VORSIS Application Note

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AP2000 and FM2000
GUI Software Version 1.6.0 and above

Understanding the Vorsis SST™
“Sweet Spot Technology”™

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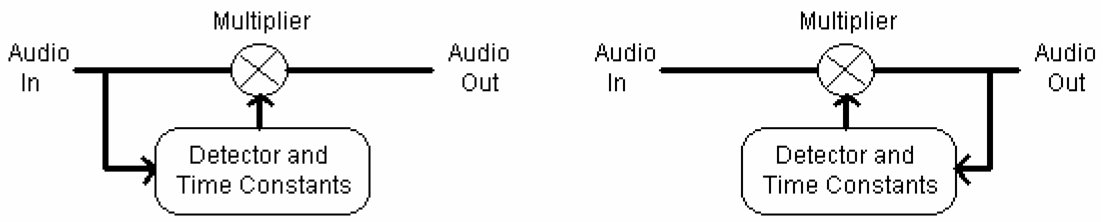
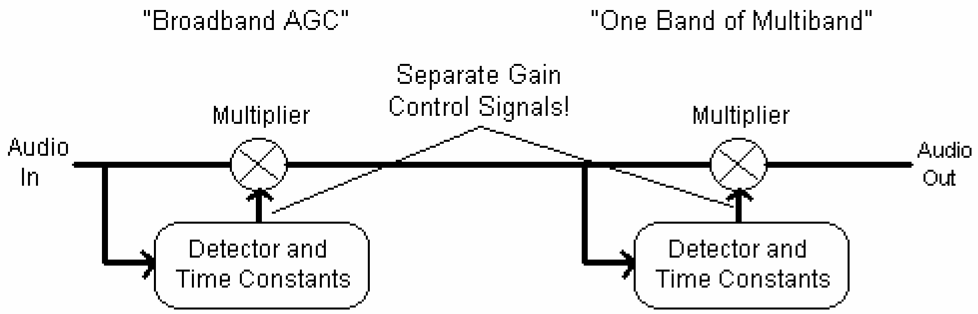
Background

In audio processor implementations where a multiband AGC or compressor is preceded by a broadband compressor serving as a pre-multiband gain leveler, the control signal for the broadband stage has been derived from either its input signal or its output signal. These are known as feed-forward and feedback topologies, respectively and are implemented as shown in the graphic below.

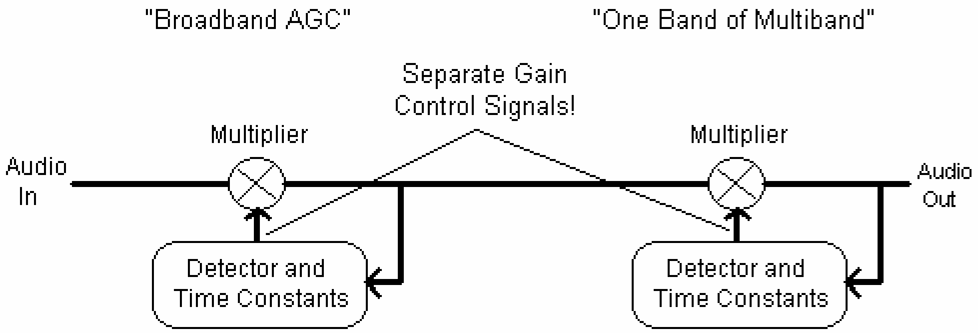


Feedforward Topology **Feedback Topology**

Although both schemes are common, one challenge is that as the next graphic shows, the control signals of the broadband and multiband compressors are completely separate entities.



Feedforward Topologies Cascaded



Feedback Topologies Cascaded

It must be obvious now that even if the broadband AGC and the multiband AGC are living in the same hardware because their control signals are completely independent <u>one does not know and cannot know what the other is doing</u>. This makes it unlikely that the multiband section will always operate as the operator wants it to as the character of the incoming program changes. This is one reason why multiband audio processors have varying spectral balance and spectral density on the air.

Those 'old-tech' solutions with their separate broadband and multiband topologies must make the assumption that the multiband section doesn't need to have carefully controlled operating conditions in order to provide the user-desired long-term spectral mix - even though this assumption is wrong...

Is there an obvious solution to this dilemma? Can we simply create a control loop around the multiband section by taking the broadband stage's control sample from the output of the multiband section? Wouldn't this fix everything that's wrong with the old way of doing things?

