EQMOD VS-PEC

Introduction, User Interface & Workflow Document

Contents:

INTRODUCTION

Periodic Error: What is it?

Periodic Error (PE) in a mount is caused by imperfections in the gear train causing a very slight 'wobble' about the axis being driven. The most significant errors are caused by the worm to worm-gear transfer and whilst this can be reduced by mechanical improvements it cannot be removed altogether, it is an inherent feature of a worm drive. The EQ6 mount has 180 teeth on its worm gear and at sidereal rate the RA worm will revolve once every 479 seconds advancing the worm gear by one tooth. The EQ5 mount has 135 teeth on its RA axis and a worm that takes 638 seconds to rotate at sidereal rate.

To the observer, periodic error appears as cyclic drift in RA occurring over the period of the worm. This can result in a total movement of up to 50-60 arcseconds on some mounts (30 arcseconds is typical). To a visual observer this does not represent any great problem, to those indulging in long exposure photography however periodic error will cause a blurring of the image as the star field move across the sensor/film during an exposure.

Although manufacturers cannot remove Periodic Error entirely they can machine the gears accurately enough to ensure that the Periodic Error response is smooth and repeatable for each revolution of the worm. If the Periodic Error can be recorded it is therefore possible to compensate for it by moving the mount in an opposite direction to the error. This is what we refer to as Periodic Error Correction or PEC.

EQMOD Variable Speed Periodic Error Correction (VS-PEC)

Before looking at how EQMOD implements VS-PEC lets first consider SYNSCAN/SKYSCAN PEC. The SYNSCAN/SKYSCAN hand controller provides a 'traditional' form of PEC that consists of recording the corrective actions taken by an operator who visually attempts to keep a target star centred using the controller slew controls. The hand controller records when, and for how long, the user makes corrections and when PEC is enabled the same corrections are played back for every subsequent worm cycle. Corrections are always made at the same speed it is just the duration and interval that vary. The PEC data is stored within the hand controller itself and is not an inherent feature of the mount stepper controller.

The EQMOD approach to PEC differs from the SYNSCAN approach in two key areas:

1.   Recording is automatic and does not rely on the user manually observing errors and initiating corrections.
2.   Correction is achieved by instantaneous adjustment of mount's tracking speed, VS-PEC

VS-PEC is an algorithm that varies the RA motor speed with the intention of cancelling any periodic errors found on the worm gear. It does this using a Periodic Error (PE) curve and synchronising it to the current worm position to determine when and by how much to change the speed of the RA motor. This is basically done to make the tracking constant at the sidereal rate minus the Periodic Errors.

Mount Periodic Error

PEC Rate Corrections
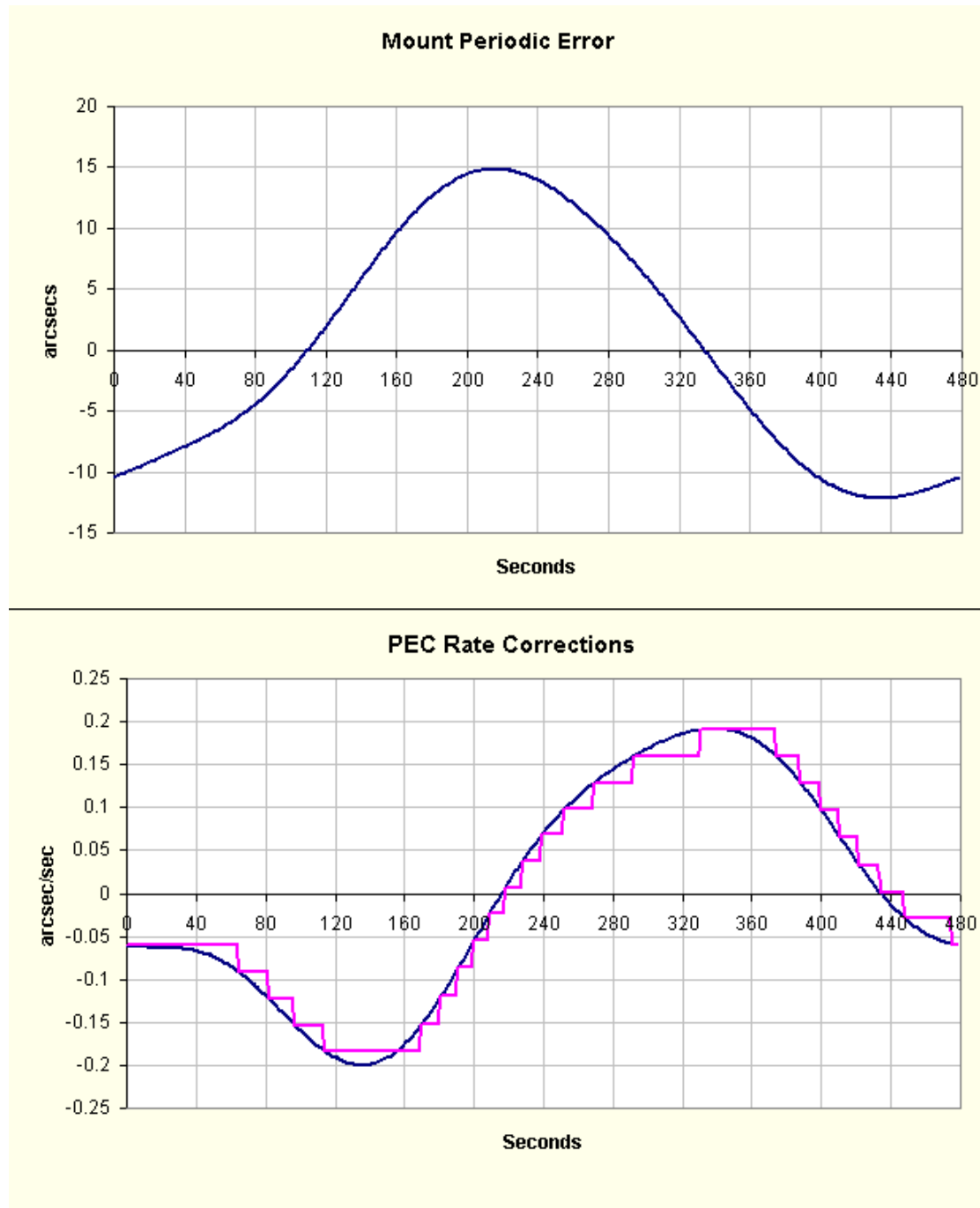
The top graph shows a typical PE trace – all high frequency signals have been filtered out to reveal the signal contributed by the mounts RA worm. The bottom graph shows in blue the rate at which the PE changes –so the highest rates correspond to the steepest parts of the PE curve and the lowest rates the flattest part. The magenta trace shows rate corrections that EQMOD sends and you can see that where the rate changes quickly, i.e. at the top and bottom of the PE curve, EQMOD sends many corrections. Where the PE curve is relatively linear, i.e. on the rising and falling slopes of the PE curve, EQMOD sends fewer corrections.

