VORSIS Application Note

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The Vorsis ITU-R BS.412-7 FM Multiplex Power Controller

AP2000/FM2000 – v1.62 and later
FM-10HD – v1.40 and later
VP8 – v1.91 and later

March 2009 – Jeff Keith

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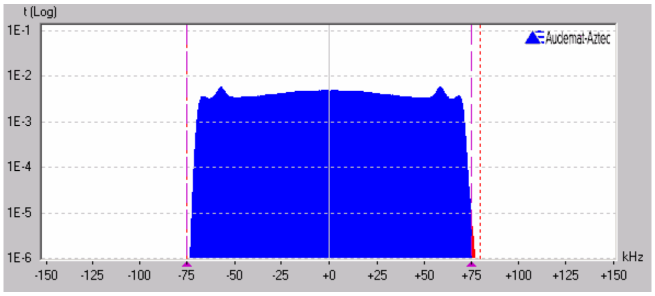
Background

Certain countries in Europe employ a formal broadcasting regulation intended to curtail FM station loudness, a regulation made necessary to mitigate adjacent channel interference due to a narrow FM channel spacing and short station-to-station geographical spacing.

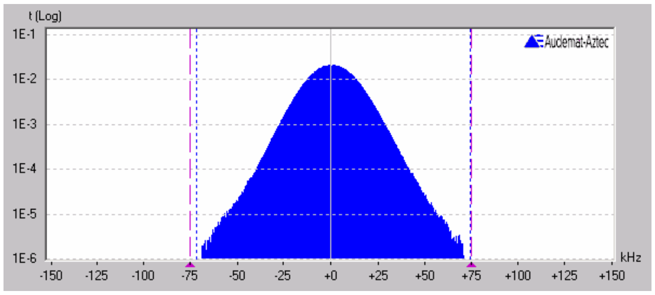
Because of market competition, asking stations to ‘voluntarily’ reduce their modulation density i.e., loudness, had little chance of success. Therefore regulating agencies in those countries created a formal standard that FM stations must adhere to known as the ITU-R BS.412-7 Multiplex Power regulation.

Adjacent Channel Interference

Regulatory intervention of FM loudness was necessary because the more a station’s broadcast channel stays ‘filled up’ with dense program modulation the more likely that interference to adjacent stations will result. The graphics below compare a very competitively processed FM station (top) with another one employing the same processor and settings but with its BS-412 MPX Power Controller enabled (bottom).



Vorsis AP2000 - “RadioActive” Factory Preset
BS-412 MPX Power Controller “Off”



Vorsis AP2000 - “RadioActive” Factory Preset
BS-412 MPX Power Controller “On”

(the shape of the ‘horns’ in the top graphic is caused by our peak control mechanism and the presence of the 19kHz stereo pilot – all FM processors have unique ‘signature horns’ when analyzed this way – with the pilot off the horns are located out at the extremes of FM deviation)

As the preceding graphics show, the average RF spectrum that an FM station "consumes" (ignoring for a moment that FM sidebands theoretically go onto infinity) is related to the *density* of its on-air processing. Therefore the more competitive a station's processing is, the more its assigned FM channel stays 'filled up' and the more likely it might interfere with neighbors on the dial.

Measuring Multiplex Power

In order to measure Multiplex (MPX) Power according to the ITU-R BS.412-7 standard special equipment is required (we prefer the Audemat DFMA02). This equipment takes into account all of the audio power contained in the 0 to 100 kHz audio baseband spectrum, including subcarriers. Each of the signals in the baseband must be demodulated, squared (to measure its "power"), summed to the other squared signals, and the resulting signal applied to an integration interval which 'accumulates' over time to determine the total amount of audio power generated by the audio processor in the MPX domain.

Controlling Multiplex Power

The BS.412-7 measurement algorithm utilizes a rolling sixty second integration period and the MPX Power Controller algorithm in the audio processor *could* be made to be exactly like the BS.412-7 measurement scheme, but…

Designing the MPX Power control algorithm to precisely mimic the measurement scheme might seem an obvious solution to creating strict adherence to the "0dB Limit", but it also causes unavoidable and objectionable audio level artifacts. We've noted such artifacts when listening to the MPX Power Controllers in other products even though they did an *exemplary* job of keeping the measured MPX power pegged at the legal limit. Why?

