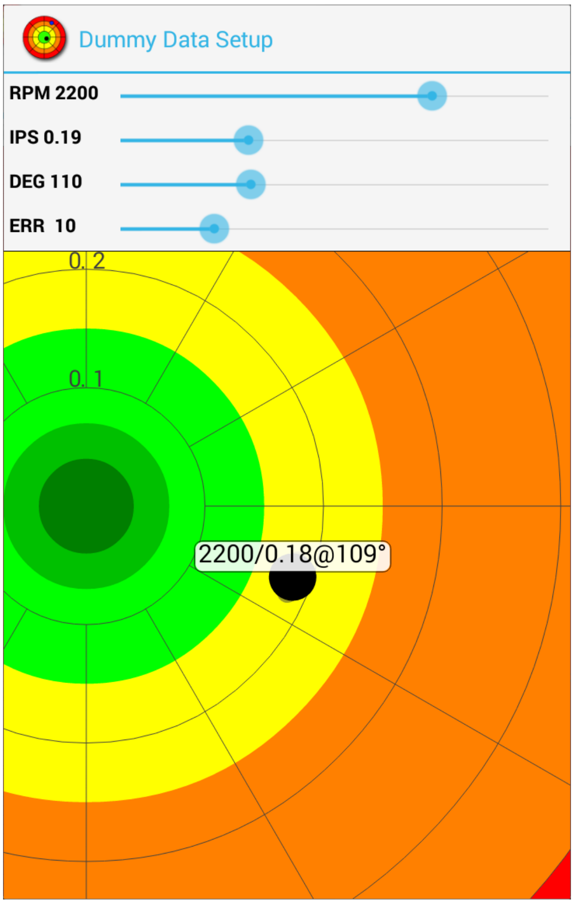


Fig 9.3. Dummy Data Setup

Chapter 10. PB-3 / PB-4 Options Submenu

The PB-3 / PB-4 options submenu is accessed from the main options menu and it contains these items:

Select PB-3	(PB-3 only) If you have paired your Android device with more than one PB-3, this menu entry is available to let you select the PB-3 to use.
Set PB-4 Network Address	(PB-4 only) This menu entry pops up a dialog box into which you may manually enter the PB-4's network address. The dialog also features a **Scan** button, this listens out for network packets broadcast by the PB-4 containing its network address.
Internal Tacho Options	(PB-3 only) Opens the internal tacho options dialog that contains options that control the behaviour of the internal optical tachometer.
Polar Options	Opens the polar options dialog that lets you configure the polar data source.
Accelerometer Scaling	Opens the accelerometer scaling dialog.
Set AP Credentials	(PB-4 only) Opens the set access point credentials dialog that lets you set the Wi-Fi network name (SSID) and password for your Wi-Fi network.
View Messages	Displays any diagnostic messages that the PB-3/PB-4 has sent to the app.

10.1. Internal Tacho Options Dialog

When the internal optical tachometer is working correctly, it detects the passage of the reflective tape once per propeller revolution. For that to occur, a threshold value, the *tacho level*, must be set to an appropriate value for the given conditions (ambient light strength, distance from the PB-3 to the reflective tape, angle of incidence of the infrared beam, etc.)

If the tacho level is too low, spurious reflections are detected and the RPM will appear erratic. If the tacho level is too high, the RPM will be erratic or not detected at all.

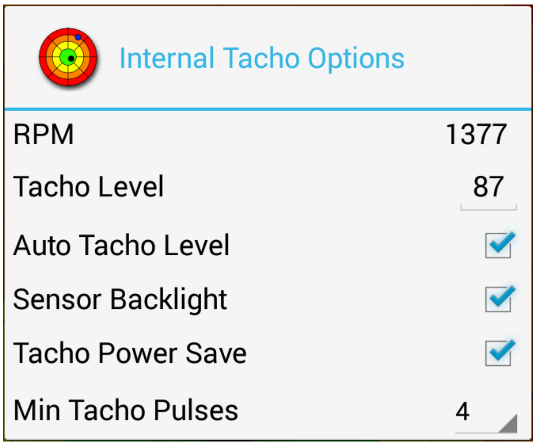


Fig 10.1. Internal Tacho Options

The PB-3 has the ability to automatically adjust the tacho level and it is recommended that you normally select the **Auto Tacho Level** checkbox.

The **Tacho Level** field shows the current tacho level and you can expect it to change every few seconds owing to the automatic level adjustment. The dialog also displays the current propeller RPM so you can see if it is being reliably detected.

In the event that the RPM is not being reliably detected (see the RPM troubleshooting section for possible reasons why that could be so) and nothing appears to improve the situation, you can disable the automatic tacho level adjustment and enter a value directly into the **Tacho Level** field.

Note

The reported RPM will be 0 if the tachometer is not detecting the optical tape and 1 if it is detecting a constant reflection (e.g. the taped propeller blade is stationary in front of the PB-3).

The **Sensor Backlight** checkbox controls an infrared LED within the PB-3 that provides extra ambient illumination to the infrared sensor, thus increasing its sensitivity when the ambient light level is low. Not all PB-3's are fitted with a sensor backlight and so for those that are not, this option does nothing. It is recommended that you leave it enabled all the time.