This approach is essentially the same as used in Satellite Tracking where the speed of the motors is varied based on another curve, the ALT/AZ orbital speed and position of the Satellite. The only difference between PEC and Satellite Tracking is that PEC applies the motor speed changes to cancel out the PE curve whilst satellite tracking applies the motor speed changes to follow the target speed curve.

PEC & Autoguiding

Traditionally there have been two schools of thought on the subject of using PEC whilst autoguiding. Some believe using PEC reduces workload of the autoguiding system whilst others believe it is better for all corrections to come from a single source and that having two competing control applications, one open loop and the other closed, leads to worse overall performance. The situation is further complicated by the fact that there are two autoguiding approaches – ST4 and pulse-guiding

With ST4 guiding the EQMOD driver has no knowledge of how the guiding program is controlling the mount. If VS-PEC is running in this case it will send out its own corrections regardless of whether the autoguider is already making corrections of its own. In such a situation there is probably no advantage in running VS-PEC at all and autoguider performance may suffer.

With ASCOM pulse-guiding the EQMOD ASCOM driver is able to arbitrate between the auto-guiding application and VS-PEC. EQMOD ASCOM and has been written to ensure that VS-PEC and pulse-guiding complement each other and don't fight. It works as follows:

- When a pulse guide command is received the correction pulse is applied using the current VS-PEC rate not sidereal.

- During the pulse period VS-PEC rate calculations continue but are not applied to the mount.

- When the Pulse finishes the rate is set to the result of the most recent VS-PEC calculation.

Using VS-PEC in combination with Pulse-Guiding has been shown to reduce the size and frequency of corrections issued by the guiding application. This we would expect. and doesn't necessarily deliver any improvement in overall performance. If using a bright enough guide star that allows the autoguider to use short exposures (0.5 seconds or faster) then the autoguider should be able to issue corrections quickly enough without using VS-PEC. Using VS-PEC as well will not do any harm and will simply mean the autoguider doesn't have to work quite   so   hard.

Where using VS-PEC and pulse-guiding together becomes advantageous is when using a mount that has a large periodic error (+/- 25 arc seconds) AND when guiding on a fainter star that requires 3 to 5 second exposures. VS-PEC can correct for much of the error before it happens and in between autoguider exposures. This greatly improves the overall guiding performance compared to autoguiding alone. The major advantage of this is that guiding on fainter stars permits many orders of magnitude more guide stars, greatly increasing the ease of locating one.

To use VS-PEC in combination with guiding it is important to start VS-PEC prior to guiding. The reason for this is as follows:

VS-PEC issues corrections to return the mount to the 'PEC centre' position. The guiding software also attempts to maintain a guide star (and therefore mount) centred. There is no guarantee that guiding target position will correspond to that of PEC, this will depend on the phase the PE at the time PEC/Guiding is started. If VS-PEC is started first it will hold the mount at 'PEC centre' ensuring that the PEC and guiding targets are in sync.

PEC & THE IMPORTANCE OF PARKING

To ensure correct synchronisation of the VS-PEC playback it is important is that the mounts stepper positions always remain in synch with their positions when the PE curve was originally recorded. The only way to do this over mount power cycles is to PARK and UNPARK the mount using EQASCOM.

Provided you always PARK at the end of your sessions, UNPARK at the start of the next, and don't move the worm in between, VS-PEC synchronisation will be retained.

Loosening the clutch and rotating RA axis shouldn't affect the worm or RA gear. The clutch disengages the axis from the RA gear not the RA gear from the worm. Provided you have Parked the mount you can therefore rotate the RA axis manually without loosing VS-PEC synchronisation. You will however loose astronomical synchronisation and unless you can accurately return the mount to its original position any saved alignment data will become void.

EQASCOM PEC USER INTERFACE

The EQASCOM PEC is one of several displays accessed by the "Display +" button. Right click this button to get a menu of all the available displays or just repeatedly click it to cycle to the PEC display.
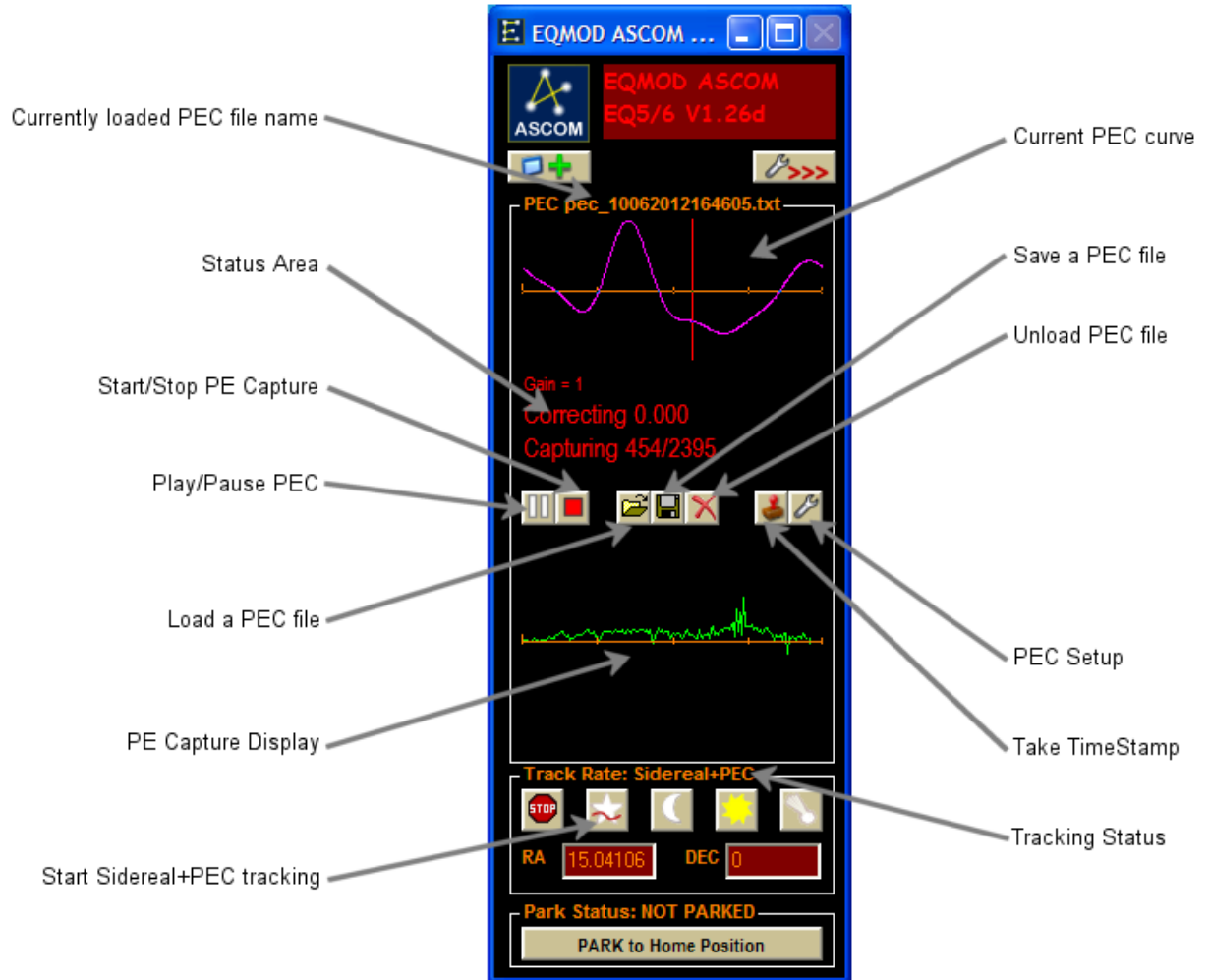
In order for PEC to be applied a PEC file must first prepared and loaded. Once loaded EQASCOM will remember where to find that file and will automatically load it on future startup.

