Application Note

74-0047-180205

Gain/Attenuation Settings for R5500-418 and -427

This application note explains how to control the wideband's front-end gain in the -418 and -427 models of ThinkRF R5500 Real-Time Spectrum Analyzer through three user-selectable gain settings and a variable attenuation. It further explains how the settings permit the trade-off between gain, noise and linearity to be performed as required in the user's application.

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The ThinkRF R5500 Real-Time Spectrum Analyzer (RTSA) 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 R5500. Conversely, the lowest gain setting allows the R5500 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 R5500-418 and -427 models provide the user with the ability to control two gain stages and a variable attenuator with allowable values of 0, 10, 20 or 30 dB. **Figure 1** shows the front-end block diagram, which displays the position of the two amps and the variable attenuator.

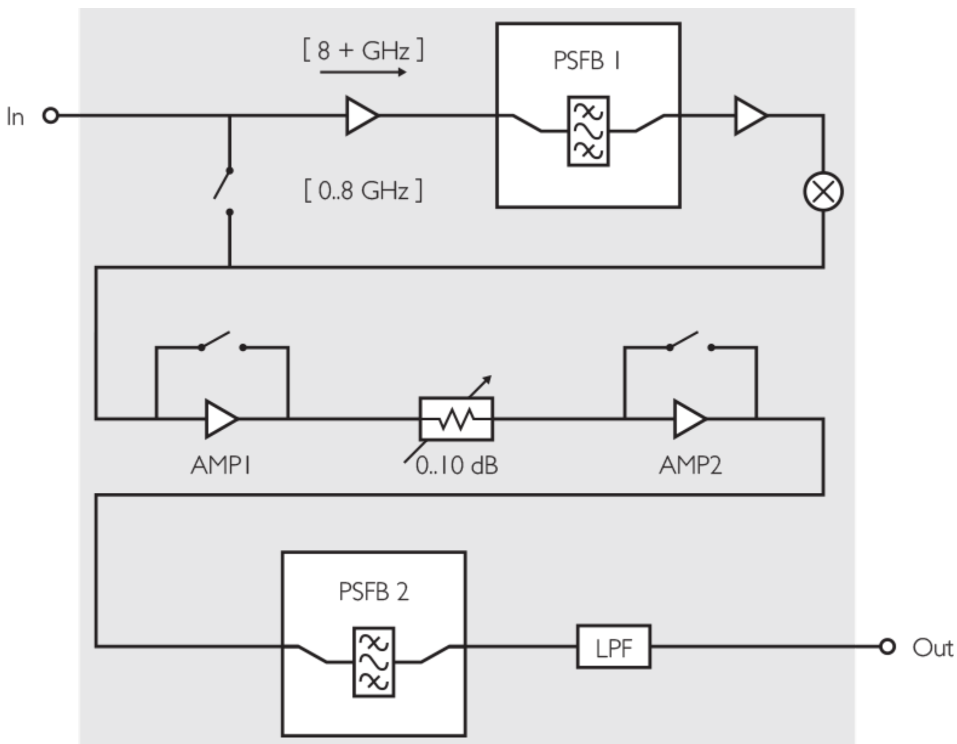

Figure 1: R5500 Real-Time Spectrum Analyzer Front-End Block Diagram

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.

Table 1: Permitted R5500-418/-427 Front-End Gain Control States and Their Performance

AMP1	AMP2	Attenuator [dB]	Control	Performance
ON	ON	0..10	Permitted	Best DANL
ON	OFF	0..10	Permitted	Good DANL and Saturation Level
OFF	ON	N/A	Not Permitted	Not Optimal
OFF	OFF	0..10	Permitted	High Saturation Level

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 RTSA 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**, and **Attenuator=0**; all other states are only nominally calibrated by design.

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, and **Attenuator**=0, the unit has the lowest P1dB (1 dB compression point) and IP3 (third order intercept point) levels. This behaviour is consistent with having the highest cascaded gain in the receiver chain.

Once **AMP2** is turned off while **AMP1** is on, 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, for instance, 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. When 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 R5500 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 **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 variable 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

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

These example tables provide a useful guide to the typical improvement that can be expected in terms of performance with larger signals being injected into the R5500. 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.

Gain Settings in Actual Use

By way of example, we can look at the spectrum display of a R5500-418 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

