Application Note

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Gain/Attenuation Settings in WSA5000 408-P, 418 and 427

This application note explains how to control the front-end gain in the ThinkRF WSA5000 408-P/418/427 through three user-selectable settings. It further explains how the settings permit the trade-off between gain, noise and linearity to be performed as required in the user application.

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The ThinkRF WSA5000 408-P/418/427 allows the user to control the front-end gain through three user-selectable settings. The settings permit the trade-off between gain, noise and linearity to be performed as required in the end-user application. Higher gain settings are useful for extracting low-level signals from noise by simultaneously amplifying the signal and reducing the noise floor level on the WSA5000. Conversely, the lowest gain setting allows the WSA5000 to process larger signals without compression or spectral splatter associated with over-driving the front end amplifier(s).

> ⚠️ **Caution:** Although the ability to process larger signal without distortion is enhanced at the lower gain settings, **the input damage level remains fixed at +10 dBm.**

The ThinkRF WSA5000 408-P/418/427 models provide the user with the ability to control two gain stages and a variable attenuator with an allowable range of 0 to 10 dB. **Figure 1** shows the front-end block diagram which displays the position of the two amps and the variable attenuator.
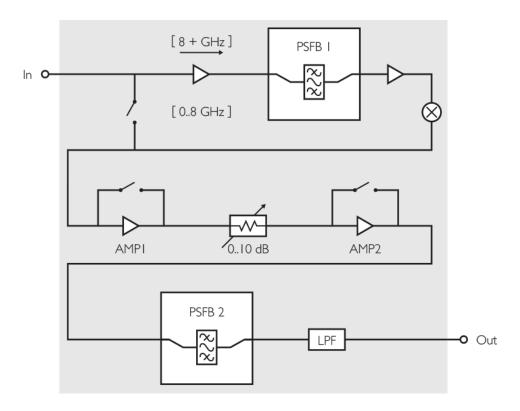

Figure 1: WSA5000 408-P/418/427 Front-End Block Diagram

Bypassing the first and then the second amplifier makes it possible to progressively increase the power handling ability in the front end of the unit. Having both amplifiers turned on provides maximum sensitivity but reduces the ability to process large signals without a loss of fidelity. Table 1 summarizes the available settings for the front end gain.

Note: The combination of **AMP1 =OFF, AMP2=ON** is not a permitted state as it leads to an inferior trade-off between sensitivity and linearity than that which could be achieved with other settings.

When using the WSA for high accuracy measurements, it is worth noting that the unit is calibrated at the factory only for the state where **AMP1=ON, AMP2=ON,** Attenuator=0; all other states are only nominally calibrated by design.

Table 1: Permitted 408-P/418/427 Front-End Gain Control States

AMP1	AMP2	Attenuator [dB]	Comment
ON	ON	0..10	Permitted
ON	OFF	0..10	Permitted
OFF	ON	N/A	Not Permitted
OFF	OFF	0..10	Permitted

To examine the changes in linearity, we refer to **Table 2** and **Table 3** which provide sample data for the various amplifier and switch configurations at 1 GHz and 6 GHz respectively. Notice that at the most sensitive setting, with [AMP1=ON, AMP2=ON, Attenuator=0], the unit has the lowest P1dB and IP3 levels. This behaviour is consistent with having the highest cascaded gain in the receive chain.

Once **AMP2** is turned off as well as **AMP1**, the P1dB and IP3 levels increase significantly. This gives the unit more headroom to process larger signals but will also be accompanied by an increase in the noise floor. At 1 GHz the P1dB in the unit increased by about 9 dB, while at 6 GHz the P1dB increased by about 8 dB. This allows the user to present signals that are 9 dB and 8 dB larger, respectively, while experiencing equal linearity at these levels.

With both **AMP1** and **AMP2** turned off, the P1dB and IP3 levels experience further increases.   In the case of the 1 GHz test, the P1dB increase by about 14 dB and in the case of the 6 GHz test, the P1dB increases by about 12 dB.

In order to realize further increases in linearity, the built-in step attenuator can be increased. On the 408-P (or on the 418 and 427 operating below 8 GHz) increasing the attenuation provides "dB-for-dB" improvements in P1dB when both of the amplifiers are turned off.

In order to illustrate how the P1dB and the IP3 levels of the WSA5000 change at different gain settings, a series of measurements were performed at 1 GHz and at 6 GHz. The results are presented in Table 2 and in Table 3, respectively.   As shown in the tables, the P1dB and the IP3 levels increase as amplifiers are removed from the signal chain (by turning them off).. Also, by modifying the attenuator setting, these values can be further increased beyond 18dBm in the 1 GHz case and beyond 16dB in the 6 GHz case.

Table 2: Typical P1dB and IP3 at 1 GHz

AMP1	AMP2	Attenuator [dB]	P1dB [dBm]	IP3 [dBm]
ON	ON	0	-23	-5
ON	OFF	0	-14	5
OFF	OFF	0	0	19
ON	ON	10	-13	5
ON	OFF	10	-4	14
OFF	OFF	10	10	28.5

These tables provide a useful guide to the typical improvement that can be expected in terms of performance with larger signals being injected into the WSA5000.However, it is important to note that as the gain is reduced and as the level of attenuation is increased, the sensitivity of the unit is reduced. This is because the reduced gain on the signal path will tend to increase the level of the noise floor thus limiting the ability of the unit to detect weaker signals.