You can tell if a PEC file has successfully loaded because the correction curve will be plotted and PEC file name displayed.

Once loaded PEC playback can be started or paused via the associated button.

When PEC is active the Sidereal Rate tracking rate button will show a red sine wave superimposed on the white star. The PEC status area will display "Correcting" followed by the currently applied correction rate (in arcsecs/sec).

When Tracking at Sidereal+PEC the Tracking Status will show "Sidereal+PEC"

The TimeStamp button is used to associate a particular motor position with a time within the EQMOD.ini file and is provided so that motor position data can be generated for PE files produced by third party PE recording programs (K3CCDTools, PHD etc). This will be discussed in more detail later.

The PEC Setup button provides access to various parameters that govern how PEC Playback and automatic PE capture operate.
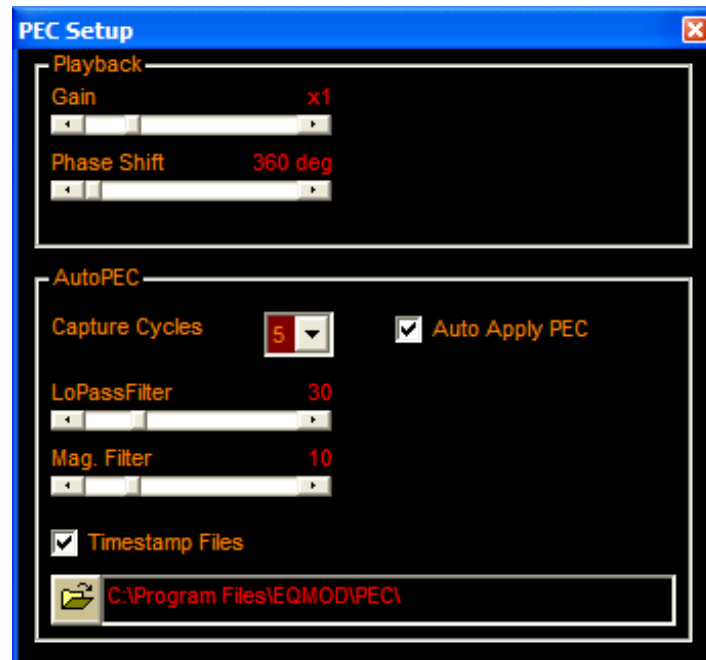
PEC Playback Settings
There are two "Advanced" controls that can be used to fine-tune the playback, the gain slider and the phase shift slider.

The gain control applies a factor to the rate correction as determined from the PEC algorithm. If when tracking at Sidereal+PEC, the rate corrections don't appear great enough to cancel all of the periodic error then try adjusting this control. The gain control can compensate for error in the original PE capture process due to variable such as focal length, pixel size, star declination, camera orientation etc.

The phase shift control allows you to advance (or retard) the curve either to either perform manual synchronisation or to compensate for time lags in the control system. Once applied the PEC curve can be re-saved with the phase shift applied (via the [Save] button) such that on subsequent load a phase shift is no longer needed.

AutoPEC Settings
Capture Cycles sets the number of worm cycles of data that is used to build the PEC curve. Usually the more cycles the better.

The two filter setting govern how EQASCOM will apply an FFT filter to the captured data in order to filter out fast transients (seeing fluctuations).
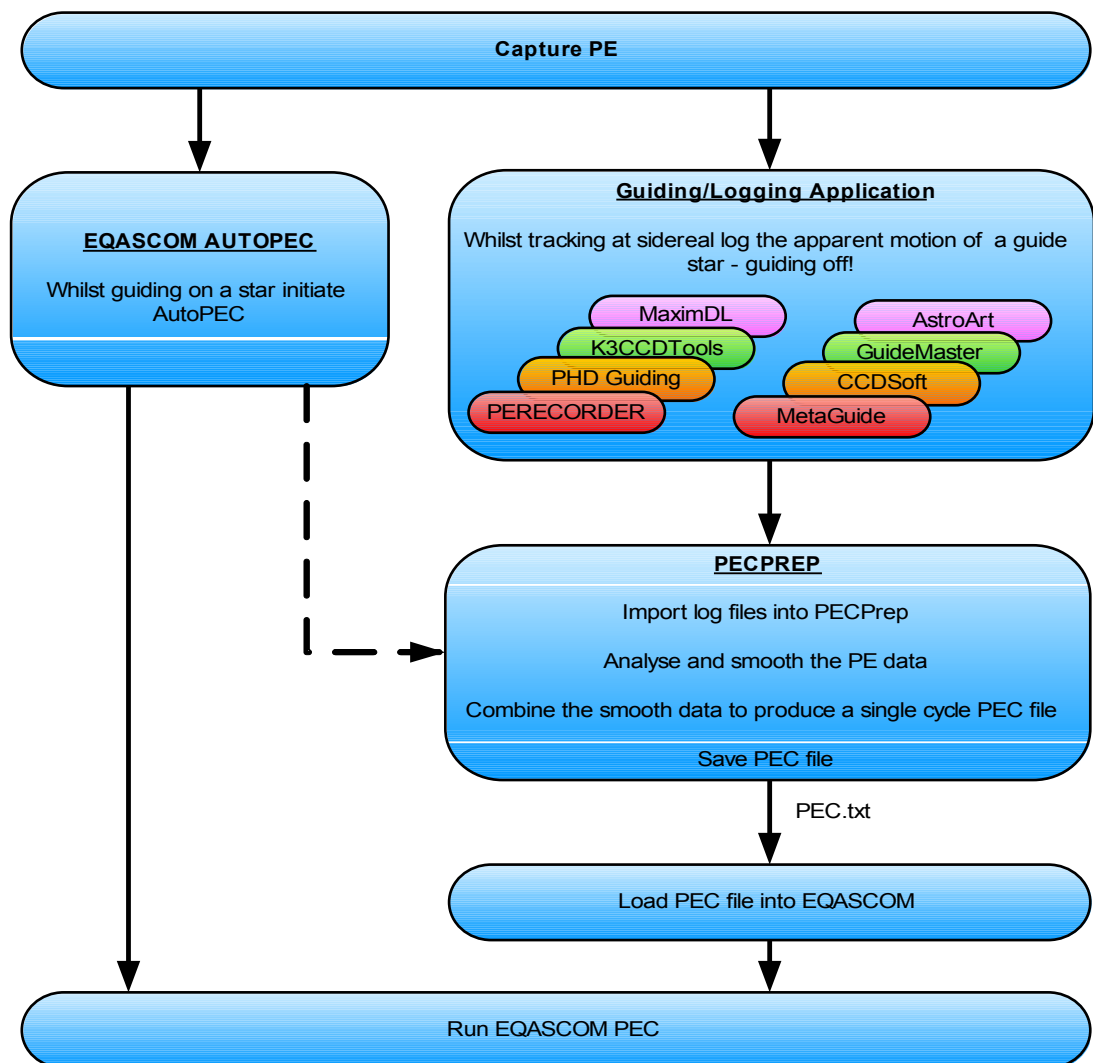
AutoPEC outputs two files – a PEC file and a PE file that can be loaded into PECPRep for further analysis. The "Timestamp files" checkbox dictates whether these files will be given unique names for each separate capture session. The location where the output files are placed can be changed.

