Technical Note:

AKELA VNA Sweep Speed and Resolution Bandwidth Calculation

The AKELA VNA is capable of two modes of sweeps: Standard and User-Defined. Each mode is described below.

Parameters for the measurement and sweep are sent to the VNA from the host computer and stored in onboard memory. The VNA can then be operated in either a synchronous or asynchronous mode. In synchronous mode, the host commands the VNA to make a measurement. In asynchronous mode, the host commands the VNA to start making measurements and then listens for the measurement data. Measurements are made continuously until the host sends a command to stop the measurement process.

1) **Standard Sweeps**

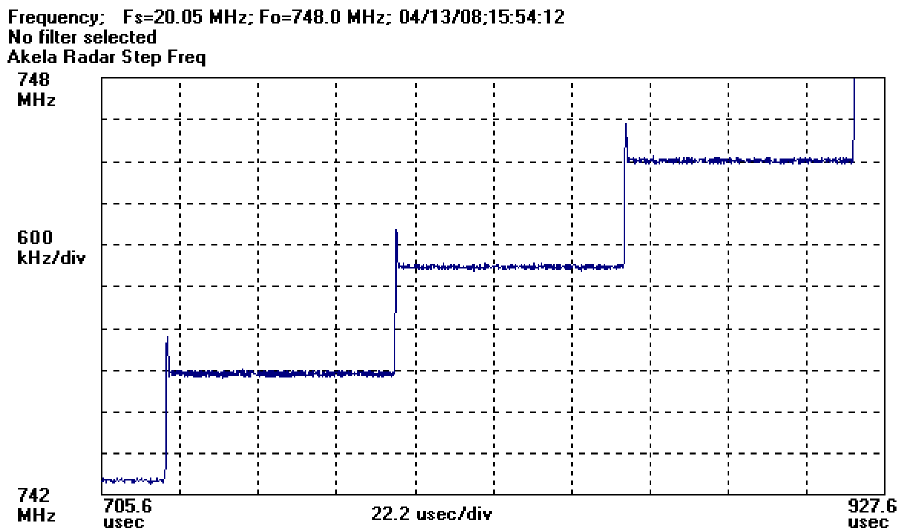
The AKELA VNA uses a stepped frequency method to perform frequency sweeps. Ports must be switched and a new frequency sweep performed to measure each of the 4 S-Parameters, plus a reference measurement, for a total of 5 sweeps per set of S-Parameters (S_{11}, S_{21}, S_{12}, S_{22}).

For each sweep, the frequency stepping rate determines the dwell time at each frequency point. AKELA's VNA has 13 user selectable frequency stepping rates:

- 20 frequencies per second.
- 39 frequencies per second.
- 78 frequencies per second.
- 156 frequencies per second.
- 312 frequencies per second.
- 550 frequencies per second.
- 1,000 frequencies per second.
- 2,000 frequencies per second.
- 3,500 frequencies per second.
- 7,000 frequencies per second.
- 15,300 frequencies per second.
- 30,000 frequencies per second.
- 45,000 frequencies per second.

The dwell time is the reciprocal of the frequency stepping rate, so at the highest stepping rate, the frequency dwell time is 22 microseconds.

The chart below shows a portion of the frequency stepping sequence for a frequency stepping rate of 15,300 frequencies per second. Note that the settling time is very fast when changing frequency.



Total sweep time is determined by dividing the number of frequencies selected (between 2 and 4096) for the measurement by the frequency stepping rate selected.

The S-parameter test set takes 2 microseconds to change from port to port but with an additional 3 dwell-times delay before sweeping begins in order to let the phase lock loop controlling the frequency value settle, since the VNA must tune from the top to the bottom of the frequency range at the end of a sweep.