Those MPX Power Controllers have, in effect, added yet another layer of audio processing that continuously chases the MPX Power levels (loudness) up and down to keep the MPX power "constant". However, this is not what audio processors without MPX Power controllers typically do – natural variances in MPX power always occur as the program content changes – and it should, otherwise the sound becomes plagued with instances of unnatural loudness.

It was clear to us that perhaps a new MPX Power controller approach, one that didn't subject a station's listeners to unnatural 'roller coaster' audio, was needed. We discovered however that accomplishing this goal *and* maintaining good compliance with the BS.412-7 regulation was not a trivial algorithm design task.

The Vorsis Approach

Our BS-412 MPX Power Controller design is based on our belief that:

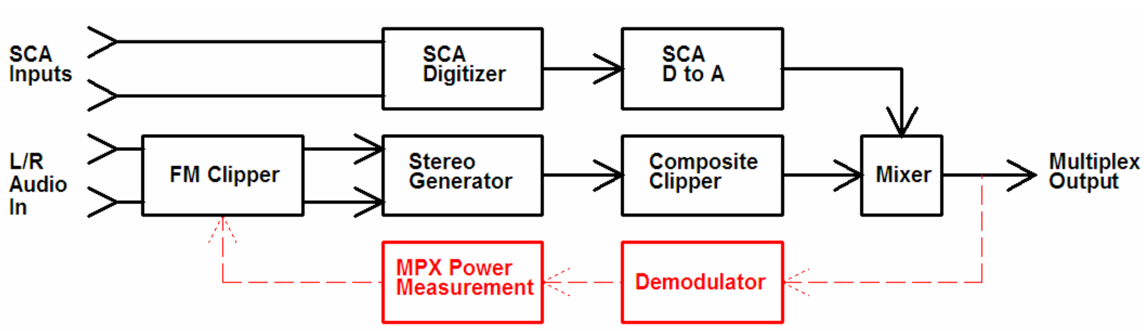
- *the task of the audio processor is to manage program content from the studio and present it in an artistically pleasing way to the station's listeners while precisely controlling modulation peaks in accordance with regulatory requirements, and;*

- *the task of the BS.412-7 MPX Power Controller is to manage the long-term MPX power level to prevent it from exceeding a specified reference level as the audio processor does its job, and;*