Selecting the **Tacho Power Save** checkbox allows the PB-3 to save battery power when the reflection from the taped blade is sufficiently bright.

The **Min Tacho Pulses** spinner sets the minimum number of infrared pulses that must be received by the tachometer to detect the passing of the taped blade. The default value is 4 but you may need to increase the value if the tachometer cannot reliably detect the taped blade due to the other blades causing spurious reflections.

10.2. Polar Options Dialog

This dialog contains options that select the origin of the polar point data and how the PB-3 averages that data. These options have no effect on the spectrum display.

The **Polar Mode** spinner selects the algorithm used by the PB-3 to calculate the polar point values (IPS/Deg) from the measured acceleration data. You can choose from: **Propeller**, **Rotor**, **Rotor 2nd Harmonic**, **Rotor 3rd Harmonic**, ...

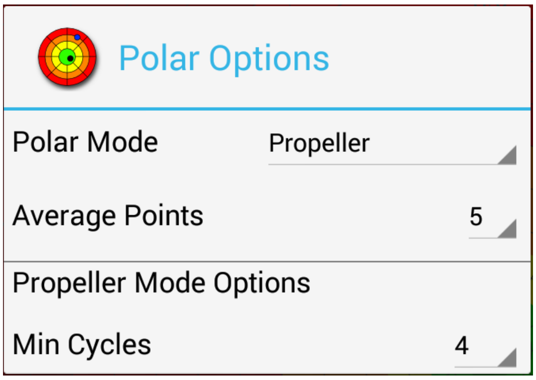


Fig 10.2. Polar Options

For propeller balancing, you can use either **Propeller** or **Rotor** polar mode. For PSRU ratios that are not 1, **Propeller** can produce more consistent results than **Rotor**. By default, propeller mode jobs use **Propeller**.

For rotor balancing, the default is **Rotor** which must be used to ensure that the strong 2nd harmonic (twice per rev) vibration that is normally present does not mask the vibration due to imbalance.

If you are interested in determining the amplitude and phase of a particular harmonic, use the appropriate **Rotor ? Harmonic** option.

The **Average Points** spinner sets the number of polar points to average when calculating the current RPM, IPS and DEG values and their associated standard deviations. The default value is 5.

When the polar mode is set to **Propeller**, the acceleration data is averaged over multiple propeller cycles to reduce the effect of spurious vibration. If the PSRU ratio has been set to 1.0, the number of cycles averaged is an even number that is proportional to the sensed RPM. The higher the RPM, the more cycles are averaged.

The **Min Cycles** spinner sets the minimum number of cycles to be averaged when the PSRU ratio is 1.0. The default value is 4.

10.3. Accelerometer Scaling Dialog

The ADC counts per G values determine the scaling of the accelerometer inputs. Unless the characteristics of the PB-3 or the accelerometer are altered, these values should not need changing from the default[1]. For each of the accelerometer axes (X and Y), the current ADC counts value is displayed along with the calculated G value and the counts per G configuration value which may be edited to alter the scaling.

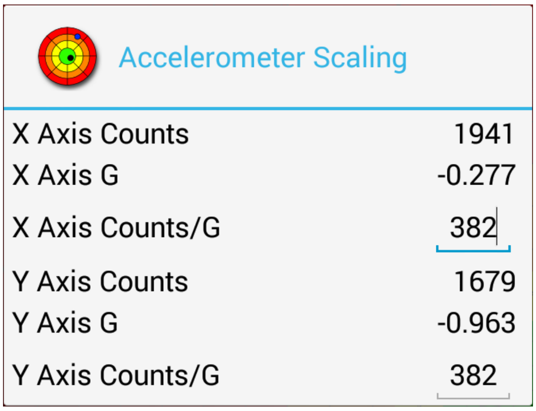


Fig 10.3. Accelerometer Scaling

Note

As the accelerometers are *DC coupled* you can use gravity to calibrate them. With an accelerometer sensing axis pointing straight down, the reported G value should be close to either + or - 1G. If you then reorientate the accelerometer so that the sensing axis is straight up, the reported G value should be close to 1G again but in the other direction (i.e. if it was +ve before, now it should be -ve, and vice versa).

Some offset is to be expected (and does not affect the operation of the balancer) so the aim is to get the span to be equal to 2G. For example, -0.95 to 1.05 has a span of 2.

To calibrate an accelerometer axis, simply subtract the smaller of the ADC counts per G values from the larger and divide the result by 2. Enter that number in the input field and then check that the span really is 2G.

[1] If the ADC counts per G value is not shown on the accelerometer label, assume a default of 1123.

Chapter 11. Propeller Balancing

11.1. Minimising Other Sources of Vibration

Propeller mass imbalance can be a major source of vibration. However, there are other sources of vibration as well. To minimise the overall vibration level and to make the dynamic balancing process more effective, all other sources of vibration must be minimised before dynamic balancing is carried out.

Important

Unless the engine is running smoothly, there is little point in trying to balance the propeller. Carburettor imbalance, dirty plugs, loose engine mounts and general wear and tear are just some of the reasons why the engine could be producing excess vibration.