The "Auto Apply PEC" checkbox determines whether the PEC file generated by AutoPEC will be automatically loaded on AutoPEC completion. If, for instance you do not wish to run PEC but do want to record your mounts PE then you would uncheck this box.

WORKFLOW

Before EQASCOM can provide Periodic Error Corrections it is first necessary to record the mounts Periodic Error so that a correction curve can be built and stored in a PEC file. This File is then loaded into EQASCOM. There are two basic procedures that can be followed to achieve this:

- AutoPEC – a feature built into EQASCOM itself that automates the entire process.

> or

- Capture and process guide logs using PECPrep. This method is more technically demanding but gives you finer control over the PEC produced.

```
                          Capture PE

   EQASCOM AUTOPEC              Guiding/Logging Application

                        Whilst tracking at sidereal log the apparent motion of a guide
 Whilst guiding on a star initiate            star - guiding off!
          AutoPEC
                            MaximDL          AstroArt
                          K3CCDTools        GuideMaster
                          PHD Guiding         CCDSoft
                          PERECORDER          MetaGuide


                                           PECPREP

                                 Import log files into PECPrep

                                 Analyse and smooth the PE data

                          Combine the smooth data to produce a single cycle PEC file

                                        Save PEC file

                                                     PEC.txt

                                    Load PEC file into EQASCOM


                          Run EQASCOM PEC
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Preparation

As our initial aim is record a PE curve that represents only the error induced by the mount RA gear train it is best to try to minimise error signals such as 'drift' cause by alignment, tracking rate errors etc.

Get as accurate a polar alignment as you can. If having done this you target star still drifts in RA, and this appears constant in different areas of the sky, it may be there is a tracking rate error present. In this case adjust the EQMOD drift compensation slider. Each increment/decrement of the slider equates to approx 0.024 arcsecs/sec change in rate.

For the purpose of recording PE use a bright star as a target – seeing conditions and wind effects don't actually matter too much as the tools we will employ can filter out this high frequency noise. PE recording is a task that can be performed at dusk prior to an observing session.

With regard to image scale pick a scale that will maintain the star image 'on chip' given the PE movement and any drift effects. Depending on you scopes focal length and imaging pixel size you may need to experiment with focal reducers / barlows to find the best image scale.

To get the best out of VS-PEC it is necessary to capture several cycles of PE data. EQMOD uses this 'raw' data to build an 'average' curve that represents a single worm cycle of the mount. The PE curve produced by individual worm cycles can vary, sometimes significantly. Only by capturing a large amount of data can we ensure that be are building a typical correction curve.

AutoPEC

AutoPEC represent by far the easiest method of recording your mounts PE and generating a PEC curve as it is fully automated form with EQASCOM itself.

- First select the number of cycles that you wish capture PE over. The longer the better the results will be.

- With you mount being guided by your auto-guiding software (either via ST-4 control or ASCOM PulseGuide) hit the record button.

- The PE will be measured and plotted on the capture graph which displays a single cycles worth of data. Each type a new cycle is started the colour of the capture graph will toggle between Red/Green. The progress of the capture is displayed in the Status Area.

- Once capture is complete the periodic error data is written out to a text file with the suffix _EQMOD. This can then be further analysed using PECPrep. A PEC file is automatically produced using the PE data and saved to disk.

- If the AutoApply PEC oprtion has been selected the PEC file will be automatically loaded into EQASCOM.

AutoPEC can be preformed whilst guiding+PEC is being applied.

PEC from Perecorder/Autoguider Logs

An alternative to AutoPEC is to take the log outputs from autoguider applications and extract the Periodic Error data from them. Usually logs are taken with guiding disabled – so that the autoguider tracks the guide star but does not attempt any correction. The only exception to this is when using MetaGuide which can produce both passive and active guiding logs that can be used by PECPrep.

Perecorder