Unfortunately the answer is "no".

While it might seem a simple and even a workable solution, the idea is fraught with control loop instabilities because of the multiplicity of time constants and control loop gains involved. The overall control loop thus formed is simply <u>not</u> stable and can <u>never</u> be (we know – we tried it!).

The instability exists because there is no defined "stable" operating point. Therefore the control loops will 'hunt' continuously causing the gains to wander up and down as one control loop tries in vain to correct for what it thinks are the errors of the other.

The basic idea behind using a broadband AGC before a multiband processor in the first place is to pre-process the incoming audio levels so that the multiband AGC is always operating in its "*Sweet Spot" - whatever that might need to be.* Unfortunately the old ways of doing things don't really do a very good job of it.

How this goal is accomplished without the inherent instabilities of multiple control loops is the secret behind our latest creation - the Vorsis *SST*^{TM}.

Sweet Spot Technology™ (SST™) Overview

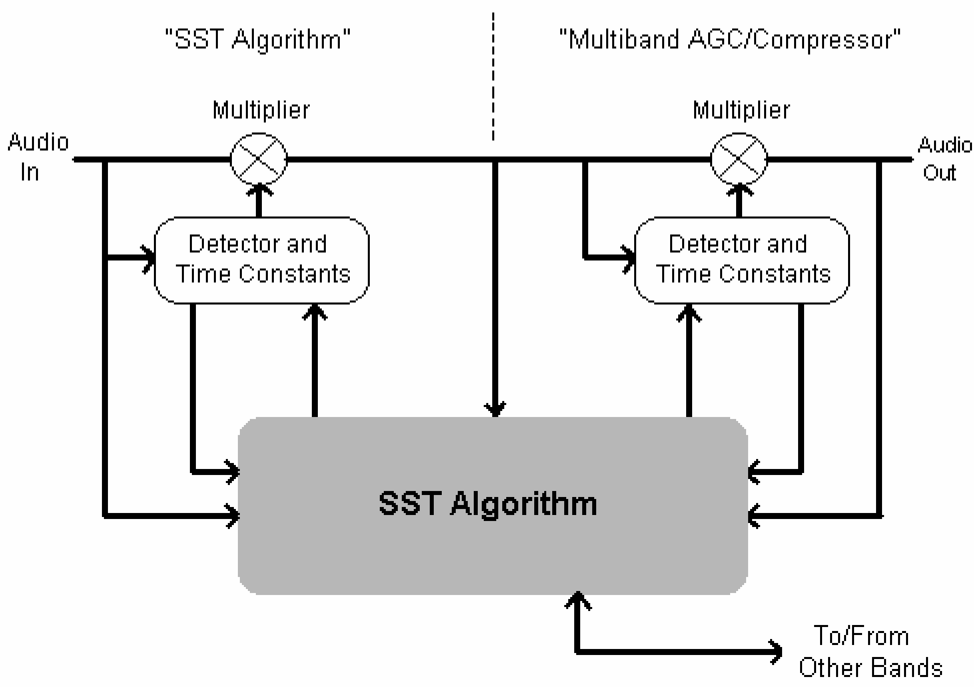
The Vorsis SST™ algorithm addresses the multiband AGC behavior challenge by:

- Computing the outputs of the individual bands on a 'spectral' basis;

- Creating a set of *predictive, forward-looking* control signals that anticipate what needs to be done in order to maintain a *historically-based target* of the user's desired spectral mix;

- Applying the resulting control signals to various parts of the multiband AGC algorithm in order to modify its behavior in real time to create exactly the sound that the end user desires.

SST™ accomplishes this task by utilizing frequency-domain, program-dependent control signals generated within the multiband section, "learning" how the operator has set the controls and what is happening with program material.



A basic diagram of the SST™ is shown above - for clarity only one of the multiband bands is shown. Of particular note is the multiplicity of input samples that the algorithm needs in order to calculate the necessary control signals.

SST™ Advantages

There are three primary advantages to the *SST*™ technology:

1. The individual bands within a multiband section may be operated with *any* desired compression ratio. This allows the ‘sound’ of the individual bands to be tuned without needing to consider how such tuning might upset the final multiband mix with certain program material;

2. The individual multiband bands may be operated with vastly different time constants enjoying the same kind of tuning freedom outlined above;

3. Once one or more of the individual band outputs cause the target spectral mix criteria to be met, the other bands will not unnecessarily *increase* or *decrease* their gains and/or output levels.