Propellers with an adjustable blade pitch will produce a lot of vibration if all the blades are not set to the same pitch. This is critical: if a blade's pitch differs from its neighbours' by even a fraction of a degree, it will produce vibration that appears to be caused by mass imbalance but cannot actually be removed by mass balancing.

Important

Before attempting to dynamically balance a variable pitch propeller (either ground adjustable or in-flight adjustable), confirm that the blades' pitch are equal to within the tolerance specified by the propeller's manufacturer (typically, 0.25°).

11.2. Propeller mass imbalance

A major source of propeller vibration is propeller mass imbalance. When an object rotates around an axis, if the mass of the object is not uniformly distributed around that axis, a force (the centripetal force) will be generated and will cause vibration. As the magnitude of the force is proportional to the square of the rotational velocity, at high RPMs (high rotational velocity) even a small mass imbalance in a propeller will generate an appreciable amount of force (and hence vibration). This vibration can be measured by mounting a sensor on the engine as close to the propeller as possible. Conventionally, the magnitude of a propeller's vibration is reported as a peak velocity in units of Inches Per Second (IPS).

11.3. Static Propeller Balancing

A propeller can be statically balanced in the workshop using a static balancing tool. This often involves suspending the propeller from its central axis. If the propeller is statically balanced, the blades should be level[1]. If one blade is heavier than the others (or its centre of mass is further from the centre of the propeller), it will dip towards the floor. If this occurs, weight can be added to the hub on the opposite side of the central axis to the dipping blade to bring the propeller level.

All propellers should be manufactured with blades that have equal mass (and mass distribution) and so a new propeller should not require static balancing. Propellers that have suffered damage to the blades (stone chips or tip abrasion) may well benefit from being statically balanced.

While statically balancing a propeller is worthwhile, the best results will be obtained if the propeller is dynamically balanced together with the spinner.

11.4. Dynamic Propeller Balancing

Dynamic propeller balancing involves measuring the actual rotational vibration generated at a realistic propeller RPM and then adding weights to the propeller hub or spinner backplate to minimise the measured vibration level. Because the balancing operation is carried out with the propeller and spinner attached to the engine, the best possible solution is obtained.

The vibration is measured using a sensor known as an accelerometer. The accelerometer is securely attached to the engine as close to the propeller as possible and it measures the acceleration of the front of the engine in one direction (normal to the propeller shaft). If the propeller is out of balance, as the centre of mass rotates around the axis of rotation, the resulting centripetal force tries to pull the propeller (along with the spinner and engine) towards the centre of mass. This rotating imbalance force acts on the mass of the engine/propeller combination and accelerates it. It is this acceleration that is measured by the accelerometer.

If the accelerometer was very selective and measured only the vibration caused by the rotating out-of-balance propeller, the signal it produced for one rotation of the propeller would look like a sine wave as shown here. In reality, the measured acceleration waveform is much more complex than a simple sine wave. This is mainly because of the vibration generated by the engine and also the turbulence generated by the rotating propeller blades. The dynamics of the engine mountings also affect the waveform.

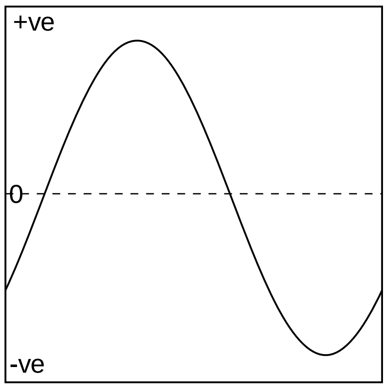


Fig 11.1. Sine Wave

The balancer's processing unit digitises the measured acceleration waveform and uses the resulting numbers to calculate

[1]The propeller will be statically balanced when the mass of each blade multiplied by the distance from the blade's centre of mass to the centre of the propeller is the same for all the blades.

the magnitude of the vibration signal. This magnitude is reported as a peak velocity in units of Inches Per Second (IPS).

The accelerometer senses the magnitude of the vibration but more information is required to carry out the balancing process. This is because it is not sufficient to know just the magnitude of the vibration signal. It is also necessary to know the *phase* of that signal. The phase of the signal is the relationship of the signal waveform to the angular position of the propeller. Given the phase information, it is possible to determine where the weight is required to be added to reduce the vibration. By detecting when one particular propeller blade passes an optical sensor, the balancer can measure and report the phase of the vibration waveform. The optical sensor also works as a tachometer to measure the propeller RPM.

11.5. Taking a Vibration Reading

Warning

Propellers can kill.

Make sure that the engine ignition is switched off before touching the propeller.

Always assume that the engine could fire when the propeller is being moved.

Make sure that the aircraft is securely chocked or tied down while carrying out the balancing process.

Please see the PB-3 Propeller Balancer Manual for a description of the PB-3 sensors and how they are attached to the aircraft.

For maximum accuracy, the dynamic balancing process should only be carried out in light winds. Ideally, the wind should be less than 5 kts. The aircraft should be positioned so that it is pointing into any wind.