PERECORDER has been written specifically for the EQMOD project and automates much of the process of PE recording. It does this by using a webcam to track the apparent movement of a target star in much the same way as a guiding application does. Through close interaction with EQASCOM perecorder is able record the mount stepper motor position associated with each PE sample. Perecorder is very easy to use and is self calibrating requiring the minimum of user input.

Currently PERECORDER only works with webcams and requires the .Net framework to be installed.

- Connect your webcam to the PC
- Start PE recorder
- Connect to you mount through ASCOM
- Make sure that the ASCOM driver is correctly set up (PERecorder reads the star declination for its computations, so the alignment should be at least roughly correct)
- Center a star in the webcam
- Press the "calibrate" button
- Optionally press the "check" button. This allows to confirm that the relationship between pixel size and arcsec on the sky is correct, if you know the focal length of your scope and/or the pixel size of the camera.
- If everything goes OK, press the "record" button
- A raw PE file will be saved in the directory you specify with the "choose" button

1. Start by checking the working directory is OK. This is the location to which PE logs will be written.
2. Connect to the mount via the [Scope…] button
3. Connect to the camera via the [Webcam] button
4. Slew to a bright star and centre on the perecorder screen.
5. Hit the calibrate button. The star will move across the screen as perecorder tracks its motion. Perecorder will then re-centre the star and output a message telling you the measured imaging resolution (arcsec/pixel).
6. Record plenty of cycles (4 or 5 at least). A cycle for the EQ6 is approx. 480s so plenty of time to pop the kettle on and have a brew!
7. End the recording.

The PE data is saved to a text file in the working directory *_raw.txt

Third Party Autoguiders .
For those users who do not have access to a webcam it is possible to use PECPRep to import K3CCDTools, PHD Guiding, MaximDL, Guidemaster, AstroArt, CDCSoft and Metaguide logs.

The key to being able to using third party logs is the timestamp button in EQMOD. This associates a time with a specific motor position and PECPrep is able to use this timestamp to calculate a corresponding motor position for each log entry.

The general workflow for PE capture is :

- Calibrate guider
- Disable guide output
- Start logging
- Start guiding.
- Whilst guiding hit the TimeStamp button on the EQASCOM PEC display.
- Capture 5 or more PE cycles.
- Stop the guide logging
- Stop guiding

See the Appendix for autoguider specific workflows.

**Using PECPrep to Analyse and filter the PE data.**
The raw data text files now need to be processed to remove any linear drift and to remove high frequency noise caused by seeing effects & wind etc. To do this we use the PECPrep tool. PECPrep has its own manual so we shall only give a brief overview of the process of PEC file generation here.

From the File menu load the autoguider/perecorder/autopec file
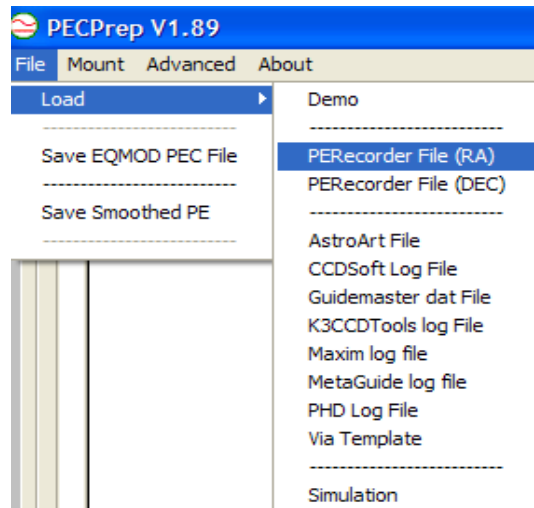
For all file types other than PERecorder files it will be necessary to apply the EQMOD timestamp as part of the import dialog. You may also have to supply details of focal length, pixel size, declination and binning so that PECPrep can correctly convert the log data into movement in arcseconds.

Once import is complete PECPrep will graph the raw data in grey. The Raw data with trend removed is shown in blue and a smoothed curve in red.
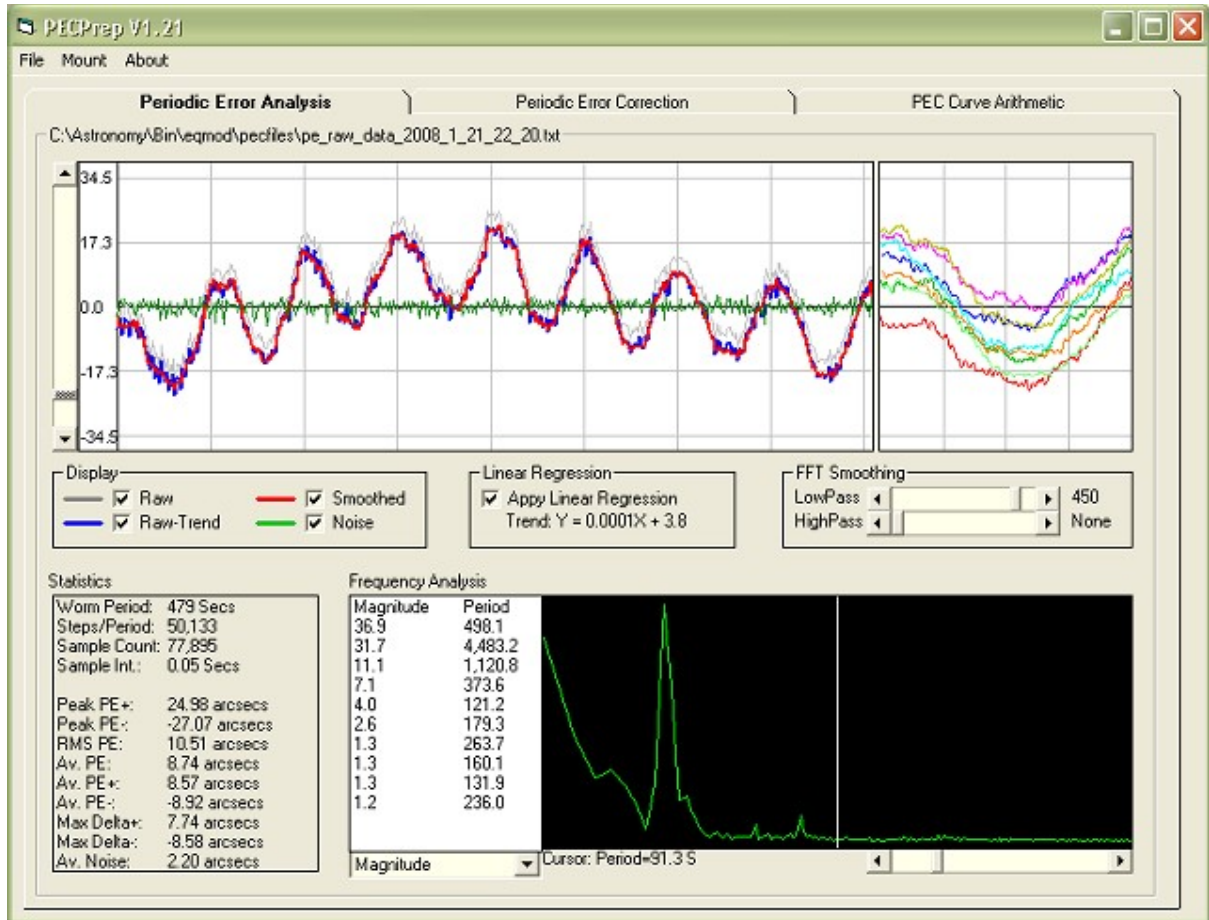
The green trace shows the 'noise' and is calculated as the raw data minus the smoothed data. Adjust the filter until the red curve gives a good fit to the blue and the green curve appears random.

The statistics frame shows the Peak, Average and RMS values of the PE curve as well as the average noise level. The Max Delta+ and Max Delta- represent the maximum positive and negative going changes between two successive samples.

The Frequency Analysis frame lists the periods of 10 most prominent signals that contribute to the PE curve. For the data above it can be seen that by far the most significant frequency is produced by the 458 second period signal (which we assume actually corresponds to the 479 second worm period). The period given is for indication only – don't expect to see and exact 479! This is because of the resolution of the Discrete Fourier Transform being used. Also the true peak may lie between samples, click on the frequency graph you see the discrete samples

Adjust the [Smoothing] sliders to apply Low Pass and High Pass FFT smoothing filters.
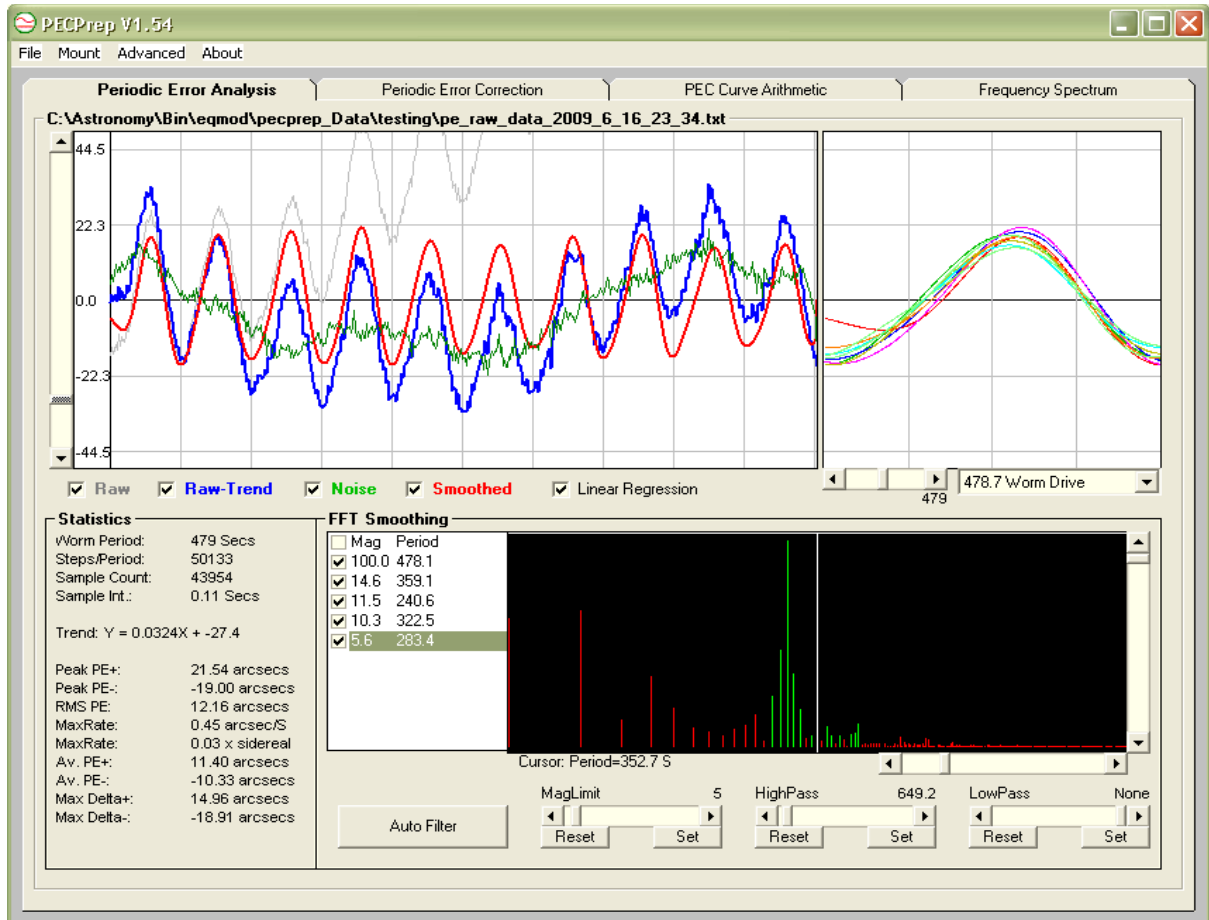
Hit the Auto filter button and PECPrep will give you a "best guess" for the filters most appropriate for your data. The red trace on the graph above shows the filterd or "smoothed" data .

To create a PEC curve click the PEC tab.
