Lelantos version 1.19 instruction manual

Introduction

Lelantos is a software tool developed to help identify RFI emitted by telephone wires carrying broadband signals. These signals are predominantly VDSL2 (**V**ery high-speed **D**igital **S**ubscriber **L**ine version **2)**. Due to the efficient encoding and scrambling used in VDSL2 these signals appear to be almost white noise so they can easily be mistaken for background noise. Lelantos understands the encoding of VDSL2 and can very reliably identify and measure its relative signal strength to other signals.

Lelantos was a Titan god in Greek mythology. His name means "something that goes unobserved"; therefore, he became the Titan of air, hunter's skill of stalking prey, and the unseen.

Installing Lelantos.

Your distribution includes this manual, Setup.exe and some example wav files. To install Lelantos run Setup.exe. If you have an earlier version of Lelantos installed you will be asked if you would like to uninstall it, click yes, and yes again when asked if you are sure; and again, if windows asks. Once you have successfully uninstalled the previous version click “Install” on the Lelantos Setup window.

Place the example wave files anywhere suitable to be opened by Lelantos. (These are real recordings done while investigating RSGB members problems.). You can skip directly to Using Lelantos with these.

Making an RF recording.

To use Lelantos in earnest one first needs to make a wav file recording of the offending RF using an SDR. Most SDR’s can be used though the minimum recording bandwidth is 192KHz of spectrum. Note the raw RF recording is needed in the standard I/Q format and that audio recordings can’t be used.

VDSL2 is broad band and extends from 138KHz to 17.664MHz depending on band plan. These frequencies are split into alternate upstream and downstream bands with only small gaps between bands. (There are RSGB articles with more detail).

If you see any structure to your RFI other than continuous almost white noise with signal level changes at band edges, then it’s something else. Though there may be a VDSL2 component which Lelantos can still find.

You can connect your SDR to your normal HF antenna but for a broader spectrum recording an untuned loop antenna is ideally required.

If your PC and SDR can handle the data rate record the widest possible spectrum. We have some good success with 8MHz bandwidth recordings but that’s not required except to get a good look at the overall VDSL2 band plan.

Fortunately, recordings can be short as they would otherwise get large quickly.

Typically, a half second recording is good enough irrespective of the bandwidth. Longer usually only gives minimal improvement. Being stereo I and Q recordings the sampling rate is

the same as the bandwidth. So, a half second 2MHz bandwidth file is 1M stereo 16-bit samples long. So that's 1M*2*2 = 4 megabytes.

Using Lelantos

Simple spectrum view (top left graph)

When you launch Lelantos it starts with just a menu bar and a large grey area below. To take you through the main features example wav files with known features are provided. Using the file open menu find and open the file Example_11to13MHz.wav.

After a few seconds Lelantos produces four graphs showing its analysis of this file.

The first (top left) graph shows in red the spectrum of the wav file. Note that its centred on 12MHz and that the SDR's filtering rolls the spectrum off at each end.

There are a number of upwards red spikes which are narrow band signals such as wanted radio signals.

There is a blue line at 12MHz that shows the boundary between the VDSL2 bands Upstream 2 and Downstream 3 (these are labelled in Blue).

Note on this first graph that the red spectrum line is fairly flat in each band (ignoring spikes) but that there is a step between bands. Upstream 2 is about 5dB stronger than Downstream 3. This is common because the downstream has been attenuated as travels to the house.

If you look more closely you will see that the VDSL2 modem is leaving a gap between Upstream 2 and Downstream 3 where the red spectrum line is lower. How much lower depends on the remaining signals and noise. This gap is always needed between bands for isolation.

Extracting the VDSL2 signal.

The narrowband signals are up to 60dB stronger than the VDSL2 so they make it difficult to quantify the VDSL2. To eliminate these signals Lelantos constructs a comb of digital notch filters. The blue line on the top left graph is 6db above the green noise floor line. All spikes above this blue line are eliminated with notch filters.