Important

Before you start the engine, check that the job parameters and PB-3 options are all set appropriately.

Make sure the engine is thoroughly warm before taking any readings.

Firstly, you need to decide what propeller RPM you are going to use while balancing. For a typical propeller, an RPM in the range 1500-2000 is often a good choice. Using the polar chart view, observe the movement of the current polar point circle and its associated grey “standard deviation ellipse”. If you think it is necessary, adjust the throttle to find the RPM that minimises the variation in the current point's position and the size of the ellipse.

Note

When you adjust the throttle it will take a few seconds for the readings to settle down and a “Toast” will pop up to tell you that the RPM is not steady enough to capture a reading.

Important

Once you have determined the best RPM to use, it is important to use the same RPM for each balancing run so that you get consistent results.

With a steady RPM being reported by the balancer, press the **Capture** button to capture a polar point. The point's details will be displayed in the captured point dialog – press the back button twice to return to the polar chart view.

Capture a few points – if the propeller is obviously out of balance, the points will be clustered together some distance away from the centre of the chart.

Now stop the engine and **double-check that the ignition is switched off**.

If the vibration level is already 0.15 IPS or less, the propeller can be considered reasonably well balanced – in ideal conditions, the balancer is capable of balancing a propeller down to about 0.03 IPS so you may wish to continue the process to achieve a better result. If you want to improve the balance, you must carry out the balancing procedure as described in the next section.

Tip

To reduce battery drain in the PB-3 and the Android device, it is best to exit the app using the back button when you are not actually capturing points or viewing the live data. When you are ready to capture a new point, just restart the app.

11.6. Balancing Procedure

Important

It is the operator's responsibility to ensure that any procedures or guidelines that have been issued by the manufacturers of the propeller, engine or aircraft or some other agency (e.g. the FAA/CAA/LAA/BMAA), that specify how the propeller is to be balanced, are adhered to.

The following instructions describe the balancing process from the point of view of operating the balancer and determining where balance weights are to be attached. The exact detail of how balance weights are attached to the hub or spinner backplate is beyond the scope of this document. If you have any doubt, please consult your inspector/engineer.

The position and the mass of the required balance weight is determined as follows:

1. With no balance weights attached to the propeller[2], capture one or more points. Using the captured point dialog, choose one of those points to be the start point.

2. Now attach a *trial weight*. The angular position of the weight is not important at this stage. For a typical composite propeller, a few AN970 washers would be a reasonable initial trial weight. So, having checked the ignition is switched off, securely attach the trial weight using an approved method.

3. With the trial weight in place, capture a few more points. When each point is captured, the resulting captured point dialog shows a solution that tells you how the amount of weight and its position should be altered to improve the balance. If the propeller is well out of balance, all of the displayed solutions should be quite similar. If the propeller is only slightly out of balance or there is an appreciable amount of vibration from other sources, the solutions will vary more and you will have to interpolate between them.

   Adjust the position and amount of weight accordingly and capture some more points to see what difference that has made.

   Note

   If you need to attach the weight at a position that falls between the available attachment points, it should be possible to attach two smaller weights either side of that position such that their combined influence is equal to the influence required – i.e. if you need to have 3 washers at a position that is 1/3 of the way

[2] Apart from any weights that were added during static balancing – don't remove those.

between two attachment points, you could put 2 washers on the preceding attachment point and 1 washer on the next attachment point (this assumes the attachment points are not more than, say, 60° apart).

Depending on the quality of the captured points and how closely you follow the instructions, you may well have to repeat this step a few times to get the best result.

Note

The app does not actually say that the propeller is balanced or not; it's left up to the operator to decide when to stop the process based on the IPS achieved.

11.7. After Balancing

When the balancing has been completed, double-check that all balance weights are securely attached. If you have been using temporary weights to carry out the balancing, they should be replaced with permanent weights whose mass and position are such that they have the same effect as the temporary weights. If in doubt, recheck the balance once the permanent weights are installed.

Remove the sensors and the tape from the propeller blade. Make an entry in the appropriate log book to record the vibration level achieved and the RPM used.

11.8. Troubleshooting

This section provides answers to common problems that can arise when balancing.

11.8.1. The displayed RPM is erratic or wrong

The RPM could be unsteady for the following reasons (most likely first):

- The optical sensor is not pointing at the reflective tape or the tape is not parallel with the sensor's window. It may help to add one or more further strips of reflective tape to increase the width of the reflective area.
- The sun is shining directly into the optical sensor's window or being “chopped” by the propeller.
- The optical sensor is either too close (< 15cm) or too far away (> 30cm) from the propeller.

- The angle of incidence of the infrared beam on the propeller blade is outside the acceptable range (15 - 40°).
- The sensor is being confused by extra reflections from shiny propeller blades. Try increasing the value of Min Tacho Pulses. You can also try adding non-reflective tape to the other blades in the same position as the reflective tape.
- The engine RPM really is changing!