The topology of the *SST*™ algorithm is more ‘intelligent’ than any other dynamic gain control implementation because it ‘knows’ what the *desired* overall spectral mix of the multiband section should be. The algorithm then works as a watchdog to maintain the user-set spectral mix under varying program conditions.

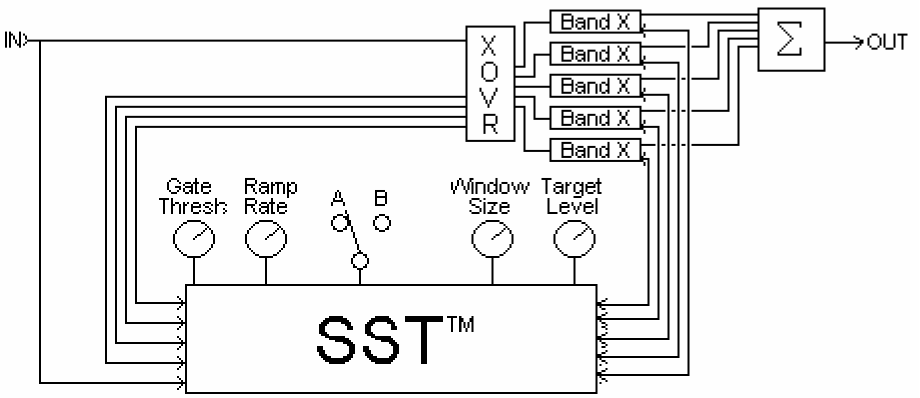
In previous topologies each of the separate sections of the gain control circuitry operated essentially on its own. That is, each had its own set of thresholds and time constants, and other than adjacent band leakage due to the slope of the crossovers one band really didn’t know what was going on in the others.

What is common to all of those previous technologies is that whatever stage *follows* the multiband section, it is charged with handling its own tasks (such as final peak limiting) as well as for “cleaning up” the mistakes of the previous section. This is why unexpected and undesirable audible artifacts creep into the older ways of doing things - artifacts that cannot simply be “tuned out” by making static adjustments to the multiband AGC or the broad band AGC that precedes it.

The *SST*™ algorithm fixes this!

Overall SST™ Block Diagram

Below is a simplified block diagram of the SST™ algorithm as it integrates into the overall multiband system.



SST™ Block Diagram

There are five operating controls associated with the SST™ to enable fine tuning of the algorithm to suit an extremely wide range of programming applications.

Gate Threshold – adjusts the audio threshold below which SST™ operation ceases. SST™ control signals will remain static until *input* audio returns that is *greater* than the setting of the SST™ Gate Threshold. Under normal operating conditions the setting of the SST™ Gate control will be somewhere between -36dBFS and -54dBFS.

Ramp Rate – adjusts the rate at which SST™-initiated spectral corrections are made. This control has an overall effect on both the long and medium-term density of the audio signal. Under normal operating conditions the Ramp Rate control will be found somewhere between 3.5 seconds and 7.0 seconds.

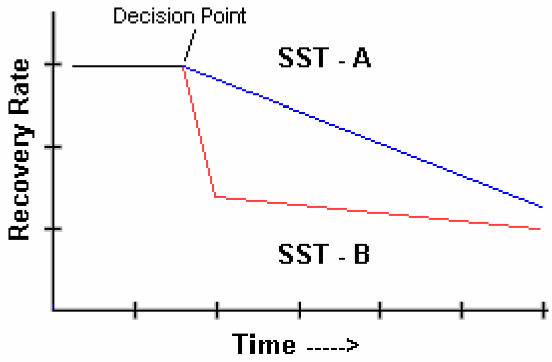
Window Size – adjusts the size of the allowable output level window *inside* which no SST™ corrections take place. The spectral levels will only undergo correction when they fall *outside* the setting of the SST™ Window Size control, noting that the window size is one-sided – it adjusts the *minimum* but *not* the maximum output level variation allowed. Please see the Window Size discussion on Page 11 for clarification noting that the usual operating range of the Window Size control will be between 3.0dB and 7.5dB.

Drive – sets a reference level within the SST™ algorithm which it then uses to maintain an artistically consistent behavior from the multiband section ensuring the best on-air consistency and highest possible audio quality over the widest range of program material. Normal Drive control settings will usually be found between +24dB and +36dB. Lower settings cause the SST™ to decrease its activity while higher settings increase it.