- *the latter task should not compromise the sound of the former!*

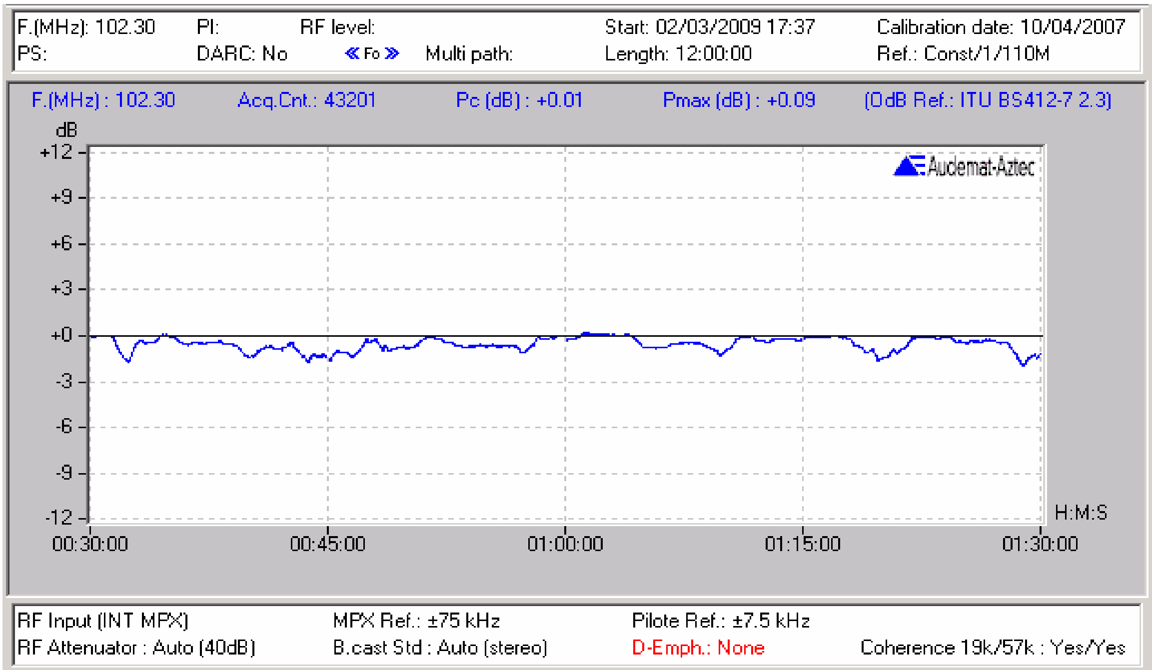
When we designed our MPX Power controller algorithm we created a method that manages MPX Power as mandated by the BS-412 regulation but *without* creating audible audio artifacts such as ducking and swelling while the controller is doing its job. Our belief is that such artifacts are an unacceptable tradeoff to impose on Vorsis audio processor users whose stations are forced by law to utilize a Multiplex Power Controller.

Our approach utilizes a specialized measurement method embedded inside a control loop containing the main FM clipper and the composite processor (clipper or lookahead limiter). The simplified block diagram shown below depicts the control loop's signal path highlighted by dashed lines for clarity.



Analysis of the audio signal flow (solid lines) shows that the demodulator and MPX Power measurement scheme's location allows it to be aware of Multiplex Power increases generated by the main and composite clippers. In this scheme it doesn't matter how hard either clipper is driven whenever the MPX Power Controller is engaged – nor does it matter what pre-emphasis setting is in effect – MPX Power will be correctly controlled by the servo action of the control loop.

Below is a measurement performed by our Audemat DFMA02 analyzer with an AP2000's BS-412 MPX Power algorithm enabled (utilizing the Factory default "QuickStart preset) while processing one hour of mixed music and talk programming.



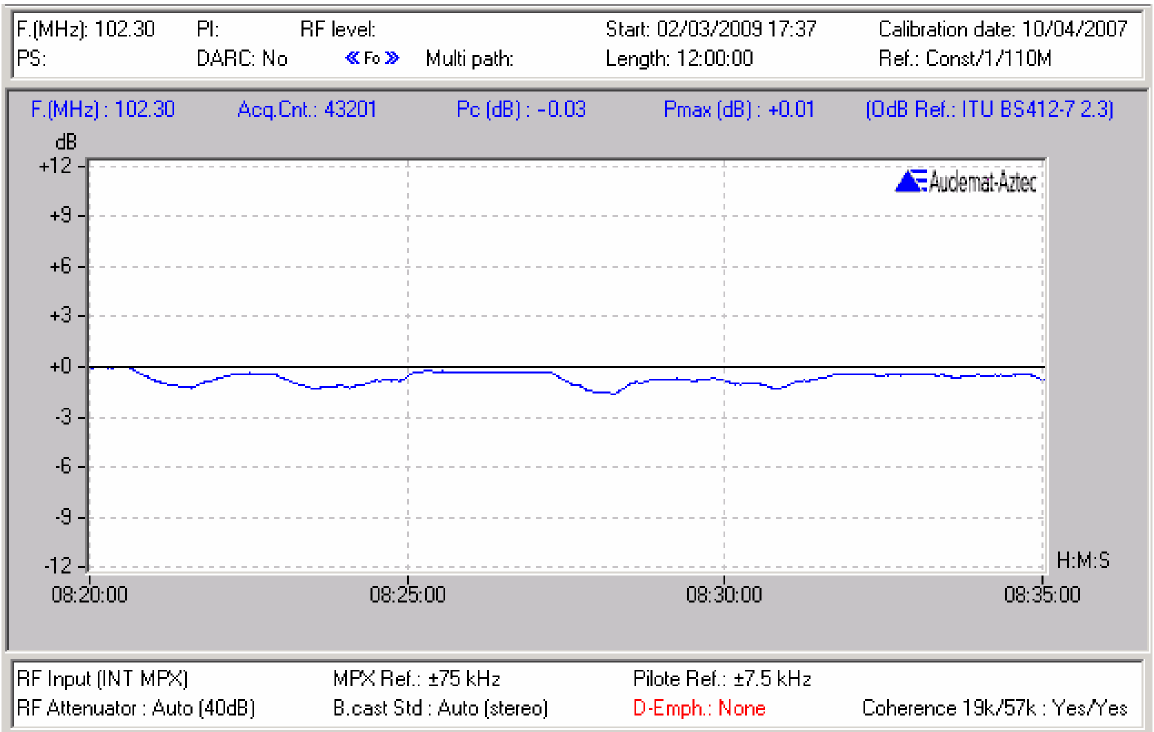
Two important data points are revealed by the above measurement:

1. The maximum MPX power measured during the one-hour test period was +0.09dB, an insignificant amount over the "0dB" reference limit and well within the specified +/-0.3dB calibration tolerance of the Audemat instrument used.

2. The BS-412 MPX power controller made no attempt to equalize normal *decreases* in program density as the program material varied. This task was, just as it should be, left to the audio processor to perform as adjusted and operating according to the settings belonging to the preset in use.

A group of listeners, all prior 'radio people', who observed the operation of our MPX Power Controller during testing noted no unnatural changes in loudness when program density decreased during the quieter portions of material. They also reported no discernable difference in the average audio levels between the subject AP2000 with its BS-412 power controller enabled and a second AP2000 whose MPX Power had been reduced to closely match the first AP2000's MPX power level simply by reducing its Main and Composite clipper drives.

Below is fifteen minutes of the previous one-hour MPX Power recording ...



Notice the time segment following 08:25:00 in the above graphic and how the MPX power controller has 'flat topped' the energy curve to prevent excessive MPX Power but has *not* modified the normal reductions in program density during the few minutes of programming on either side of the excess energy. Natural decreases in program density were *allowed* to occur.

Similar behavior occurred during other instances of MPX energy being constrained below the legal limit. Natural decreases in program density were not 'chased' by our BS-412 algorithm. Indeed, such passages were left to sound just as they would sound if the MPX Power Controller were not engaged.

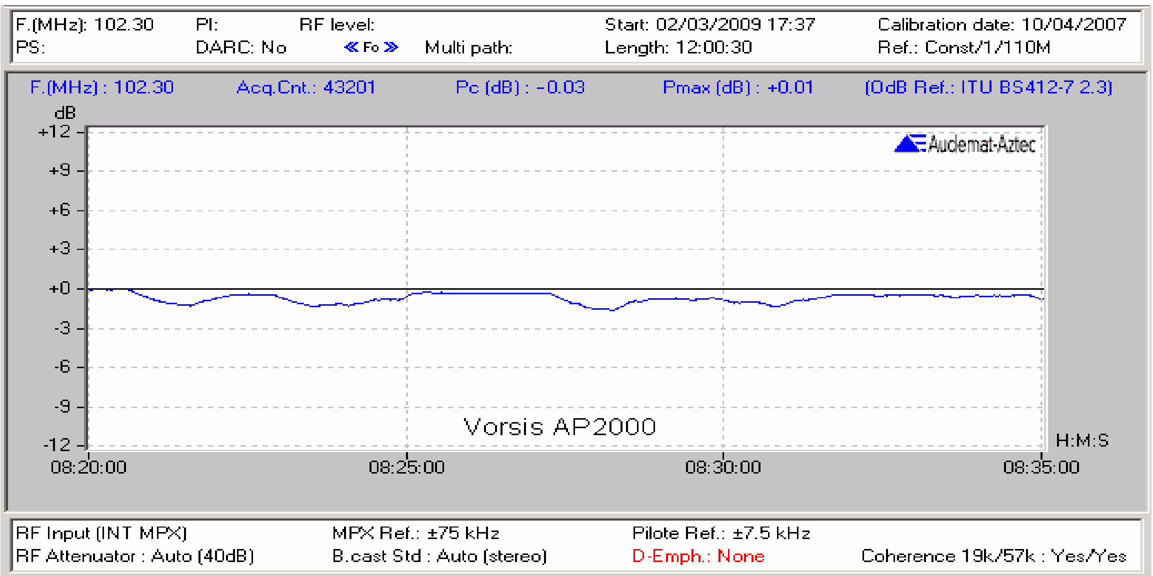
In the above example the Vorsis MPX Power Controller has limited the maximum MPX energy as required by the BS-412 regulation but has accomplished it without "reprocessing" the audio to keep audio density constantly slammed against the "0dB" limit of the MPX Power reference.[1]