11.8.2. The current polar point position varies widely

This indicates that the vibration waveform is not consistent from one propeller revolution to the next. This implies that some (perhaps most) of the measured vibration is out of phase with the propeller. Any of the following problems will cause the position of the polar point to vary:

- The incorrect PSRU ratio is being used.
- You are using the wrong accelerometer axis.
- The RPM is not being reliably detected. Unless the RPM is correct, the IPS and DEG and their associated standard deviations are meaningless.
- The wind is gusting. At low vibration levels, just a few knots of wind can make it appreciably harder to obtain reliable data.
- The engine is not running smoothly or the engine mounts are in poor condition.
- You are using an RPM that is triggering an airframe resonance.
- The accelerometer is not securely mounted or the sensing axis is not pointing at the propeller's axis of rotation or the sensing axis is parallel with the direction of movement of the engine's pistons.
- The spinner is wobbling.
- The engine cowling is not fitted to minimise the effects of turbulence.

11.8.3. Adding weight does not reduce the vibration level

If the balancer shows a significant level of vibration with a small standard deviation and adding weight doesn't appear to reduce the level or substantially change the angle, any of the following could be true:

- The incorrect PSRU ratio is being used.
- You are using the wrong accelerometer axis.

Adding weight does not reduce the vibration level

- The propeller is suffering from pitch imbalance (the blades don't have equal pitch). Pitch imbalance has to be corrected before the propeller can be dynamically balanced.
- The amount of weight being added is too small to have an effect. The heavier the propeller/spinner, the more weight has to be added to reduce a given level of vibration.
- The weight is not being added at the correct position.

Chapter 12. Rotor Balancing

Acknowledgement

Smart Avionics gratefully acknowledges the assistance freely given by Mike Goodrich during the development and testing of the app's rotor balancing capabilities. Mike provided much useful knowledge that aided the development process and has tirelessly been the guinea pig testing numerous versions of the software. *Any errors or omissions in the hardware, software or documentation are the responsibility of Smart Avionics Ltd. and not Mike Goodrich.*

This chapter aims to provide an overview of the rotor balancing process. Although the emphasis is on gyroplane rotor balancing, it is also largely applicable to helicopter rotors.

Please see the PB-3 Propeller Balancer Manual and the Red LED Tacho Sensor Manual for details of how the sensors are attached to the aircraft.

12.1. Causes Of Rotor Vibration

Mass imbalance is one of the causes of rotor vibration and the PB-3 system can help you balance the rotor to eliminate that vibration. Other vibrations may also be present. In particular, gyroplanes often suffer strong vibration at twice the rotor frequency. This “× 2” (times 2) vibration is often much larger than the vibration due to imbalance and so even when the rotor has been mass balanced satisfactorily, vibration will still be noticeable to the occupants.

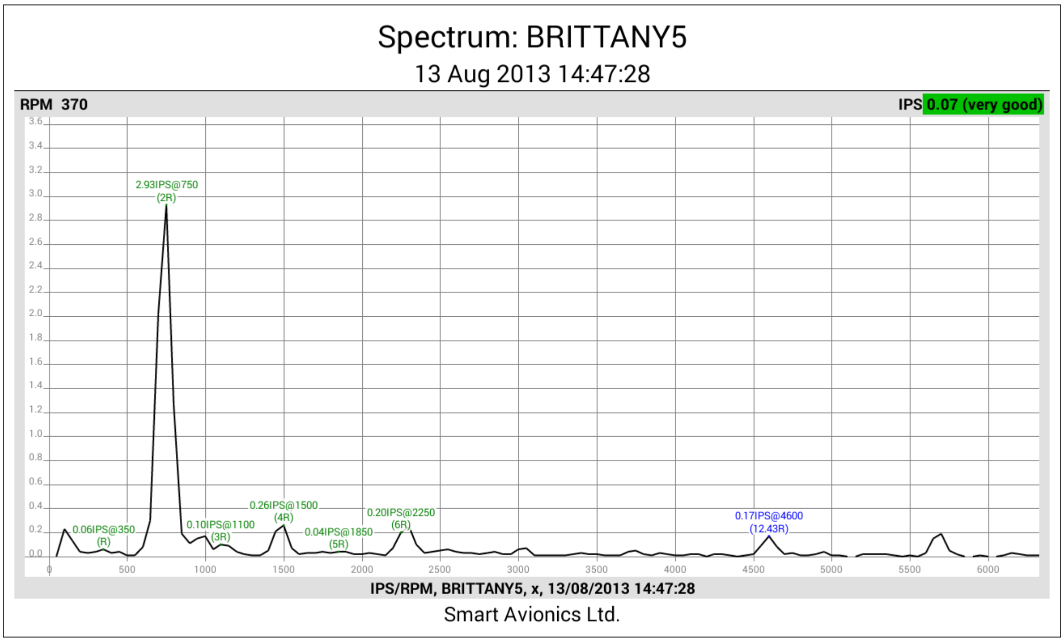


Fig 12.1. Rotor Spectrum With Large × 2 Peak

The above spectrum is from a gyroplane rotor that shows the very large × 2 vibration still present after the rotor was balanced. You can see that the vibration at the rotor RPM (350) was only 0.06 IPS but the × 2 vibration at 750 RPM was 2.93 IPS, that's nearly 50 times larger!