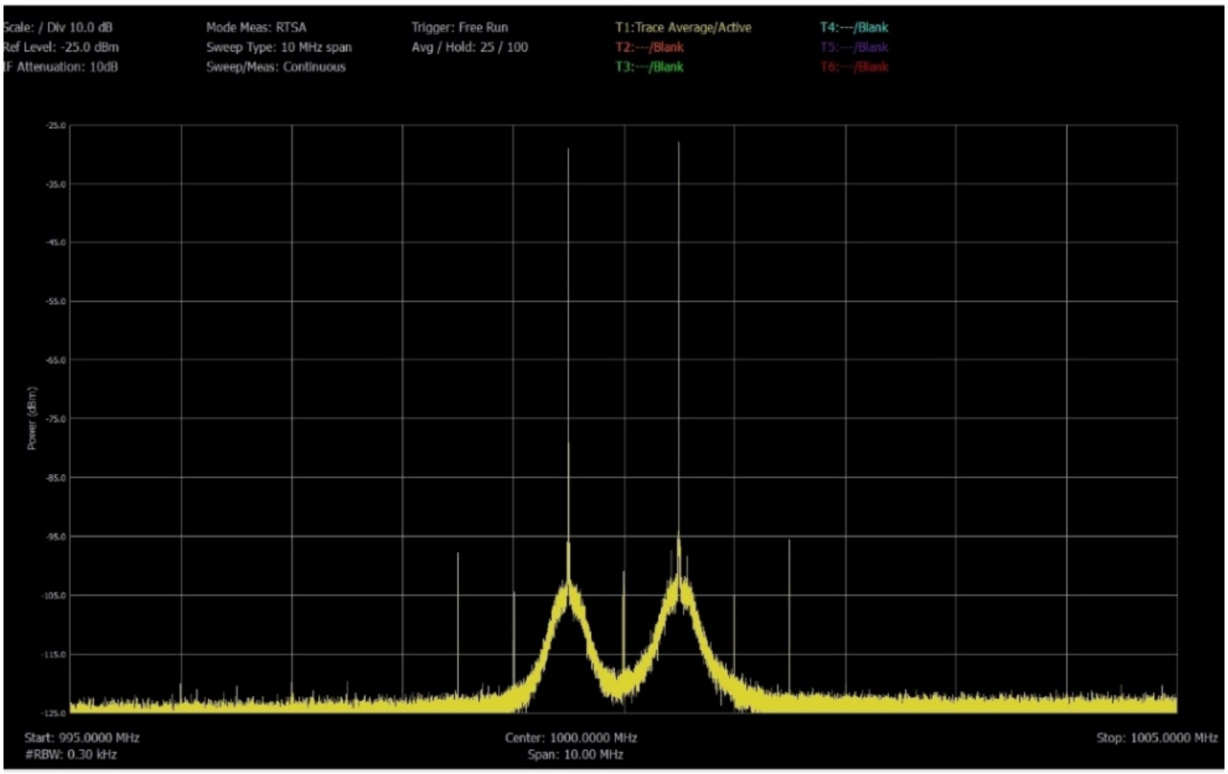

Figure 2: AMP1=ON, AMP2=ON, Attenuator=10dB

Referring to **Figure 2**, the two input tones produce an intermodulation product at 989.5 MHz with an amplitude of -98.4 dBm. 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**.

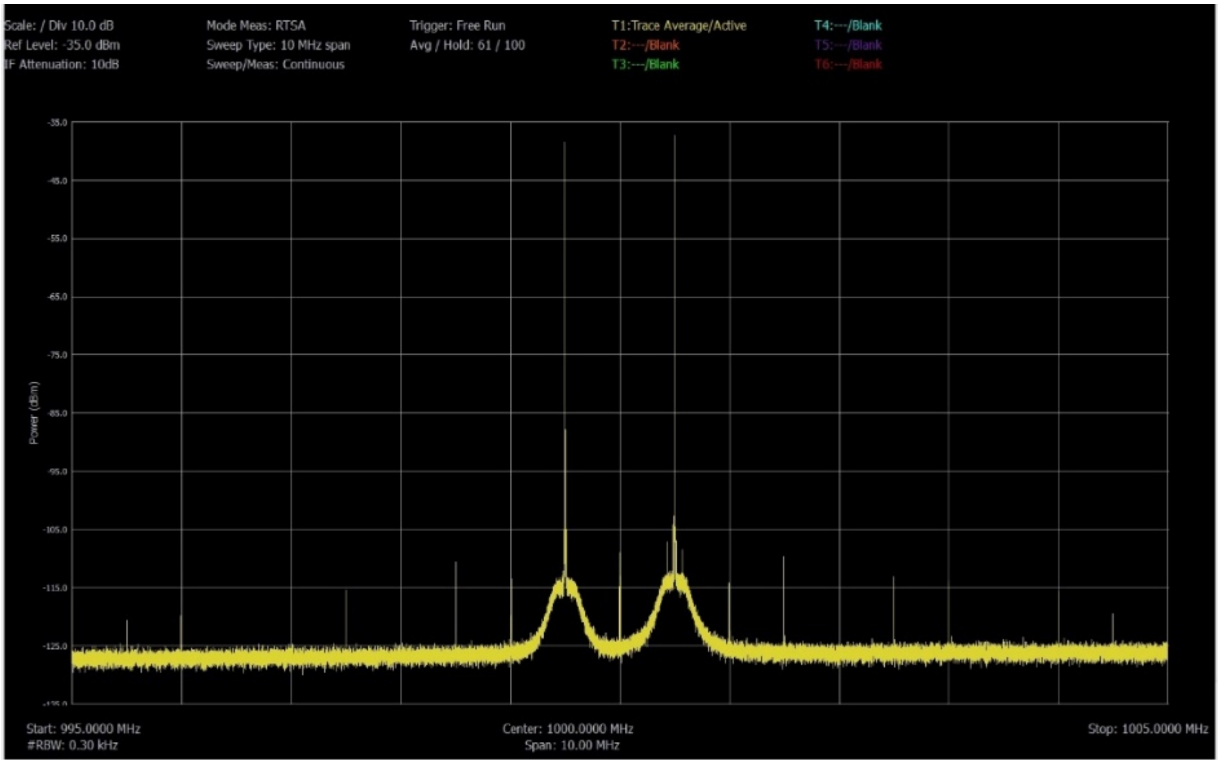

Figure 3: AMP1=ON, AMP2=OFF, Attenuator=10dB.