SST-A and SST-B – this is a new control as of software version 1.6.x and allows the user to tweak the SST™ ramp trajectory as it makes real-time operating adjustments to the five band AGC.

SST–A utilizes a linear ramp between the decision point and the next computed target spectral gain. SST-B utilizes a much faster initial ramp followed by a slower one, completing the target sound retuning of the multiband AGC much quicker than SST-A can.

A comparison of the two behaviors is shown below.



Ramp Comparison of SST-A vs SST-B

The difference in ‘sound’ between the SST-A and SST-B settings is subtle with some program material but nonetheless important when the dynamics of the station’s sound are taken into consideration.

SST-A is more subtle in its influence on the spectral behavior of the multiband section while SST-B is the more aggressive setting.

Format-wise, an A/C format might prefer the SST-A setting while a Hot CHR might prefer the behavior of SST-B instead.

Spectral Regulation

One of the ways to demonstrate the effectiveness of the SST™ technology is to compare its performance to that of a popular setup – a broadband AGC commonly found installed in front of a multiband processing structure.

Following is a pair of graphics of such a comparison. The two data curves represent the variation in RMS energy at the multiband output when:

(1) The conventional broadband AGC* placed before our five-band AGC/Compressor and then;

(2) The conventional broadband AGC replaced by the SST™**.

Our five-band AGC/Compressor (which uses a feed-forward technology) was set up to utilize typical time constants and ratios and the settings were adjusted to be the same across all five bands as follows:

Compressor Attack = 10mS
Compressor Release = 300mS
AGC Attack = 400mS
AGC Release = 5 Sec
Compression Ratio = 4:1

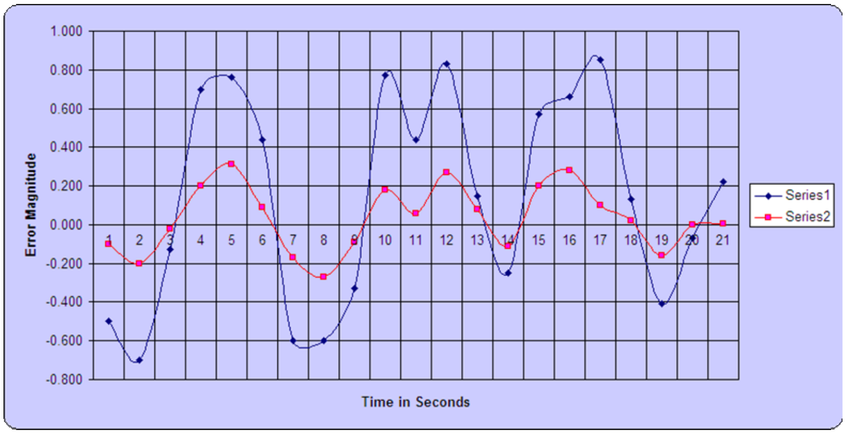
For these measurements the SST™ "Window Size" and "Ramp Rate" controls were set to 6dB and 3.00 seconds respectively and the SST-B type recovery ramp was utilized. The program content was a 60 second musical segment of "Take It to the Limit" by the Eagles (scale=3 seconds/div).

* Aphex Systems Ltd. Model 320A Compellor.

** The SST does not go *before or after* the multiband structure – it is actually an integral and *internal* part of the multiband algorithm itself!

Spectral Regulation using a 6dB Window Size

The data labeled “Series 1” <blue line> in the plot below represents spectral regulation at the output of our five-band AGC/Compressor when the popular feedback type AGC* is placed prior to our five band AGC/Compressor.



The data labeled “Series 2” <red line> is a plot of the spectral regulation for the same five band algorithm, but this time its behavior is being governed by the SST™ algorithm operating with the controls set as described previously.