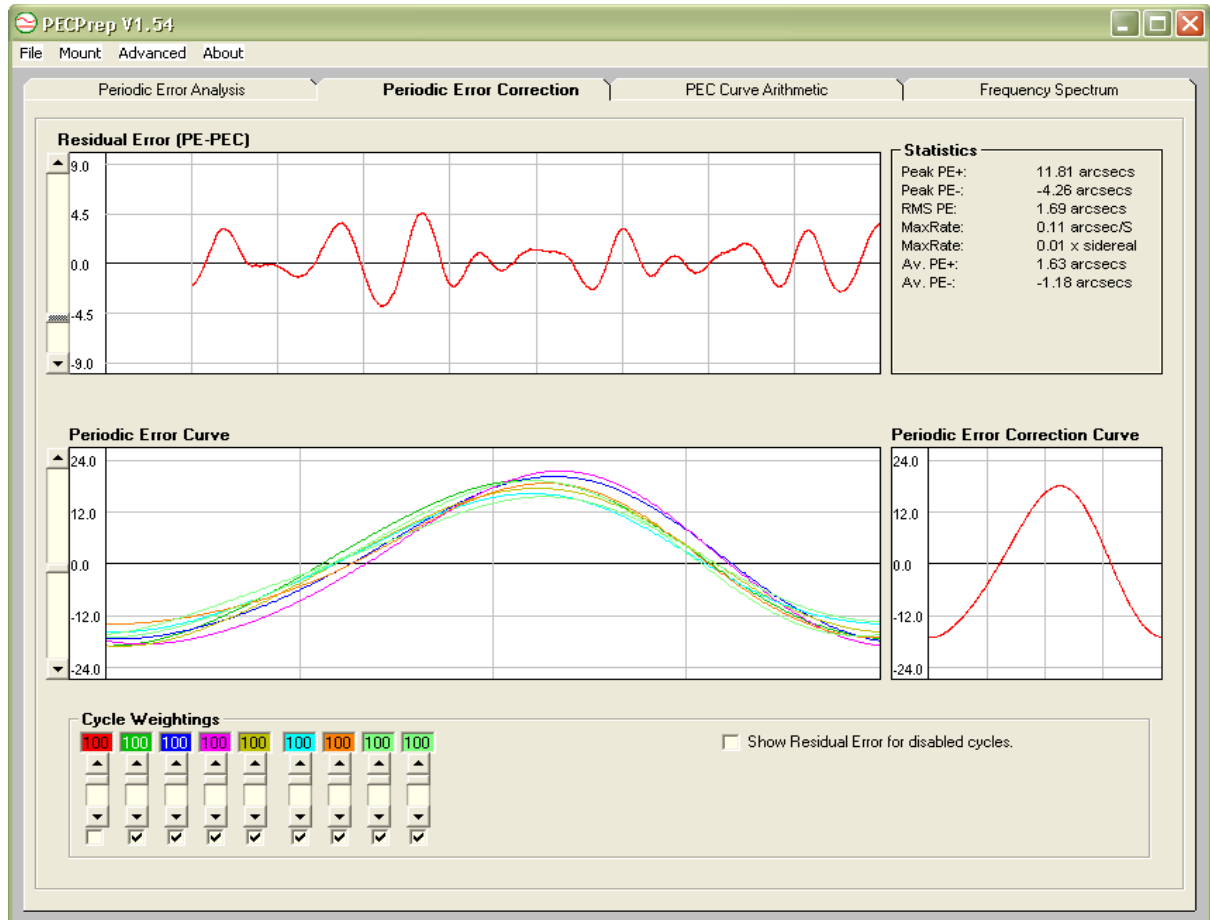
The lower left graph shows the PE data for each captured worm cycle overlaid on top of each other. In this way you can easily spot any cycles that are not 'typical' in their response. The average of the individual cycles results in the PEC curve shown on the right. Each cycle is given a weighting in this calculation and by adjusting the sliders you can change the relative influence of each cycles in generating the final PEC curve. To remove a cycle completely, uncheck the associated check box. In this way you can remove cycles which appear 'non' typical.

The residual error graph shows the signal that will be left by subtracting the PEC curve from the smoothed PE curve. The sliders on the side of the graphs allow you to zoom the vertical scale of the graph.

Adjust the sliders to obtain the flattest Residual Error response you can and then save the PEC file via the file menu.
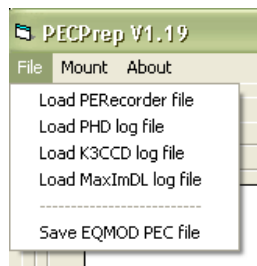
You can choose any name or location to save your PEC file.

APPENDIX A: PHD Workflow

1. Find target star and start tracking
2. In PHD make sure the log info option is checked.
3. In PHD make sure the "disable guide output" is checked or In EQMOD uncheck the pulseguiding enable boxes. (see note below re: DEC guiding)
4. Delete/move/rename any existing PHD logfile for the current date.
5. In PHD set the maximum search region you can get.
6. Calibrate in PHD then start guiding.
7. Capture 5 or more PE cycles.
8. In EQMOD hit the [TimeStamp] button on the PEC display.
9. Stop guiding.
10. Run PECPrep.
11. Make sure PECPrep has the correct mount type selected.
12. Load the PHD file from the file menu.
13. When prompted the focal length you were using, the pixel size of the imaging device, binning and star declination. The pixel width corresponds to the 'X' display axis.
14. Select the "apply EQMOD Timestamp" option and select your PHD log file. PECPrep will automatically convert the PHD log file to perecorder format, load the file PECPrep and save the new format file with "_EQMOD" appended to the filename. If you wish to come back to this data at a later time you can load this _EQMOD file directly without the need to go through the conversion process again.

APPENDIX B: K3CCDTools Workflow

1. Make sure K3CCDTools has been configured with your camera and scope parameters.
2. Set EQMOD tracking at sidereal
3. Find target star.
4. Use the K3CCDTools drift explored 'measure angle' tool to determine and compensate for any camera angle misalignments.
5. In K3CCDTools set the drift explorer to log to file.
6. Capture 5 or more PE cycles.
7. In EQMOD hit the [TimeStamp] button on the PEC display.
8. Stop the k3ccdtool log.
9. Run PECPrep
10. Make sure PECPrep has the correct mount type selected.
11. Load the K3CCDTools file from the file menu.
12. When prompted select the "Apply EQMOD Timestamp" option, enter the star declination and then select your K3CCDTools drift log. PECPrep will automatically convert the drift log to perecorder format, load the file PECPrep and saves the new format file with "_EQMOD" appended to the filename.

APPENDIX C: MAXIMDL Workflow

1. Find target star and start tracking
2. In PHD make sure the log info option is checked.
3. In Maxim make sure that RA guiding is disabled (Guider Settings window) or uncheck the pulseguiding enable boxes in EQASCOM
4. Delete/move/rename any existing track.log file for the current date.
5. Capture 5 or more PE cycles.
6. In EQMOD hit the [TimeStamp] button on the PEC display.
7. Make a note of the camera angle as displayed on the Guider Settings window.
8. Run PECPrep.
9. Make sure PECPrep has the correct mount type selected.
10. Select "Load MaximDL file" from the file menu.
11. When prompted, the focal length you were using, the pixel dimensions size of the imaging device, binning, camera angle and star declination. Select the "apply EQMOD Timestamp" option and select your Maxim track.log file. PECPrep will automatically convert the Maxim log file to perecorder format, load the file PECPrep and save the new format file with "_EQMOD" appended to the filename. If you wish to come back to this data at a later time you can load this _EQMOD file directly without the need to go through the conversion process again.

APPENDIX D: Q&A

Q What is Periodic Error?
A: Periodic Error (PE) is movement in a mount caused by imperfections in the gear train resulting in a very slight 'wobble' about the axis being driven. The most significant contribution to PE is the worm to worm gear transfer. PE can be reduced by mechanical improvements but it cannot be removed altogether, it is an inherent feature of a worm drive and the other mechanical components that make up the RA drive.

Q: What is VS-PEC