Unlike, rotor mass imbalance, the × 2 vibration cannot be suppressed by simply adding weights. It is fundamental to the geometry of a (2 bladed) rotor system and the physical properties of its components (blades, hub, mast, etc.) The × 2 vibration can be caused by a variety of reasons. Some possibilities are:

- The rotor “teeter height” is wrong.
- The rotor blades are exhibiting in-plane resonance which is excited twice per revolution when the blades are perpendicular to the machine's direction of flight.
- When the blades are perpendicular to the direction of flight more drag is produced.

Furthermore, the amount of × 2 vibration being produced is influenced by the flight conditions (rotor speed, airspeed, etc.) At this time, the PB-3 system can only report the magnitude of the × 2 vibration and it does not offer any suggestions as to how the level of vibration can be reduced. Perhaps in the future when the causes of the × 2 vibration are better understood, it will be able to make helpful suggestions.

12.2. Rotor Mass Balancing

When a propeller is balanced, it is normally the case that the balance weight can be added almost anywhere on spinner backplate and so both the angular position and amount can be varied as required. By contrast, gyroplane rotors are mass balanced by making adjustments in one or two fixed axes[1]:

Spanwise The spanwise balance of a gyroplane rotor can be adjusted by adding weight to one rotor blade tip or the other.

Chordwise The chordwise balance of a gyroplane rotor is most often adjusted by shifting the mass of the rotor blades along the teeter pivot. Exactly how this is done depends on the mechanical design of the particular rotor system but it could involve changing shims or adjusting a threaded component (nut, barrel, etc.) The amount of movement required is often small (a fraction of a mm).

What you need to know to balance the rotor is how much adjustment (magnitude and sense) is required for each of these axes. You can determine that information using a polar chart that has been augmented with *move*

[1]Don't confuse these axes with the accelerometer axes, they are different.

lines. A move line is literally a line drawn on a polar chart that shows the direction a polar point would move when a particular adjustment is made to the system. For a gyroplane rotor, two move lines are required, one for the spanwise balance and another for the chordwise balance.

Important

Before you start capturing any data, please ensure that the current job has been configured correctly using the job setup dialog. It is strongly recommended that you use the big capture button to capture the data while flying as this greatly simplifies the user interface. Also, if the machine has an open cockpit, take precautions to avoid the Android device disappearing aft through the propeller! If possible, attach it firmly to a knee pad or to the aircraft structure.

12.2.1. Defining move lines

It is straightforward to define a move line. All you have to do is capture two or more polar points that correspond to known conditions and tell the app what those conditions were.

For example, to define the spanwise move line you would add weight to one of the rotor blade tips, capture a few polar points, move the weight to the other rotor blade tip, capture a few more points, remove the weight again (to return the rotor to the original condition) and, finally, define the move line.

The process can be repeated to define the chordwise move line. This time the adjustments would involve shifting the rotor mass on the teeter pivot. Once both move lines are defined, you can balance the rotor.

Important

To ensure that the move lines are good, follow this advice:

- Only make one adjustment at a time.
- Always fly the aircraft at the same speed and weight when capturing the data.
- Fly smoothly and avoid turbulence.
- Capture multiple points (3, say) to avoid being fooled by a “rogue point”.
- Make the adjustment large enough to produce a noticeable effect. If you are unsure how big an adjustment to make, start small and keep doubling the adjustment until it produces at least 0.5 IPS (preferably 1 IPS) of movement on the polar chart compared to the original condition.

Note

Move lines are only valid for a given flight condition (airspeed, AUW, etc.) and sensor configuration. If you move the sensors or, say, invert an accelerometer axis, the move lines will no longer valid.

Aircraft of the same type and configuration should have very similar move lines so you may well be able to use move lines defined on one aircraft on another aircraft.

12.2.2. Using the move lines to balance

With the move lines defined, fly again in the original configuration (no weights added or rotor shifting) and capture a few polar points. If you now select one of those points in the polar point list the point's captured point dialog will show the suggested adjustments required to improve the balance. Carry out the suggested adjustment and capture some more points. Repeat as required.

Although multiple adjustments may be suggested, it is recommended that you only make one adjustment at a time and then capture further polar points for comparison. It is also recommended that you make use of the feature that allows you to add a note (some text) to a polar point so that you can track the adjustments you make.

Chapter 13. Two Plane Balancing

This manual has so far described how propellers and rotors can be balanced by measuring the vibration in a *single plane* (I'm referring to the abstract geometric surface, not the aircraft!) The accelerometer has been mounted as close as possible to the hub of the propeller/rotor and orientated such that it is sensing the vibration in the propeller/rotor's plane of rotation.

Single plane balancing generally works well when the diameter of the object being balanced is much greater than its depth and also when it is attached to the supporting shaft at exactly 90°. Aircraft propellers and gyroplane/helicopter rotors typically satisfy those conditions and so can be balanced satisfactorily using the single plane method. When the depth of the object being balanced is increased relative to its diameter or if it "wobbles" on the supporting shaft, *two plane balancing* is required. This chapter describes how the app can be used to carry out two plane balancing using the *two plane balancing view* which is accessible through the options menu.