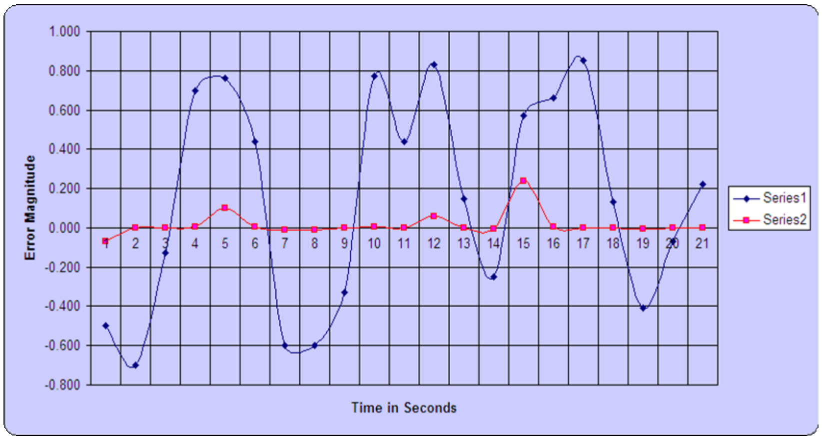
As the graphic shows, the spectral regulation at the output of our five band compressor is approximately four times *better* when the SST™ is employed as compared to having the audio pre-processed with the popular broadband AGC* that was mentioned previously.

The SST™ affords a *significant* improvement in audio level management, performing this function *without* destroying the short term program elements that give the program its intended musical character.

One thing that is interesting about how the SST™ behaves is observed when it is handling very highly processed programming. The SST™ reads this energy, knows what its peak to average ratio is, and causes a *decrease* in the processing action contributed by the five band AGC/Compressor. The end result is that the SST™ *prevents* additional and unnecessary processing of program material that is already highly processed and simply doesn’t require more.

Spectral Regulation with a 2dB Window Size

Spectral regulation can be further tightened if desired as the next figure shows. For this measurement we've set the "Window Size" control to its lowest setting; 2.0dB. Note to self: this is an extreme setting!



The improvement in regulation is now roughly 20dB or tenfold over the popular broadband AGC, an even more impressive improvement than the 6dB Window Size example.

A Window Size setting of 2dB is usually not desirable for the majority of program formats because it removes medium term dynamics that are *needed* for material to sound good to the ear. The exercise simply demonstrates how tight the spectral regulation *can* be with the SST® algorithm <u>if</u> such regulation is the goal.

This reminds us… Beware of unintentionally creating fatigue factors when adjusting an audio processing's short term density. Very high average levels, while quite loud, tend to become tiring to the ear after a short period of time. Our belief is that the 'washing out' of short term dynamics is one of the causes of listener fatigue. Mighty impressive loudness does little to boost the station's ratings when the audio is so busy and fatiguing that no one can listen to the station anymore!

Creating a wall of sound is <u>easy</u> – any processor can do that …

With today's advanced audio processing technology
FM radio stations have no reason to not sound good.

Give the audio a rest sometimes!

The SST™ in Operation

The setting of the “Window Size” control is not critical and for most program formats the correct setting will be somewhere between 5.0 dB and 8.0 dB.

The improved spectral regulation when SST™ is in circuit is because:

- Compression ratios are multiplied dynamically according to program content requirements and because of the measurement behavior of the SST™ they can be made high without sounding ‘tight’.

- The multiband stages have been intimately ‘married’ by the SST™ algorithm because its various data inputs let it “know” about various inputs to the SST™. SST™ knows about the input levels to the individual bands, each band’s output level, and the ‘dynamics difference attributes’ of each band’s gain control signal as it is managing program level dynamics in real time.

As in conventional multiband audio processors, the individual outputs of the multiband section are supposed to represent the *user-set* target spectral mix. It is important that this spectral mix always be what the user has chosen because otherwise the audio processor is simply not doing its job!

