3/28/2024

Variable Attenuator Repeatability

Three methods to control the variable attenuator and how they affect repeatability

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2 INTRODUCTION

The two primary technologies used for electronically tunable attenuation in the mm-wave are PIN diode and rotary vane. Micro Harmonics has developed a third approach that uses the principle of Faraday rotation to rotate the RF signal polarity into a fixed resistive vane. There are no moving parts and no sensitivity to electrostatic discharge. Micro Harmonic's voltage variable attenuator (VA) is controlled using a DC voltage supply. The DC voltage sets the current in the magnetic coil, which controls the magnetic bias field. **The purpose of this application note is to explain three different methods for controlling the attenuation of the variable attenuator and *how each method affects the repeatability*.**

Repeatability tests were performed on the voltage variable attenuator using three different methods:

1. No reset
2. Reset @ 10V
3. Reset @ 0V

The idea of a "reset" is motivated by the phenomenon of hysteresis. Hysteresis is the primary detractor from the repeatability of the VA. In short, the voltage variable attenuator "remembers" its history. That is, the ferrite core is subject to residual magnetization based on the strength of the field generated from the electromagnetic coil surrounding it. Therefore, the exact attenuation level is a function of the control voltage *and the history of the control voltage*. Though the phenomenon of hysteresis has useful applications, for the purpose of the variable attenuator it is an unavoidable nuisance.

However, hysteresis can be substantially mitigated by resetting the VA. The basic idea is to make sure that the control voltage "history" is always the same. Before changing the control voltage to a new level, a standard control voltage is applied to the VA to "reset" the history. Or, in the case of "no reset," control voltage is applied to the VA with no regard for the history. Each method has advantages and disadvantages.

Before showing the reset methods, the effect of hysteresis will be demonstrated by sweeping the control voltage from 0V to 10V, and then back down to 0V. Note, in this application note only the results from testing performed at 92.5 GHz (middle of W-band) on a VA100 (WR-10 variable attenuator) are shown. Testing results from the W-band VA have demonstrated that the effects of hysteresis are independent of frequency. In Figure 1 the blue trace shows the attenuation as the voltage is swept up, and the gold trace shows the attenuation as the voltage is swept down. The traces mostly overlap but where they do not, demonstrates the effect of hysteresis. For example, the attenuation is about 20 dB when 1V is applied to the control voltage port. But the attenuation is slightly greater if "approaching" from 0V (blue), and slightly lower if "approaching" from 10V (gold).