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. With both amplifiers now turned off, the input signal level is now -53.1 dBm, as shown in **Figure 4**.

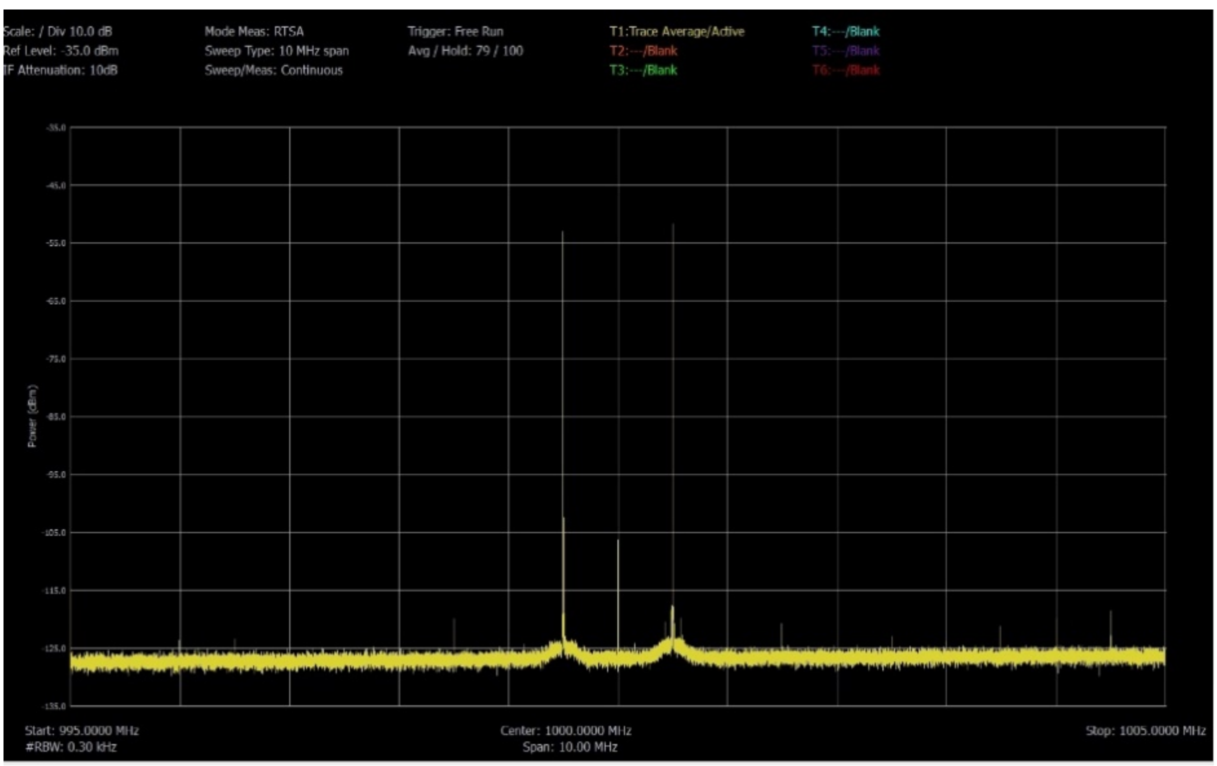

Figure 4: AMP1=OFF, AMP2=OFF, Attenuator=10dB.

In other words, the displayed level of the input signal has dropped by 14.3 dB. The intermodulation product at 989.5 MHz is now displayed at -119.2 dBm, representing a reduction of 8.9 dB. It is worthwhile to note here that the 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, there is 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 R5500's gain settings. Please refer to the *ThinkRF R5500 Programmer's Guide* for more information.

:INPut:GAIN

This command sets or queries the input gain stage for a RTSA. 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.

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. - R5500-408 & its variant: No controllable gain stage - R5500-418, -427 and their variants: 1, 2 **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 R5500-418, -427 and their variants.

:INPut:ATTenuator:VARiable

This command sets or queries the variable attenuation of the RFE of R5500-418, -427 and their variants.

Syntax	:INPut:ATTenuator:VARiable <integer [dB]> :INPut:ATTenuator?
Parameter	0 | 10 | 20 | 30 [dB]
Input Data Type	Integer, optional character unit
Query Response	0 | 10 | 20 | 30
Output Data Type	Integer
*RST State	30
Examples	`:INP:ATT:VAR 0` `:INPUT:ATT:VAR?`

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