Notched spectrum view (top right graph)

The second (top right) graph shows, in red, the same spectrum after notching out the narrow band signals. The notched sections of the red line are joined up in blue to distinguish them. The levels either side and at the gap between Upstream 2 and Downstream 3 are now clearer.

I will explain later how the green line is derived which shows the spectrum of the VDSL2 separately from the overall spectrum. You can see that below 12MHz the VDSL2 accounts for virtually all of the signal. In fact, it's virtually all VDSL2 for reasons that will become clear later.

Symbol alignment (bottom left graph)

VDSL2 transmits data as a series of symbols. The symbol rate is 4000 per second or one every 250us. Between each symbol there is an inter symbol gap. The gap is exactly 5/69ths of 250us. These gaps are not empty, they are filled with a "cyclic extension" (CE) which, though it still looks like more white noise, is what Lelantos detects. (There are RSGB articles with more detail).

In order to measure the VDSL2 Lelantos needs to synchronise with these symbols. While synchronising it also needs to allow for any small errors in the SDR's frequency calibration. The third (bottom left) graph shows how the alignment of the CE correlation varies with different adjustments for the SDR's calibration in parts per million (PPM).

You can see from the I/Q correlation graphs that the peak is at -10 PPM. This alone is very strong evidence that we are seeing VDSL2.

Symbol timing (bottom right graph)

The bottom right graph shows a timing graph of the VDSL2 symbols being detected. The bottom scale is in degrees. 360 degrees is one symbol time.

At 0 degrees there is a large square peak. This same peak occurs at 360 degrees one symbol time later. These peaks are the gaps between the symbols. The blue lines shown on the horizontal axis show the expected width of these peaks given that they are 5/69ths of the cycle time.

The actual data is transmitted during the period between these two peaks. It produces no signal as it is effectively random so has zero correlation.

Additional phone lines

Note that there is a smaller peak near 135 degrees and a still smaller one near 175 degrees. This pattern also repeats 360 degrees later. These are actually signals from other phone lines also carrying VDSL2. Their symbols are at the same rate as the first phone line but are not synchronised with it. So there are actually at least 3 phone lines contributing to the total RFI.

Viewing other VDSL2 signals

On the top right graph the green line actually shows just the spectrum of the first (strongest signal) phone line. Lelantos can let you view the spectrum of other lines identified on the bottom right graph. To do this left click with the mouse on the lower right graph at the centre of the peak corresponding to the line you wish to view.

Viewing multiple VDSL2 signals

If you right click either graph this brings up a menu. Select view params. This brings up the view parameters menu. Look for "Multi Phone Line Spectra" and tick "Allow" and then "OK"

Now left clicking the top right graph clears all green lines and left clicking the bottom right graph adds lines to the top graph for each phone line.

In addition, if there are multiple phone lines selected a "line sum" graph is added. If you do this for all 3 lines you will see that the "Line sum" graph closely matches the full red spectra graph showing that indeed almost all the spectrum power is VDSL2.

Advanced features

There are many additional features described in the release notes that follow.

The release notes of previous version 88

- Lelantos now establishes the noise floor across the spectrum much better and by default eliminates any signals more than 6 dB (adjustable) above that. The thresholds are shown on the graph.
- I have fixed the problem with negative correlations. This has been a major area of confusion and problems for a long time. Very pleased to get to the bottom of it (see explanation below)

- You can zoom and pan the spectrum graphs. Place the mouse over one and zoom with the scroll wheel. You can also left click and drag to pan. (values in view menu change to correspond)
- You can resize the graph windows. Drag the splitter bars.
- You can turn on / off the FFT of FFT graph (defaults off)
- Automatically decripts any files in the SDRuno OLD FORMAT. You can save them in the new format but make sure the max length has been set big (in analysis settings) or they may be truncated (above graph it warns trimmed Length)
- The spectrum of the correlation is shown. However this does not yet allow for any carriers that are notched (more than 6dB above). This reduces their graphed signal strength.
- Notched carriers are shown as blue sections on the second spectrum graph. These are points above the blue line on the first spectrum graph.