Table 3: Typical P1dB and IP3 at 6 GHz

AMP1	AMP2	Attenuator [dB]	P1dB [dBm]	IP3 [dBm]
ON	ON	0	-7.1	-1
ON	OFF	0	0.5	7
OFF	OFF	0	12.8	30
ON	ON	10	3.4	9
ON	OFF	10	6.1	13.5
OFF	OFF	10	>16	29

Gains Settings in Actual Use

By way of example, we can look at the spectrum display of a WSA500-418 at various gain settings. To best illustrate the effects of the gain settings, the unit is excited by two tones as follows:

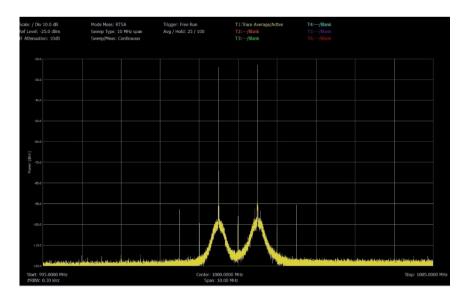|	Frequency	Amplitude
Tone 1	1,000.5 MHz	-38 dBm
Tone 2	999.5 MHz	-38 dBm

*Figure 2:*AMP1=ON, *AMP2*=ON, Attenuator =10dB.

Referring to Figure 2, the two input tones produce an intermodulation product at 989.5MHz with an amplitude of -98.4dBm. This product is caused by a nonlinear process that is inherent to radio frequency amplifiers and frequency mixers which is more pronounced as the signal level increases.

In order to examine to effect of reducing the gain in the signal chain, AMP2 is subsequently turned OFF. The effect of this change can be examined in Figure 3.
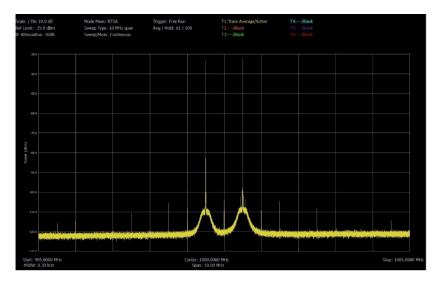

Figure 3: AMP1=ON, AMP2=OFF, Attenuator =10dB.

Once AMP2 is turned OFF, the level of the tones drops by about 9 dB   What is interesting though is that the level of the intermodulation product at 989.5 MHz drops by 12 dB. Hence the intermodulation product is decreasing more rapidly than the desired signals.

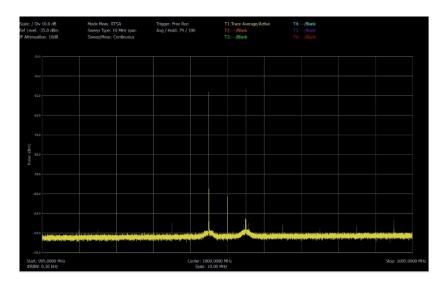To further explore the effect of gain reduction, AMP1 is turned OFF.

Figure 4: AMP1=OFF, AMP2=OFF, Attenuator =10dB.

With both amplifiers now turned off, the input signal level is now -53.1 dBm. In other words, the displayed level of the input signal has dropped by 14.3 dB. The intermodulation product at 989.5MHz is now displayed at -119.2 dBm, representing a reduction of 8.9 dB. It is worthwhile to note here that that desired signal dropped by a larger amount than the intermodulation product (14.4 dB vs 8.9 dB) since this is an indication that we have reached the point of diminishing returns with regards to the gain/linearity trade-off. Turning off AMP1 may have been of benefit for larger signals, but in this case theyre was no benefit accrued by turning off AMP1. Therefore the best compromise for the signal level being presented is AMP1=ON, AMP2=OFF.

Gain Control Command

The following SCPI commands are for controlling the ThinkRF WSA5000 Wireless Signal Analyzer and are an excerpt from the *ThinkRF WSA5000 Programmer's Guide*. Please refer to the *ThinkRF WSA5000 Programmer's Guide* for more information.

:INPut:GAIN

This command sets or queries the input gain stage for a WSA. The number of gain stages is dependent on the models as listed below. Any out of range index will result in an Execution Error response. Contact ThinkRF's Support for further details and the gain ranges of each stage.

Syntax	:INPut:GAIN <Index> <Boolean>
	:INPut:GAIN? <Index>
Parameter	<Integer> <ON | OFF | 1 | 0>
Input Data Type	<Integer> <Character | Integer>
Allowable Values	Index: Varies depending on the product model. For example:
	- WSA5000-408: 1
	- WSA5000-408-P, 418, 427 and their variants: 1, 2, 3
	Boolean: ON | OFF | 1 | 0
Query Response	1 | 0
Output Data Type	Integer
*RST State	1 for all available stages
Examples	`:INPUT:GAIN 2 ON`
	`:INP:GAIN? 1`
	`:INP:GAIN 1 0`

Note: The reference level context information is **only valid** when all the gain stages are enabled for WSA5000-408-P, 418, 427 and their variants.

:INPut:ATTenuator:VARiable

This command sets or queries the variable attenuation of the WSA5000's RFE.

Note: This command applies to WSA5000-408-P, -418, -427, and their variants only. For WSA5000 -2XX, -3XX, -408 and some of their variants, see :INPut:ATTenuator command instead in the *ThinkRF WSA5000 Programmer's Guide*.

Syntax	:INPut:ATTenuator:VARiable <integer [dB]> :INPut:ATTenuator?
Parameter	<Attenuation [dB]>
Input Data Type	Integer, optional character unit
Allowable Values	0 – 25 dB
Query Response	1 | 0
Output Data Type	<integer>
*RST State	0
Examples	`:INP:ATT:VAR 5` `:INPUT:ATT:VAR?`

This command is not available for sweep mode. The desired attenuation should be set before sweep mode starts.

Contact us for more information

Please contact us via email at *sales@thinkrf.com* or via phone at +1.613.369.5104.

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