For example, a sweep of all 4 S-Parameters at 1024 frequencies from 1,000 MHz to 6,000 MHz at a frequency stepping rate of 15,300 frequencies per second would take:

1 sweep - 1024 frequencies divided by 15,300 frequencies per second = 66.928 milliseconds
5 sweeps (4 S-parameters plus 1 reference) = 5 x 66.928 = 334.64 milliseconds
4 changes from port to port at 2 microseconds – 4 x 0.002 = 0.008 milliseconds
1 delay time after changing ports at 3 point times per delay = 3/15300 = 0.196 milliseconds
4 delay times per 4 S-parameter measurement = 4 x 0.196 = 0.784 milliseconds
2 band-changes = 0.1333 * 2 = 0.266 milliseconds

Total measurement time = 333.64 + 0.008 + 0.196 + 0.784 + 0.266 = 334.894 milliseconds

Resolution bandwidth is determined by the frequency stepping rate selected. AKELA uses a digital filter clocked synchronously with the A/D sampling clock to recover the information for each frequency point. To obey the Nyquist rate relationship, the resulting bandwidth of the digital filter, and, therefore, the resolution bandwidth is 1/2 half of the frequency stepping rate. For the VNA's highest recommended frequency stepping rate of 45kHz, the resolution bandwidth is 22.5 kHz. An analog filter in the VNA sets the highest possible frequency stepping rate of 90kHz.

The frequency stepping rate has a direct effect on the VNA's effective dynamic range. Slowing down the frequency stepping rate allows the VNA to integrate the measurement data over a longer time to reduce the effects of system noise. It is possible to achieve a measurement dynamic range greater than the instantaneous dynamic range by using this technique, however, it is **important that the VNA calibration be performed at the same conditions** otherwise corrections made to the measurement by the VNA based on an old calibration can add noise to the measurement. The limit on instantaneous dynamic range is set by the quantization noise and non-linearity of the A/D converter that is used. The current AKELA VNA has an instantaneous dynamic range floor of approximately 74 dB. (The next-generation AKELA VNA will have an instantaneous dynamic range floor of about 84 dB and a maximum frequency stepping rate of 90,000 frequencies per second.)

2) Band-Switching Times

The AKELA VNA internally breaks up the range of frequencies it can tune into a number of bands. For the current VNAs, there are 4 bands:

- 375 MHz – 700 MHz,
- 700 MHz – 1400 MHz
- 1400 MHz – 2800 MHz
- 2800 MHz – 6050 MHz

The above is correct for the current VNA model, but for any future (or current) VNAs, the number and frequencies for the band boundaries of a particular VNA can be accessed through the C/Python API via the **getHardwareDetails()** call.

Switching frequencies across the band-boundary incurs an additional delay versus the normal intra-band frequency step, as an additional frequency divider needs to be switched into/out-of the signal path, and the PLLs have to be allowed to re-settle. Therefore, it is a good idea to try to minimize band-crossing for a custom sweep, in order to achieve the maximum possible sweep-rate.

The time it takes to tune across each band-boundary is a function of the overall sample-rate of the VNA. The delay times are an additional number of frequency sample durations:

Hop Rate	Delay (integer samples)	Delay (time)
45K points/second	4	(1 / 45,000) * 4 = 88.8 uS
30K points/second	3	(1 / 30,000) * 3 = 100 uS
15K points/second	2	(1 / 15,000) * 2 = 133.3 uS
7K points/second	1	(1 / 7,000) * 1 = 142.8 uS
3K points/second	1	(1 / 3,000) * 1 = 333.3 uS
2K points/second	1	(1 / 2,000) * 1 = 500 uS
1K points/second	1	(1 / 1,000) * 1 = 1 mS
550 points/second	0	No additional delay
312 points/second	0	No additional delay
156 points/second	0	No additional delay
78 points/second	0	No additional delay
39 points/second	0	No additional delay
20 points/second	0	No additional delay

3) **Software-Defined Sweeps**

The AKELA VNA is not capable of sweeping using a linear ramp, but can simulate a more linear sweep by using more points at the expense of overall sweep speed.

Since the AKELA VNA is software defined, there are additional capabilities such as segmented sweeps, adaptive point spacing, external control, and interface that are possible but which are currently not incorporated in the VNA user application. This capability can be accessed through the software API, via the **setFrequencies()** call, which allows the user to specify the frequency of every point in a sweep individually, and the order in which the points will be sampled. The modular design of the VNA also permits the development of frequency extensions without changing the fundamental VNA operation.

The VNA Applications Programming Interface allows users to incorporate control of the operating parameters of the VNA into their own control interface software to allow customization of the VNA operation for user requirements. See the online AKELA API reference (http://akelainc.github.io/) for complete API documentation.