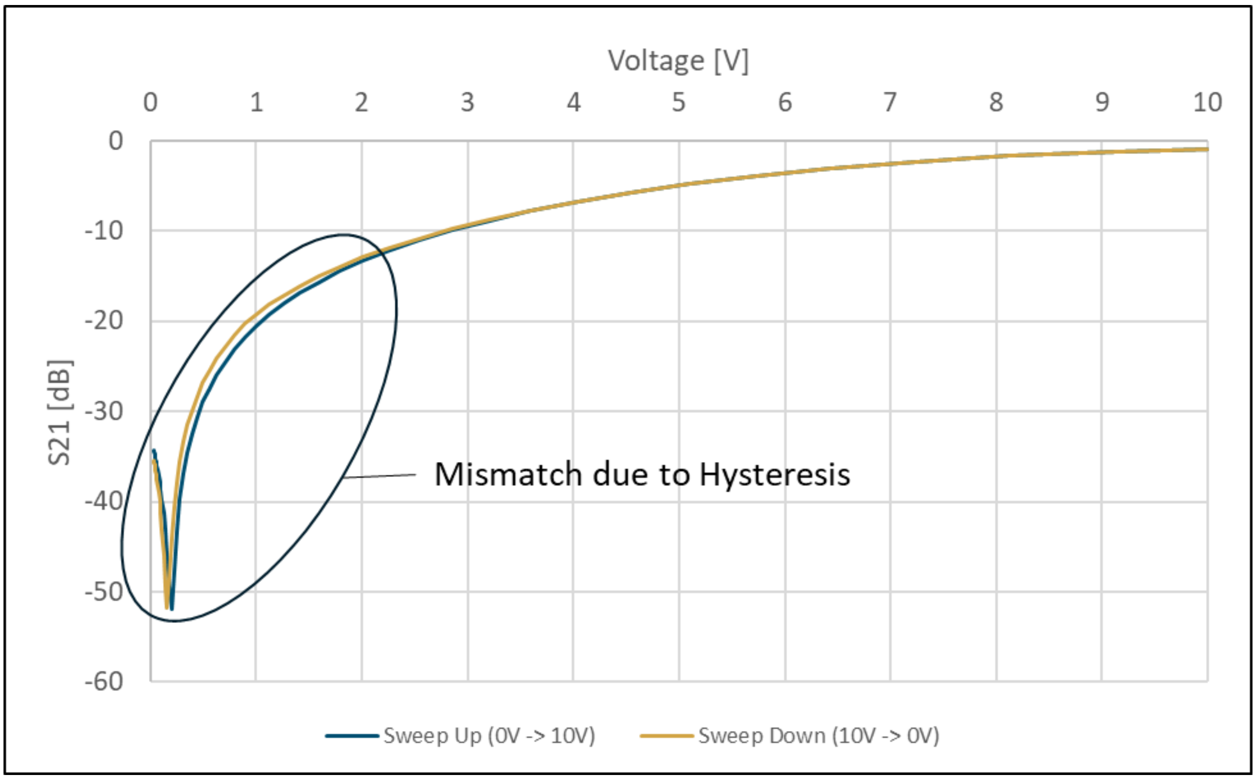

Figure 1: Hysteresis effect in variable attenuator demonstrated by voltage sweeps

A good way to understand the reset methods and how they affect repeatability is to see a snapshot of the tests used to characterize the repeatability. One test from each reset method will be shown. For each reset method, the control voltage will be swept up and then down. Sweeping the control voltage in both directions from minimum to maximum ensures that the repeatability is measured against the most diverse history. The attenuation of the VA across time as the control voltage is swept is shown in Figure 2. Note that max attenuation does not occur at 0V because the ferrite is permanently magnetized. Also note that the voltage sweep is exponential to obtain and more linearized attenuation sweep.

