Refine attenuation

Summary

Attenuation is the reduction of strength, power, or amplitude of a signal. Refine attenuation is the improvement or purification of the signal's strength, amplitude, or power. This report describes how the `refine_attenuation.py` script works, what it does, how to use it, and how to interpret the output results. The attenuation on a radio telescope is needed to set the correct voltage levels for the system's receiver. The `refine_attenuation.py` script iteratively changes the attenuation until it is at an appropriate level. The output results and diagnostic information are then emailed to the operator.

Introduction

The refined attenuation script is designed to ensure that the telescope receivers and correlator operate at appropriate voltage levels. The script should be run to test the receiver system after routine telescope maintenance to verify if there are no necessary updates required. The algorithm changes each antenna's attenuation level by evaluating the ADC samples' standard deviation and the voltage amplitude within a coarse frequency channel until the values fall within an acceptable range.

The expected range and minimum thresholds

The standard deviation of the ADC samples is measured for both the UHF and L-band and a threshold of 12 is used. This is done to ensure there is enough timing information to maintain the receiver sampling rate. The voltage and voltage range thresholds are are measured from the ADC samples and a suitable range is 190 and 190+ 20 for L-band, and $\sqrt{2}$ x $Lband_{(voltage)}$ and $\sqrt{2}$ x $Lband_{(voltage\,range)}$ for the UHF-band. Given the threshold, if the antenna's standard deviation and voltage are not within the acceptable range, the algorithm changes or updates the attenuation levels until the values lie within the appropriate range.

Attenuation change update conditions

The antenna's attenuation is changed if the voltage is outside of the range and if the ADC standard deviation below the threshold. If the voltage is too low we reduce the attenuation by 1dB and too high it is reduced by 1dB. If the antenna's attenuation is less than maximum attenuation of 32, and greater 0 dB the attenuation will be changed. If the attenuation can't be changed due being outside of this range of 0 to 32 or the values are within the acceptable range the algorithm stops updating the antenna and proceeds to the next antenna, and all output updates and final results are emailed to the operator.

The observation output report

During the `refine_attenuation.py` observation, the code produces a progress report script that gives the user useful information about the observation progress. The report shows the standard deviation, voltage level, and attenuation values for each antenna update (for both H and V polarizations), shown below :

```
2023-06-21 08:27:33.771Z INFO   m008 ADC rms h: 18.3   vlevel: 286.1
Attenuation : 15
2023-06-21 08:28:05.078Z INFO   m008 ADC rms v: 17.8   vlevel: 269.2
Attenuation : 16
```

If the updated values require further updates the algorithm changes the attenuation levels and re-evaluates. When the attenuation changes are being made, the report script will show the attenuation changes, i.e, attenuation is changing from what to what, as shown in the following lines :

```
2023-06-21 08:27:33.773Z INFO    'u' band m008 h: Changing
attenuation from 15dB to 14dB
2023-06-21 08:28:05.079Z INFO    'u' band m008 v: Changing
attenuation from 16dB to 15dB
```

Once the script has completed adjusting the attenuation of the antennas a report is generated and the default values are read from `katconfig` file and this informs what is later reported back.

Output Emails

The end of the refine attenuation process is two results emails sent to the operators. The first email is titled “`Summary: Changing attenuation`”, this email summarizes the entire observation and is important to be seen by the operators as it highlights the antennas that have changed, and should be updated in the config. The second email is titled “`Details: Changing attenuation`”, this email contains all the debug information, it highlights all the detailed changes or updates made during the observation and is useful for a deeper understanding of what happened during the observation.

The "Summary : Changing attenuation" email

This email consists of three tables. The first table shows the final values of the attenuation for each antenna's polarization. The table has four columns, namely; the antenna name, antenna band, H polarization value, and the V polarization value as shown below :

Antenna	Band	H-pol	V-pol
m027	l	4.000	1.000
m036	l	1.000	2.000
m037	l	2.000	1.000
m034	l	4.000	3.000
m032	l	3.000	2.000

The second table shows **only** the updated antennas (where attenuation was changed). This table is titled “`Antennas that changed`”, and each row under this table gives

information that indicates which antenna has changed. Giving information of antenna name, band, antenna polarization, and the attenuation change.