A: VS-PEC is **V**ariable **S**peed **P**eriodic **E**rror **C**orrection. This is a technique developed for the EQMOD project that varies the mount tracking speed to compensate for Periodic Error. This differs from PEC as applied by the SYNSCAN hand controller which uses constant speed corrections of varying duration.

Q: What are the benefits of using VS-PEC?
A: VS-PEC basically provides an improvement in tracking performance. Typically this is an advantage when using the mount for astrophotography.

Q: How much improvement will I see with VS-PEC?
A: Its difficult to give absolute figures because every mount differs in its periodic error. PEC is most effective if the mount periodic error varies smoothly and is consistent in amplitude over many cycles. If the periodic error appears erratic then you should first consider mechanical adjustments.

Q: Do I have to purchase/use third party tools?
A: Not at all. The EQMOD Project team have provided all the tools necessary to record and analyse periodic error and generate PEC files for EQASCOM to use. All these tools are available free of charge and are designed to integrate closely together and work with the latest versions and features of EQASCOM.

Q: Can I use third party tools?
A: Possibly. The EQASCOM developers have included a special ASCOM compliant interface (CommandString) which allows third party tools access to the EQASCOM PEC Engine.

Q: What is the advantage over auto-guiding?
A: For long exposure astrophotography most folks will need autoguiding but this doesn't preclude the use of PEC as well. Perhaps the question that should be asked is: Does using PEC lead to improved guiding?

Q: Can ST4 AutoGuiding and VS-PEC be run simultaneously?
A: The Jury is still out on this but we can foresee problems. Consider the case where PEC has the mount under control. A disturbance is then introduced that takes the guider outside its guiding threshold/deadzone and triggers correction pulse. The pulse duration is calculated based upon the error detected when PEC is active. As soon as the pulse starts the mount controller moves at an absolute rate and any contribution form PEC is lost. This loss of the contribution made by PEC could immediately induce a greater error and create a further disturbance to the system. Through further ST-4 pulses the guiding program should be able to the mount back to within its guiding threshold at which time PEC would switch in again. So the effect of using ST-4 guiding and PEC is that only one is ever active at a particular instance in time and when the control flips between them there could be additional disturbances introduced.

Q: Can ASCOM PulseGuiding and VS-PEC be run simultaneously?

A: Yes. EQMOD VS-PEC is designed to work alongside pulse guiding and can actually improve guiding performance when tracking on fainter guide stars. Unlike ST-4 guiding, ASCOM PulseGuide Pulses result in the tracking rate being adjust relative to the current rate and consequently are applied "on top" of PEC not in place of it.

Q: Does using PEC lead to improved guiding?

A: Having PEC active should certainly reduce the the amount/duration of corrections a guiding system needs to issue. Some folks refer to this as the guider "working less hard" but that doesn't necessarily deliver better images. It all depends on you imaging scale - and the rates of change of errors that need to be corrected. It could be that guiding alone will always keep your error sub-pixel so clearly the addition of PEC would make no noticeable difference.

What PEC can do is offer greater scope in selecting more aggressive/responsive settings within the guiding application. So using PEC can deliver more responsive guiding without loss of control. Also PEC can allow the use of longer guide exposures as it will keeps the mount on track during the exposure time when the guider cannot act. This not only opens up fainter guide stars but also means the user has a wider range of guide exposures available to provide the guider with the best quality star image upon which to make its centroid calculations. Ultimately the better the guide star image the more accurate guiding.

Q: What do I need to record PE?

A: A star, an imaging device and a capture/autoguiding program. The simplest approach is to use the EQASCOM's AutoPEC function whilst guiding.

Q: How long does it take to record PE?

A: For an EQ6 type mount you really need to record at least 40 minutes of data. For an EQ5 mount 55 minutes of data. With brighter stars you can record PE during dusk or periods if during poor seeing when other observation is impractical (the smoothing process is able to remove seeing and wind disturbances in the recorded signal).

Q: How often would I need to record/process PE?

A: You might need to re-record your PE if you change the loading of the mount, or if you fail to park the mount (there are means to resynchronise manually if this happens but re-recording may be the simpler option).

Q: How do I analyse my PE and create a PEC Curve for EQASCOM?