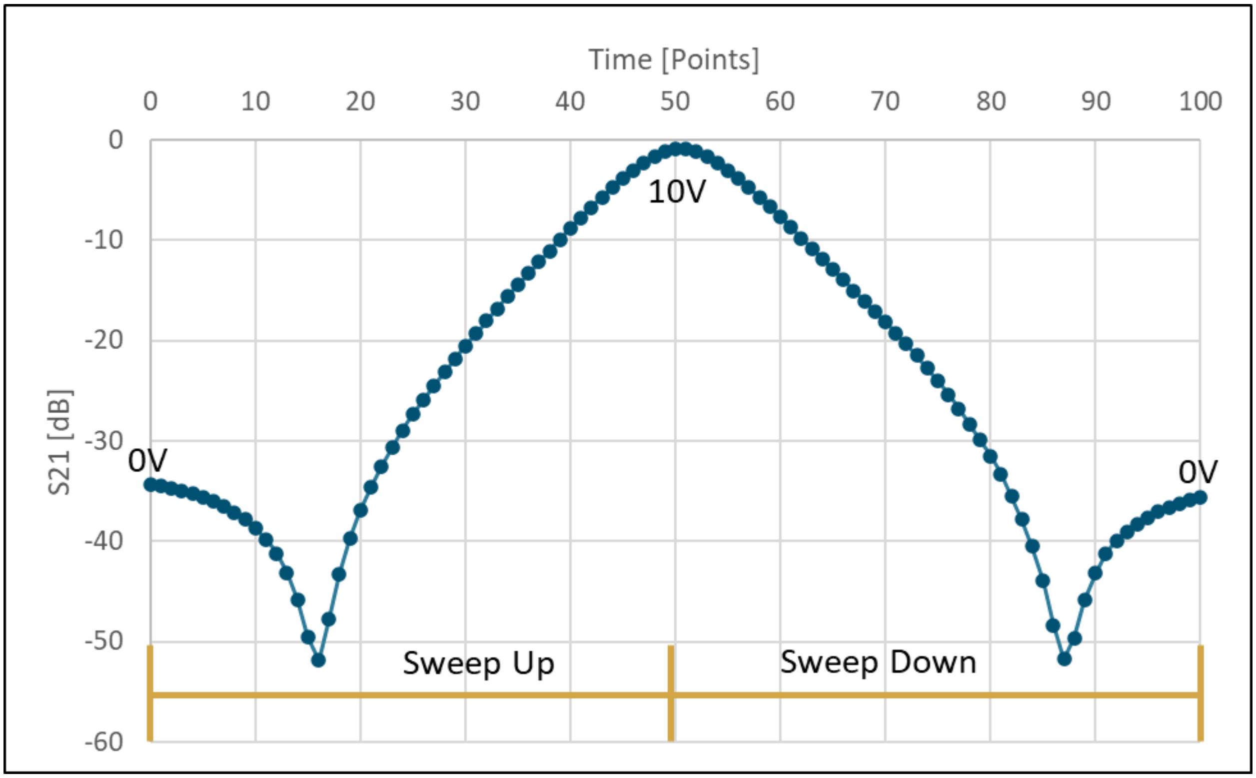

Figure 2: Attenuation at 92.5 GHz of variable attenuator over time as control voltage is swept up and down

3 Reset Methods

For each reset method a trial voltage is selected. The trial voltage is 0.87V which yields about 20 dB attenuation for this particular voltage variable attenuator at 92.5 GHz (as observed in Figure 1). The idea is to see how much variation in attenuation there is when applying a consistent trial voltage of 0.87V, as the history of the control voltage differs. The voltage sweep demonstrated in Figure 2 is used to simulate the full gamut of control voltage possibilities.

3.1 No Reset

The data in Figure 3 was generated by applying the trial control voltage to the VA between each sweep step. It can be observed that the attenuation achieved *by the same trial voltage* shifts up as the sweep voltage sweeps higher than the trial voltage. The attenuation achieved by the trial voltage then shifts back down as the sweep voltage falls below the trial voltage. Depending on the history (the sweep voltage), the trial voltage might achieve 20 dB attenuation or 21 dB attenuation or somewhere in between.