Antennas that changed:

'l' band m036 h: Changing attenuation from 2dB to 1dB

'l' band m036 v: Changing attenuation from 3dB to 2dB

'l' band m032 h: Changing attenuation from 4dB to 3dB

The final table of this email is designed to make the `katconfig` value updates easy. The table is titled `"Changed antennas updates"`, and its rows are written in a format that aids the changes to the config file in `katconfig`. The format is; antenna name, H-polarization, and V-polarization.

Changed antennas updates (ant, H-pol, V-pol):

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m036, 1, 2

m032, 3, 2

The "Details: Changing attenuation" email

This email has more detailed information about the changes that took place for each antenna, and this information is in a time ordered format. The number of tables in this email is equal to the number of (antennas, polarizations) involved (each (antennas, polarizations) has its table for each polarization). The tables are titled: “Refine attenuation report for : antenna_name + pol, antenna band, No. of the changes/updates made”. Under each table, there are the following columns: Attenuation value, standard

deviations of ADC samples (Std) , Voltage value, change in attenuation (Delta atten), change in std (Delta Std), and change in voltage (Delta Voltage).

Refine attenuation report for: m027h,Band = I, No. of evaluations = 1

Attenuation	Std	Voltage	Delta atten	Delta Std	Delta Voltage
4.000	14.888	195.907	0.000	0.000	0.000
4.000	15.231	197.270	0.000	0.343	1.363

Refine attenuation report for: m036h,Band = I, No. of evaluations = 2

Attenuation	Std	Voltage	Delta atten	Delta Std	Delta Voltage
2.000	15.276	189.566	0.000	0.000	0.000
1.000	16.072	209.156	-1.000	0.796	19.590
1.000	16.834	211.844	0.000	0.762	2.688

Things to note from results

The expected change in attenuation values (Delta atten) for each iteration are either -1, 0, or 1, anything except the values should be considered an error. The final Standard deviation values must be greater than 12, anything less than 12 would likely induce erroneous results in the script and on the telescope. The Delta Voltage (change in the voltage) column and Delta Std (change in standard deviation) column, don't have a linear change with time. But very large changes must be noted and investigated as they could be RFI or other erroneous causes . For example

Attenuation	Std	Voltage	Delta atten	Delta Std	Delta Voltage
4.000	14.556	183.545	0.000	0.000	0.000
3.000	16.151	202.995	-1.000	1.594	19.440
3.000	15.886	202.244	0.000	-0.264	-0.751

A once-off high change in power during the observation at a particular time could be an indication of a possible RFI.

Attenuation	Std	Voltage	Delta atten	Delta Std	Delta Voltage
4.000	14.556	183.545	0.000	0.000	0.000
3.000	19.150	285.55	-1.000	4.594	102.012
3.000	15.886	202.244	0.000	-3.264	-83,306
3.000	15.622	201.694	0.000	-0.264	-0.751

Possible causes of the script not converging

As highlighted earlier, the algorithm will continue updating the values until it gets values that lie within the appropriate range. It is important to note that the script has a limited number of iterations for each antenna to get updated (generally a maximum of 20 loops). The attenuation can only be set to values between 0 and 32. So it is possible for the algorithm to not converge or continue updating until it exhausts the maximum number of loops without getting the correct values.

There are several possible reasons for this to occur:
It is possible for the change in attenuation to result in voltage values that are outside the acceptable range such as below the minimum threshold and then when decreased it is

above the maximum range. If such an incident happens, it is most likely for the algorithm to oscillate continually in these ranges until it maximizes the number of iterations, unless by any chance the updates end up pushing the voltage level back to the normal range.

Another possibility is when an antenna does not have enough power or voltage for the script. In this case, the script will reduce the attenuation, to try and increase the voltage level of the antenna to be above the threshold. If the antenna doesn't have enough power, the algorithm will keep on trying until it exhausts the number of iterations or the attenuation stops at 0. The same will occur if the power is too high and the attenuation reached is 32. This most often happens when the RF lines in the receiver/digitiser have been swapped and changing the power has no effect on the measured voltage.