A: Use PECPrep. PECPrep has been written specifically for this purpose and contains a number of analysis and manipulation tools.

Q: What's the difference between a PE Curve and a PEC Curve?

A: There isn't a big difference but the PE Curve is the raw response of your mount, whilst the PEC curve is the data formatted for EQASCOM to apply corrections to the mount.

Q: Where is the VS-PEC data held?

A: VS-PEC data is stored in a text file on your PC and loaded by the EQASCOM driver. EQASCOM uses the file to send rate change commands to the mount. Whilst the mount may continue to track at sidereal rate when EQASCOM has been disconnected, it cannot track using VS-PEC.

Q: Must I always Park the mount?
A: Yes, Parking ensures that VS-PEC synchronisation is maintained.

Q: Will I loose VS-PEC synchronisation If I manually move the RA axis?
A: No, provided the mount is Parked. The clutch disengages the RA Axis from the RA gear, the RA worm will not move when the axis is rotated.

Q: Is PECPrep as reliable as commercial PEC tools?
A: PECPrep is written by a professional software developer with over 25 years experience of developing controls software and firmware. The techniques used in providing frequency analysis and filtering are the same as have been previously employed successfully in industrial vibration analysis/management products.

PECPrep is not only free but much of its source code is open for public scrutiny and the willingness to share and discuss our algorithms has occasionally led to public criticism by those aggressively promoting alternate approaches. A "popular" criticism is that the frequencies, magnitudes and phases PECPrep displays are not strictly accurate and so cannot be used to build an accurate PEC curve. This actually shows a very basic misunderstanding of the PECPrep tool and of how spectrum analysers work, which can be deliberately tuned to focus in on one particular characteristic at the expense of accurately resolving others. Ultimately the frequency domain data PECPrep provides is for reference and diagnosis purposes only. The frequency domain values actually play no part in the generation of the PEC curve which is performed totally in the time domain based upon the captured data. The correction signal produced is always fixed to the mounts fundamental frequency and, if analysed, will be found to only contain harmonics of that frequency.

The best advice that can be offered is to keep an open mind and to try it out yourself, you have nothing to loose. Do not be swayed by the opinions of others who may have their own products to push and who have only a limited understanding of the underlying technology and techniques upon which PECPrep is based.

APPENDIX E: EQASCOM PEC Command Interface

This specification details how EQASCOM has used the ASCOM CommandString interface to make some PEC functions available to third party clients.

Command	Third Party Client Sends	EQASCOM Responds
Disable PEC	:PECENA,0#	
Enable PEC	:PECENA,1#	
Get PEC State	:PECSTA#	0# (PEC Disabled) 1# (PEC Enabled)
Get Worm Tooth Count	:PECWTC#	worm_tooth_count#
Get Worm position	:PECIDX#	worm_position#
Get PEC Info	:PECINFO#	row_count,max_position #
Set Table Row	:PECSET,row_index,worm_position,pe #	1# (success) 0# (failure)
Get Table Row	":PECSET,row_index#	1,worm_position,pe# 0# (failure)
Load PEC Table	:PECLOAD,full_file_name#	1# (success) 0# (failure)
Save PEC Table	:PECSAVE,full_file_name#	1# (success) 0# (failure)
Set PEC Gain	:PECGAIN,gain#	1# (success) 0# (failure)
Set PEC Phase	:PECPHASE,phase#	1# (success) 0# (failure)

All commands from the client begin with ":"
All commands end with "#"

Parameters are comma separated and passed as ASCII encoded integers. Avoid using any locale grouping settings (i.e. send 50132 rather than 50,132).

worm_tooth_count	Number of teeth on RA axis gear.
row_count	Number or rows in the PEC table. Equates to the worm period.
max_position	Maximum worm position = microsteps per worm revolution -1
worm_position	Current worm position (0 to max_position)
pe	Periodic error * 1000

row_index	PEC table index (0 to row_count –1)
full_file_name	Full file path.

Writes to the EQASCOM PEC table using the PECSET command are buffered into a temporary table. When the last row is written the table is automatically saved to disk as %APPDATA%\EQMOD\pec.txt and then loaded as the current PEC definition. EQASCOM will then use this file location for future automatic loads until such time as the user manually specifies an alternate filepath.

Reads of the EQASCOM PEC table using the PECGET command read the specified row of the currently loaded PEC file.

Steps per worm revolution, Worm period and Worm tooth count are all determined from parameters read from the mount itself. If the mount (or simulator) is not currently connected then reading these parameters will result in a value of –1.