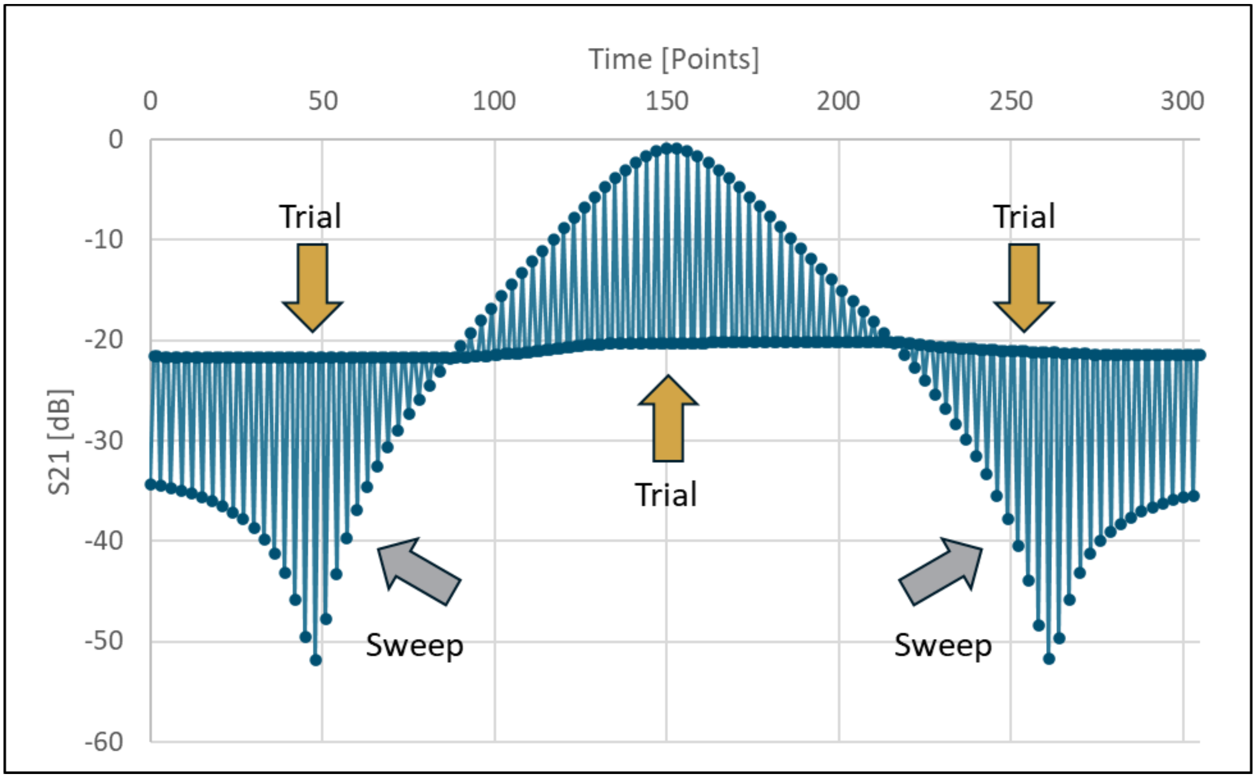

Figure 3: Example of testing repeatability of the variable attenuator at 20 dB using the no reset method

Using the no reset method, as demonstrated, yields the least repeatable results. But it has the advantage of requiring no additional control logic.

3.2 Reset @ 10 Volts

The reset @ 10V method resets the VA by applying 10V to the control circuit before applying the trial voltage. The order of operation for the repeatability test is to apply the voltages as such:

1. sweep voltage
2. reset voltage (10V)
3. trial voltage

Because the reset voltage is applied immediately before the trial voltage, the most immediate history of the VA is always consistent. This technique largely mitigates the inconsistency from hysteresis because the immediate history is fixed at 10V. It can be seen from Figure 4 that the trial voltages now consistently achieve almost a perfect 20 dB attenuation, even though the variable attenuator was still swept from 0V to 10V and back to 0V.