New features in version 100 (since version 88)

- Fixed a bug in the phase correction for non-integral delays. The rotation now correctly depends on the non-integral cycles of the local oscillator not the sample rate. (This didn't previously show up on wav files where the LO and sample rates were harmonically related)
- Added default settings for the Analysis and View parameters. These can be set using the file and view menu prior to opening any files. Defaults will apply to all files opened. Once opened the individual per file settings can be changed.
- The View params and Analysis params menus can be accessed by right clicking or now by accessing the file and view menus while a file is open.
- Added view options to enable / disable some graphs.
- You can disable spectrum masking by setting the carrier notch level to 0dB.
- By default when spectrum masking is in use the masked points on the second spectrum are omitted and the omitted sections are shown in blue. There is now a 'reveal' option on the view menu that shows the true spectrum with no omissions so that one can see the shape and depth of the notches being applied.
- When some frequencies are notched to remove strong narrow band signals this reduces the measured VDSL2 spectrum in that area. The spectrum graph points are now adjusted to allow for the percentage of notched spectrum near each point. This adjustment cannot compensate for large percentages of localised notching.
- If you click on the time domain correlation graph at the centre of the peak for a VDSL2 line then the spectrum of that peak is shown on the overall spectrum graph. The Time domain window is constructed to align with the point on the cycle clicked. The FFT will be lower resolution due to the restricted window. Also the dynamic range is restricted to say 25dB below the full spectra. This improves with longer wav files. Increase the "Max file length M samples" if needed. Default is 3 Mega samples.
- There is a new "Multi Phone Line Spectra" option. If enabled then when clicking on the time domain correlation at several line positions their individual correlation spectra are plotted. Also the sum of their spectral power is plotted. The correlation spectra are scaled to be comparable to the full spectra in red. Clicking on the spectrum graph clears all these lines. Care should be taken not to click at two points separated by less than 1.5 CE widths as the time domain windows will overlap leading to some points being summed twice.
- There is a view option to show "Graph I/Q rotate". This shows the same points as the per line correlation spectrum but instead of in dBs the values are linear Real /

Imaginary showing + and -. The scale is an internal one. If the I/Q phase is correctly aligned over the spectrum then the Real component should be positive, and the imaginary balanced on the zero line.

- You can now click on the above Correlation Real Imaginary graph to adjust the I/Q phase correcting the correlation graphs. This manual adjustment should only be necessary if the SDR has put erroneous frequency parameters in the wav file. The horizontal scale is marked in degrees to facilitate this. The expected value based on the CE VDSL2 timing and the Local Oscillator frequency is shown as “expected” above this graph. A blue line shows the current setting.

New features in version 101

- There is a new Compare option. First open two wav files as usual. The first file is expected to be the “Here” file and the second one the “There file”. Now select new from the menu. In the dialog box that appears click “compare”. The spectra of both the opened files are shown on the same graph. The zero dB points are aligned on the assumption that the strongest signal is the same in each file. You can zoom and pan the combined graph as usual.

New features in version 106 (since version 101)