13.1. Two Plane Balancing Method

The two plane balancing method is really very similar to the single plane balancing method. It involves measuring the vibration when no trial mass is attached, measuring the vibration with trial mass attached and then calculating a solution from those measurements. The difference is that the trial mass is attached twice, once in each plane, and for each position of the trial mass (not present, attached in plane 1 and attached in plane 2), vibration readings are captured from both planes. So that means that 6 IPS/DEG values are required to be able to calculate the two plane balance solutions that are needed.

13.1.1. Measurement and correction planes

The planes in which the accelerometer(s) are mounted are called measurement planes. The planes in which the trial masses and the final correction masses are attached are called the correction planes. Typically, accelerometers are mounted as close as possible to the bearings that support the object being balanced. Generally speaking, the object being balanced is either supported by bearings at each end so that its mass is (mostly) between the bearings or it has significant mass that overhangs one bearing. For items that are supported at both ends, the measurement and correction planes may be close together as is shown in the next figure.

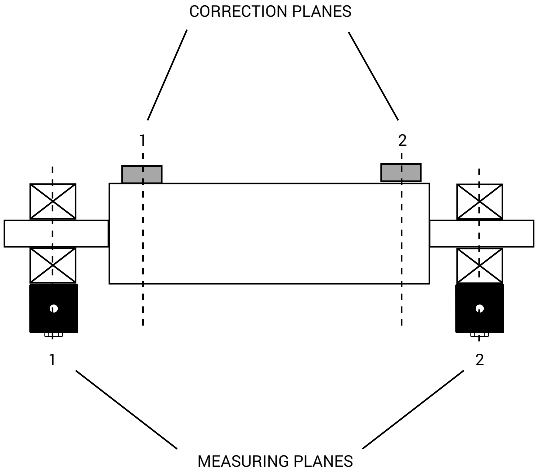


Fig 13.1. Two Plane Balancing An Object Supported At Both Ends

For overhung items, the configuration is as shown in the next figure. Note how the #1 measurement plane is close to the #1 correction plane but the #2 measurement plane is far from the #2 correction plane.

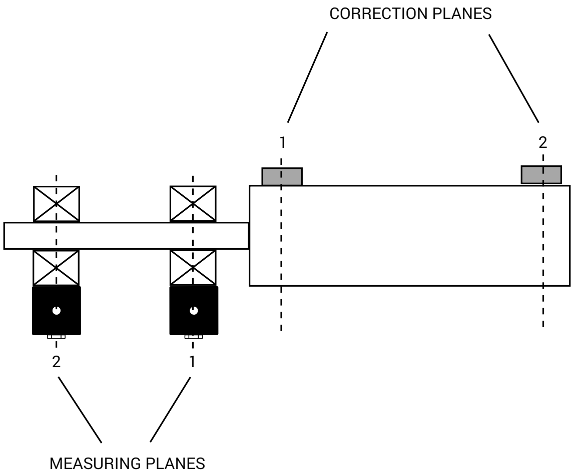


Fig 13.2. Two Plane Balancing An Overhung Object

13.2. Two Plane Balancing View

The two plane balancing view presents a table into which the 6 required IPS/DEG values are entered. Each of the values is entered by pressing the appropriate button and selecting a polar point from a list that contains the current job's polar points. Once the data has been entered, the resulting solutions are shown below the table in the same format (**ANGLE × SCALE**) as the propeller mode polar chart solutions. There are two solutions, one for each correction plane. Here is the two plane balancing view that already has the IPS/DEG data entered into it and is therefore displaying solutions.