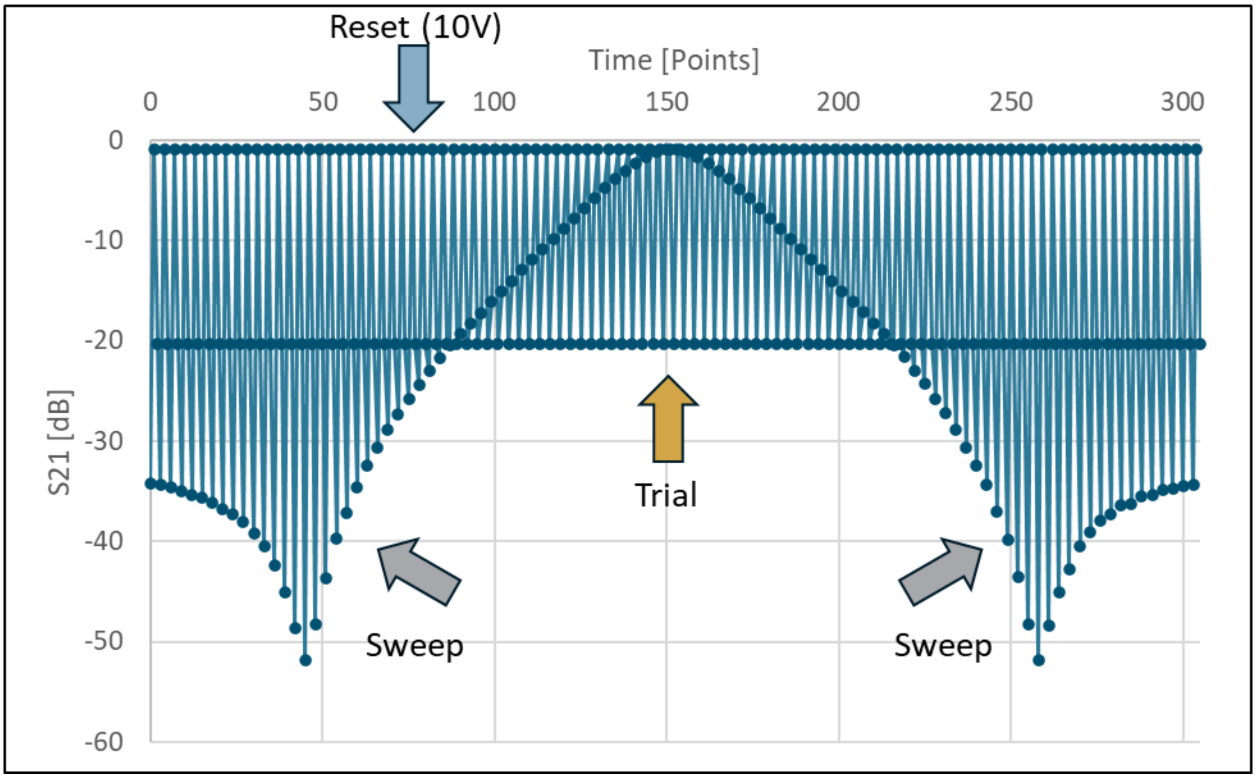

Figure 4: Example of testing repeatability of the variable attenuator at 20 dB using the reset @ 10V reset method

Resetting at 10V, as demonstrated, yields the best repeatability. But it has the disadvantage of requiring additional control logic. A second, more subtle disadvantage is that resetting at 10V will temporarily set the attenuator to nominally zero dB attenuation (i.e., the insertion loss). This might be unacceptable depending on the system requirements.

3.3 Reset @ 0 Volts

The reset @ 0V method is the exact same as the reset @ 10V method except that the VA is reset by applying 0V to the control circuit instead of 10V. The order of operation for the repeatability test is the same:

1. sweep voltage
2. reset voltage (0V)
3. trial voltage

Resetting at 0V also largely mitigates the inconsistency from hysteresis because the history is always fixed at 0V. It can be seen from Figure 5 that the trial voltages now consistently achieve almost a perfect 21 dB attenuation, even though the variable attenuator was still swept from 0V to 10V and back to 0V. Note that the attenuation level achieved at the trial voltage of 0.87V is different between resetting at 10V and 0V (as expected from hysteresis).