- The View menu has been reorganised to make the grouping of existing features clearer and to allow for expansion.
- There are new Spectrum calibration options in the view menu. If one selects the tick box to “show” the calibration a new graph line “Here Calibration” appears. This will initially be a flat line along the 0dB axis (of the same colour as the “Here Calibration” text).
- While Spectrum calibration is set to “show” one can also tick the “There” option. If this is done during a Here / There compare the Spectrum calibration of the “There(Second)” graph is shown instead of that for the “Here(First)”
- While either Spectrum calibration curve is shown one can adjust the calibration of that curve. To do this hold down the shift key and with the left mouse button drag any point on the graph vertically. If only one point is dragged, then a constant scalar gain adjustment is applied. The value of the adjustment can be seen by the position of the Calibration curve relative to the 0dB axis. This same adjustment is applied to all views of the “Here” or “There” graphs. This works on both “Compare” and single document views.
- When additional points are dragged with the left mouse button (while pressing the shift key) these points are added to the calibration curve and linear interpolation is applied between the points.
- Note that the calibration points are moved by the vertical distance one drags the mouse irrespective of the vertical start point. So one can drag either the calibration curve or the graph one is calibrating (or any point vertically between).
- The zoom and pan features also work so that one can zoom in to a particular point.
- In order to move an existing point, place the mouse on that point and drag it to a preferred position. Note that if one is “near” an existing point it is moved. However, if not “near” an existing point then a new point is created. “near” is defined as 1/32 of the width of the current zoom view. So one can zoom in to create close points rather than move existing ones.

- To delete an existing point, hold down the control key and select it. One needs to be “near” the point. If one is “near” more than one point the nearest is deleted. Using zoom may help.
- Holding down Shift and Control and left clicking anywhere in the graph deletes all points.
- In single document mode when two spectrum graphs are shown (Full and Notched) then any calibration adjustments to either apply to all curves on both.
- If calibrations are done to a Compare of two documents, then the calibrations of the original documents graphs are independent of the calibrations of the compare document graphs.
- The calibrations are protected from any changes while the calibration curves are not shown.
- Currently calibrations cannot be loaded or saved.

New features in version 111 (since version 106)

- The previous version 106 calibrations are now called view calibrations. In addition to these existing view calibrations, Antenna calibrations are now supported. Antenna calibrations are loaded when a wave file is opened and affect the VDSL2 analysis. View calibrations are applied on top of any antenna calibration and only affect the spectrum graphs of the results of analysis.
- Antenna calibrations are loaded from csv files. Lelantos looks for these csv files in the same folder as the wave file being loaded. Alternatively, if there is a sub folder of that called “calibration” Lelantos will look there first.
- If there is a csv file of the same name as the wav file, that will be used as the antenna calibration. If not any other csv file (not matching any wav file) will be read in.
- The data in the csv file should consist of two or more columns. The first must be the frequency in Hz. The second must be the calibration point in dB. Fixed point or scientific notation may be used.
- Columns in csv files are ideally separated by single commas or semicolons. However, a space or tab is also acceptable. Additional spaces or tabs are ignored. The frequency points may be any value in any order. Headings and blank lines before the data are ignored.
- Once loaded the antenna calibration will be normalised so that the centre frequency point will be 0dB.
- The view menu now has buttons to save and load view calibrations. The here / there checkbox is only available during a compare and determines which view calibration is saved or loaded.
- Saved view calibrations are stored in the same format as the csv files but with the extension “.vew”. They are always stored in a sub folder “calibration” and always with the same name as the wav file.
- If there is a saved vew file it will be loaded when a wav file is open, at the same time as any antenna calibration is loaded.
- All calibrations now use cubic interpolation rather than linear interpolation. This results in smooth curves through the defined points.
- When Calibration curves are being shown the positions of the defined points can be seen by changes in the colour of the graph.

New features in version 114 (since version 111)

- Added loading of 32-bit integer format. Works with ddc files if renamed wav.
- No longer reports VDSL2 signal level in dBs relative to others on graph as its misleading.
- Added band-plan feature (and define band 17A) to graph class with names to improve user experience and in particular graphs used in reports.

New features in version 118 (since version 114)

- Locked the toolbars since reconfiguring them is not useful and can be confusing.
- Improved release procedure. Build numbers are auto-inserted in all contexts.

New features in version 119 (since version 118)

- When setting an averaging bandwidth in the view parameters the correlation spectrum graph is scaled with the bandwidth.