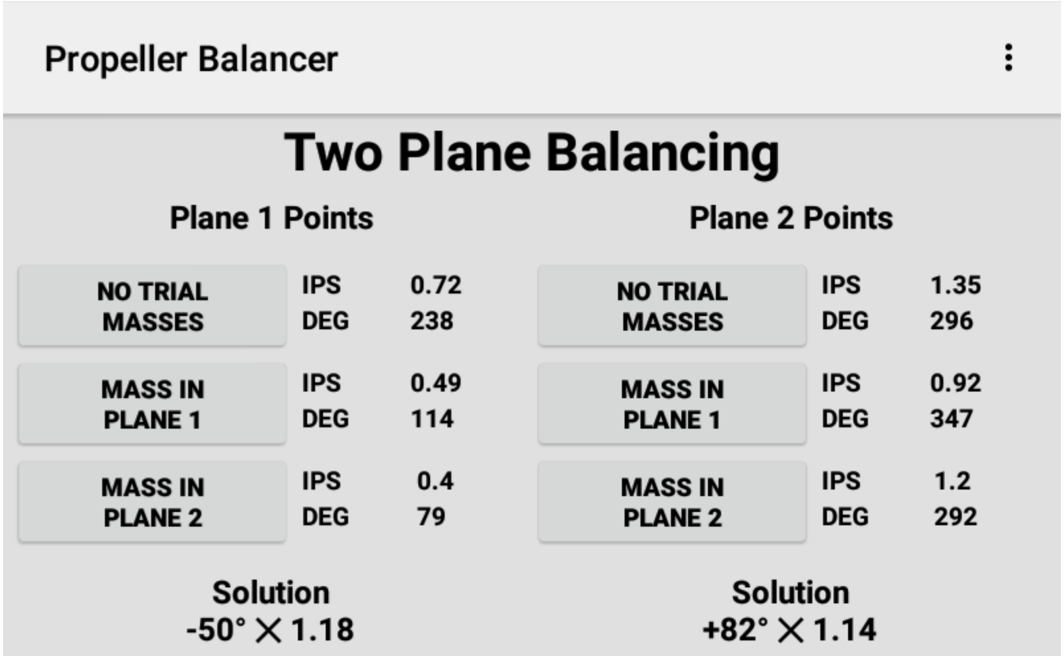


Fig 13.3. Two Plane Balancing View

Use the Android back button when you want to leave the two plane balancing view. The data values entered are persistent so you can leave the view and return to it and the values will still be there. An option menu item is provided to zero all of the data values which is a good idea when starting a new calculation.

13.2.1. Single accelerometer procedure

The two plane balancing procedure when using a single accelerometer is as follows:

- Mount the accelerometer so that it is sensing vibration in measurement plane 1.
- With no trial mass attached in either correction plane, capture a couple of points
- Attach a trial mass so that it is in correction plane 1 and capture a couple of points, mark the position of the mass and remove it.
- Now attach the same mass so that it is in correction plane 2 and capture a couple more points. Mark the position of the mass and remove it. You now have data for the 3 points in the left hand column of the table.
- Move the accelerometer so that it is now sensing vibration in measurement plane 2.

- As above, capture 3 further sets of readings for the no-mass, mass in correction plane 1 and mass in correction plane 2 configurations to provide the data for the 3 points in the right hand column. It is important that when you attach the trial mass you use the same positions as you did previously. It is also important that all of the points have the same RPM.
- Enter all 6 points into the two plane balancing view and you will get two solutions, one for the mass in each correction plane.

In the example shown above, the plane 1 solution is -50° × 1.18 which says attach a mass that is 1.18 times the trial mass in a position that is 50° backwards (against the direction of rotation) from the position of the trial mass. The plane 2 solution is +82° × 1.14 which says attach a mass that is 1.14 times the trial mass in a position which is 82° forwards (in the direction of rotation) from the position of the trial mass.

13.2.2. Dual accelerometer procedure

The procedure when using dual accelerometers is as follows:

- Mount the two accelerometers such that one is sensing the vibration in measurement plane 1 and the other is sensing the vibration in measurement plane 2.
- With no trial mass attached in either plane, capture a couple of points from each accelerometer.
- Attach a trial mass so that it is in correction plane 1 and capture a couple of points from each accelerometer. Mark the position of the mass and remove it.
- Now attach the same mass so that it is in correction plane 2 and capture a couple of points from each accelerometer. Mark the position of the mass and remove it. You now have all 6 points required. Take care to select the correct points when entering the data into the view.

Appendix A. Exported CSV Data Formats

A.1. Polar Point Data Format

The polar point CSV data contains one row per exported point and each row contains these columns:

Date The date the point was captured.

Time The time the point was captured.

Axis The point's axis, 'X' or 'Y'.

Rpm The propeller RPM.

RpmSD The Standard Deviation of the propeller RPM.

Ips The vibration magnitude.

IpsSD The Standard Deviation of the vibration magnitude.

Deg The vibration phase angle.

DegSD The Standard Deviation of the vibration phase angle.

Attrs A bit mask of attributes. The bits have these meanings:

- **Bit 0** Accelerometer channel used (0 = X, 1 = Y).
- **Bit 1** Tachometer channel used (0 = internal, 1 = external).
- **Bit 2** Logger status (0 = point was manually captured, 1 = point was captured by the logger).
- **Bit 8** Start point status (0 = point is not a start point, 1 = point is a start point).

Tag The point's Job Tag (an empty string if it doesn't have a Job Tag).

Notes A string containing any notes associated with the point.

A.2. Spectrum Data Format

The spectrum CSV data contains one row per exported spectrum and each row contains these columns:

Date The date the spectrum was captured.

Time The time the spectrum was captured.

Axis	The spectrum's axis, 'X' or 'Y'.	
PropRpm	The propeller RPM.	
EngineRpm	The engine RPM (i.e. PropRpm x PSRU ratio).	
RpmPerLine	The “width” of each of the spectral lines.	
PropIps	The vibration magnitude at the propeller RPM.	
NumLines	The number of spectral lines (magnitudes).	
Attrs	A bit mask of attributes. The bits have these meanings:	
	Bit 0	Accelerometer channel used (0 = X, 1 = Y).
	Bit 1	Tachometer channel used (0 = internal, 1 = external).
	Bits 8-9	FFT Window type used (0 = None, 1 = Hann, 2 = Flat Top).
Tag	The spectrum's Job Tag (an empty string if it doesn't have a Job Tag).	
Notes	A string containing any notes associated with the spectrum.	
V… or A…	*NumLines* number of vibration magnitudes expressed as either velocities (in IPS, column name begins with a **V**) or accelerations (in G, column name begins with an **A**).	

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