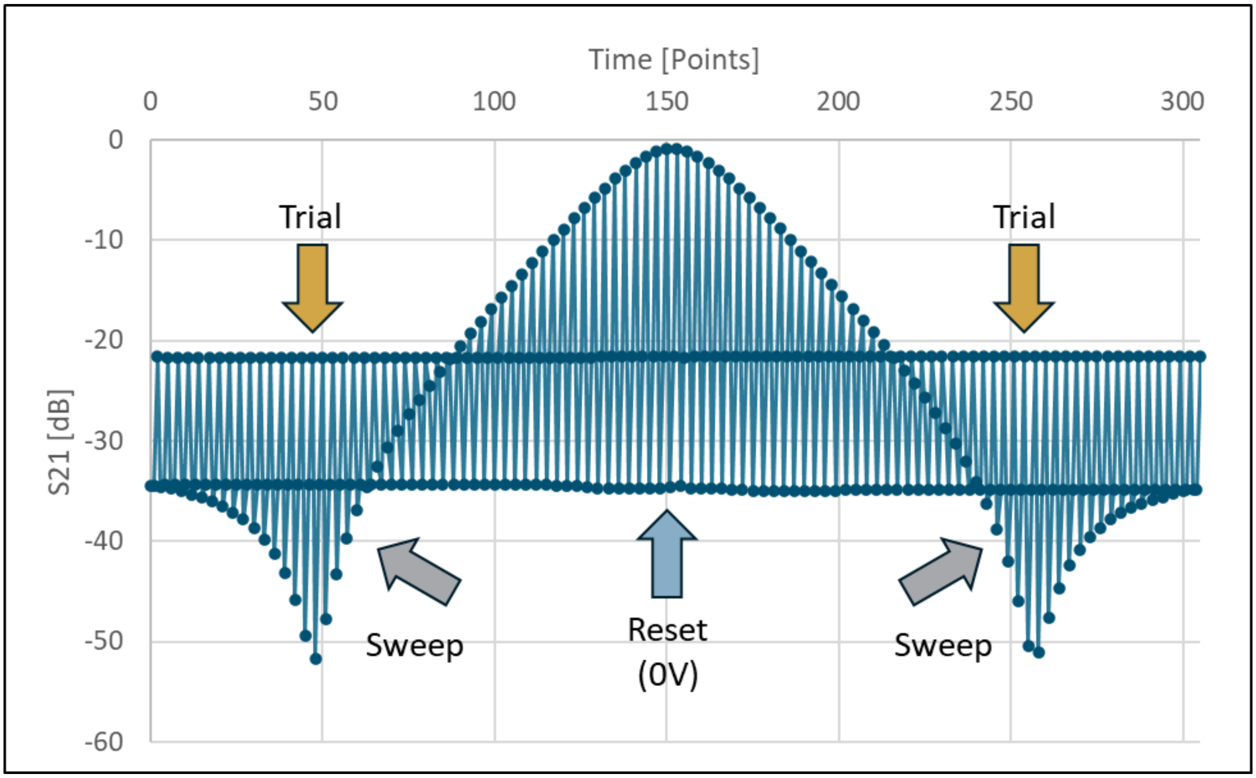

Figure 5: Example of testing repeatability of the variable attenuator at 20 dB using the reset @ 0V reset method

Resetting at 0V, as demonstrated, yields great repeatability. But it has the disadvantage of requiring additional control logic. Though it is not discernible from Figure 4 or Figure 5, it is interesting to note that resetting at 10V yields a slightly better repeatability than resetting at 0V. Resetting at 0V also does not generate risk since the attenuation achieved at 0V is usually about 35 dB, which is the highest level of attenuation specified for the VA.

3.4 Reset @ X Volts

It should be briefly mentioned that technically any arbitrary voltage within the allowable control voltage range can be used to reset the variable attenuator. *However, for the reset to be helpful, it must always be either the highest or lowest voltage used for the given test scenario*. For example, 2V could be used as the reset voltage for the variable attenuator if the control voltage range is constrained to 0-2V *or* 2-10V for this given experiment.

4 CONCLUSION

Though hysteresis is a nuisance when it comes to repeatability for the variable attenuator, adding additional control logic to reset the variable attenuator can drastically improve the repeatability. Though not discussed, the repeatability is dependent on the attenuation level; the variable attenuator decreases in repeatability as attenuation increases. A summary graphic of the repeatability for different reset methods at different levels of attenuation (and at three different frequencies) is provided in Figure 6.