Ramp Rate Control

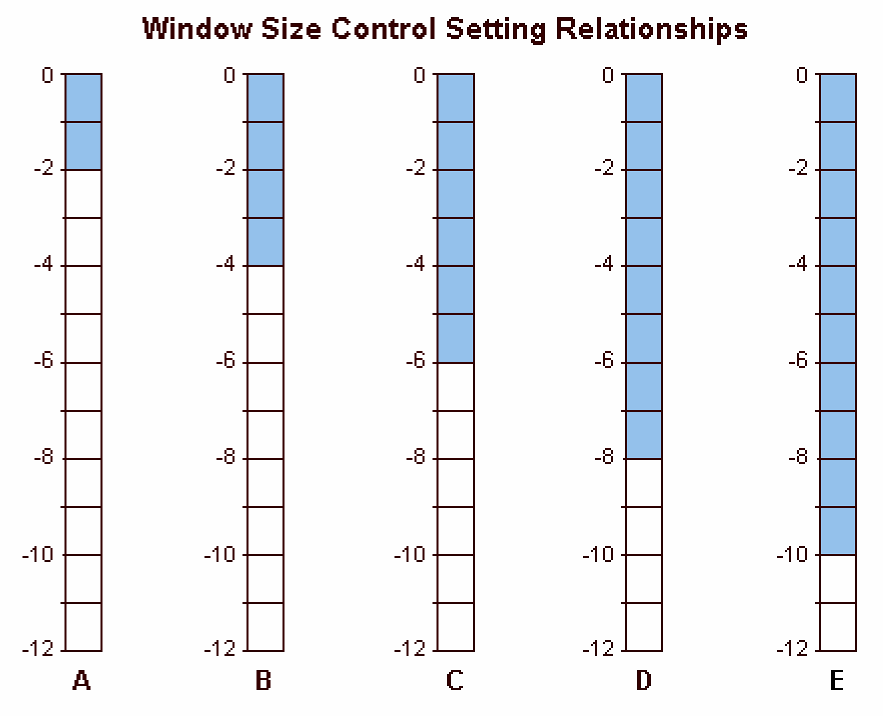
The “Ramp Rate” control adjusts the speed at which the SST™ algorithm calculates and then corrects spectral balance changes within the multiband stage. There is an intimate relationship between the measurement and the adjustment schemes within the algorithm and the Ramp Rate control will affect the rapidity of correction only when the spectral density balance tries to wander outside that set by the Window Size control.

Note that the Ramp Rate control has only a minimal effect on the initial recovery ramp of the SST-B algorithm while it is modifying the multiband AGC’s operating characteristics as program energy falls.

Window Size Control

When the customer-set spectral balance tries to wander outside the blue shaded areas shown in the figure below the SST™ will take corrective measures to keep it within the shaded area. The following figure helps to visualize the behavior of the Window Size Control at some of its various settings.

The area formed by the shaded squares in each column below represents the "sloppiness" of spectral regulation that is permitted to occur and is governed by the setting of the Window Size control.



Interpreting Window Size

Column A – The Window Size control has been set to "2dB" allowing a +0 /-2dB regulation error before correction is enabled. This is a very 'tight' setting and may not sound good with some types of programming.

Column B – The Window Size control has been set to "4dB" allowing a +0 /-4dB regulation error before correction is enabled. This is the minimum setting that we feel is useful for the majority of program material. The regulation will be tight but not overly so and program dynamics will sound 'right' on a wide variety of programming.

Column C – The Window Size control has been set to “6dB” allowing a +0 /-6dB regulation before correction is enabled. This is our favorite setting of the Window Size control. There is enough ‘slop’ so that the SST™ isn’t always working on every little nuance, but is still tight enough to provide excellent medium to long-term regulation of the behavior of the multiband AGC section.

Column D – The Window Size control has been set to “8dB” allowing a +0 /- 8dB regulation before correction is enabled. This is probably the highest setting of the SST™ that is useful for the majority of ‘energetic’ programming.

Column E – The Window Size control has been set to “10dB” which allows a +0 /- 10dB spectral regulation before correction is enabled. At this setting the SST™ is doing more of a general watchdog service for the multiband AGC instead of intimately working with it to maintain spectral balance in the medium term. This kind of setting is useful for program formats that require very loose gain control in order for the programming to not sound unnaturally processed. Such formats might include Jazz and Classical.

The adjustment range of each SST™ control has been carefully optimized to ensure that the algorithm always behaves predictably when controls are adjusted over their ranges. The extremes of all SST™ controls have been carefully windowed to ensure that the algorithm cannot get confused, stuck, or otherwise misbehave by setting its controls to ‘odd’ or ‘unreasonable’ settings.

Summary

It is important to keep in mind that the graphic on Page 12 shows that the area represented by the *shaded* blocks is the <u>*average*</u>*, not the peak,* spectral error that is allowed to exist without being corrected. Said another way, if the average user-set *spectral balance* is <u>*within*</u> the shaded area it will <u>*not*</u> be modified.

As far as levels are concerned, the *average* audio level is not allowed to wander *above* the fixed “0dB” upper boundary of the Window. This behavior was designed into the SS™T primarily to better manage the dynamic range within the five-band AGC.

This is an excellent time to mention that because of the type and shape of gain trajectories involved in the SST™ algorithm, as well as when and how correction adjustments are made, the SST™ is a 'distortionless' process. That is, its operation <u>does not</u> generate harmonic *or* intermodulation products. In fact, its operation in concert with the multiband AGC actually serves to *reduce* processing distortion, not increase it!

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