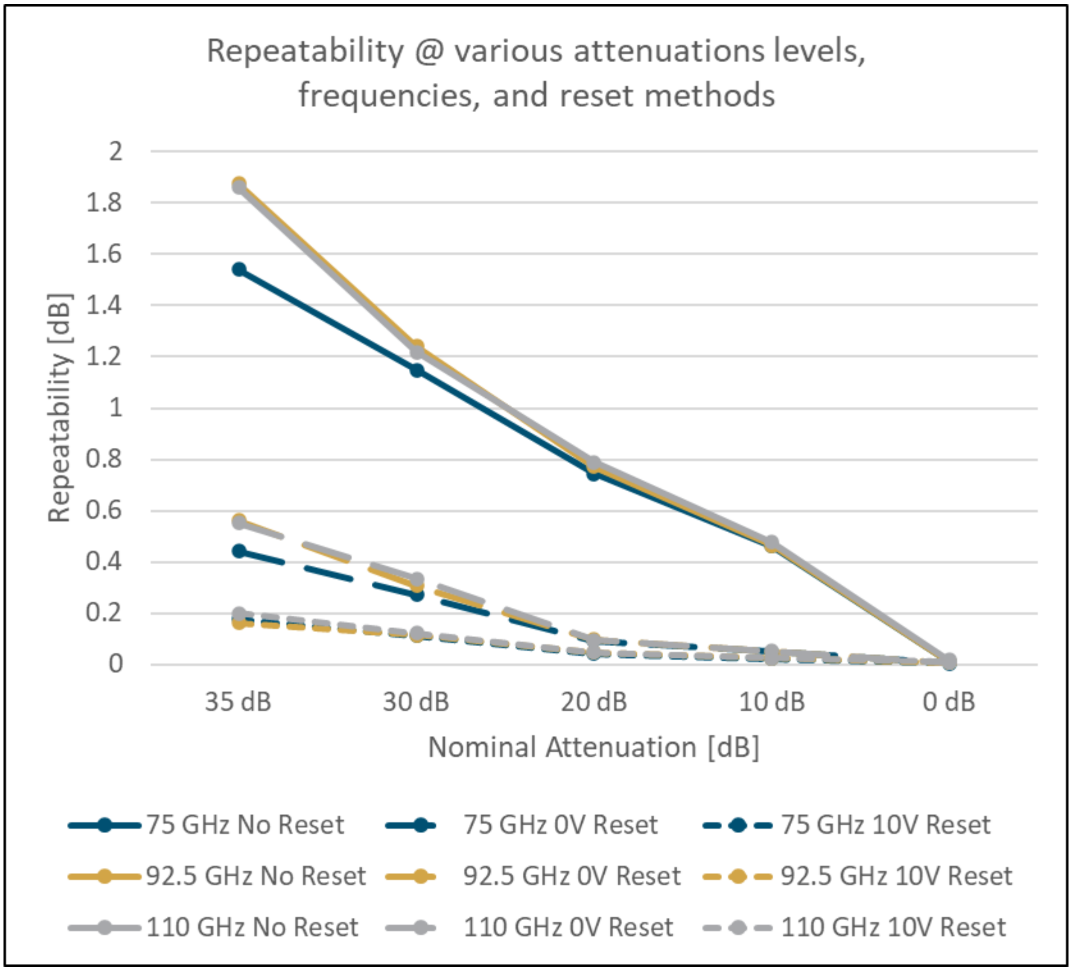

Figure 6: Summary chart showing repeatability of WR-10 variable attenuator at different levels of attenuation for the three reset methods

The advantages and disadvantages of each repeatability method are summarized in Table 1 below.

Table 1: Summary of the advantages and disadvantages of the three reset methods

Reset Method	*Repeatability*	*Requires Additional Control Logic*	*Risk*
No Reset	Worst	No	None
Reset @ 10V	Best	Yes	0 dB attenuation during reset
Reset @ 0V	Good	Yes	None