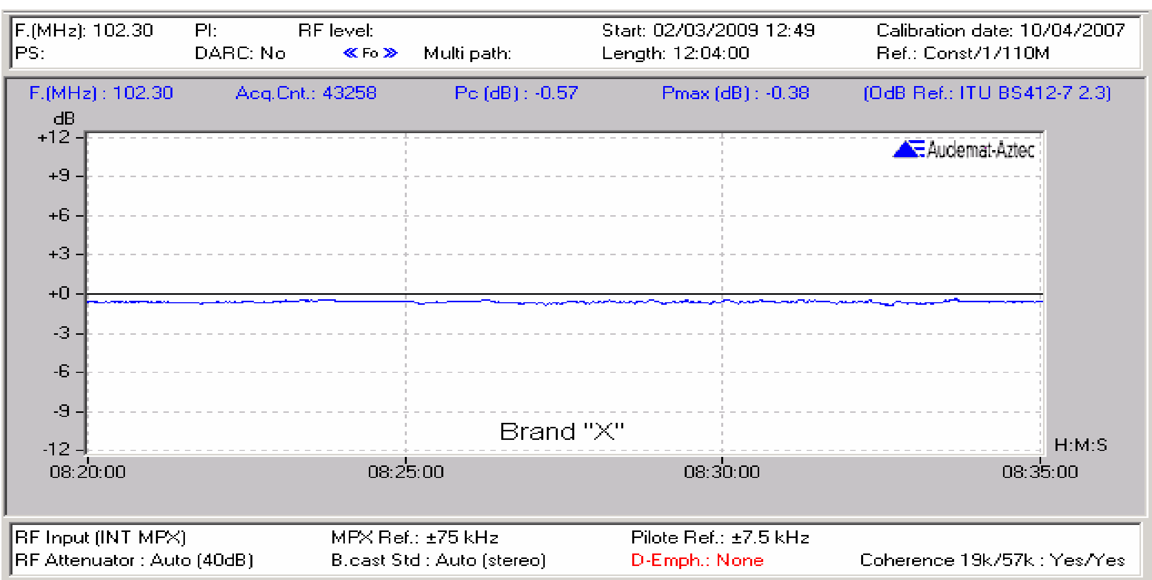
[1] Exactly how we achieve compliance with the ITU-R BS.412-7 Multiplex Power regulation while also allowing artistically correct 'program dynamics' that are virtually indistinguishable from an audio processor operating without its BS-412 MPX Power controller engaged will not be revealed.

Opposing Viewpoints?

One could make the argument that the Vorsis MPX Power Controller doesn't manage MPX energy consistently by pointing out the decreases in audio density in our own graphics as 'proof'. However, we'll argue that the audio processor is responsible for managing loudness and density while the MPX Power Controller's job is "preventing MPX energy above a certain level" and <u>nothing</u> more.

Please see the graphics below for a comparison of our method to a Brand "X" MPX Power Controller during the same fifteen minute segment of program material.



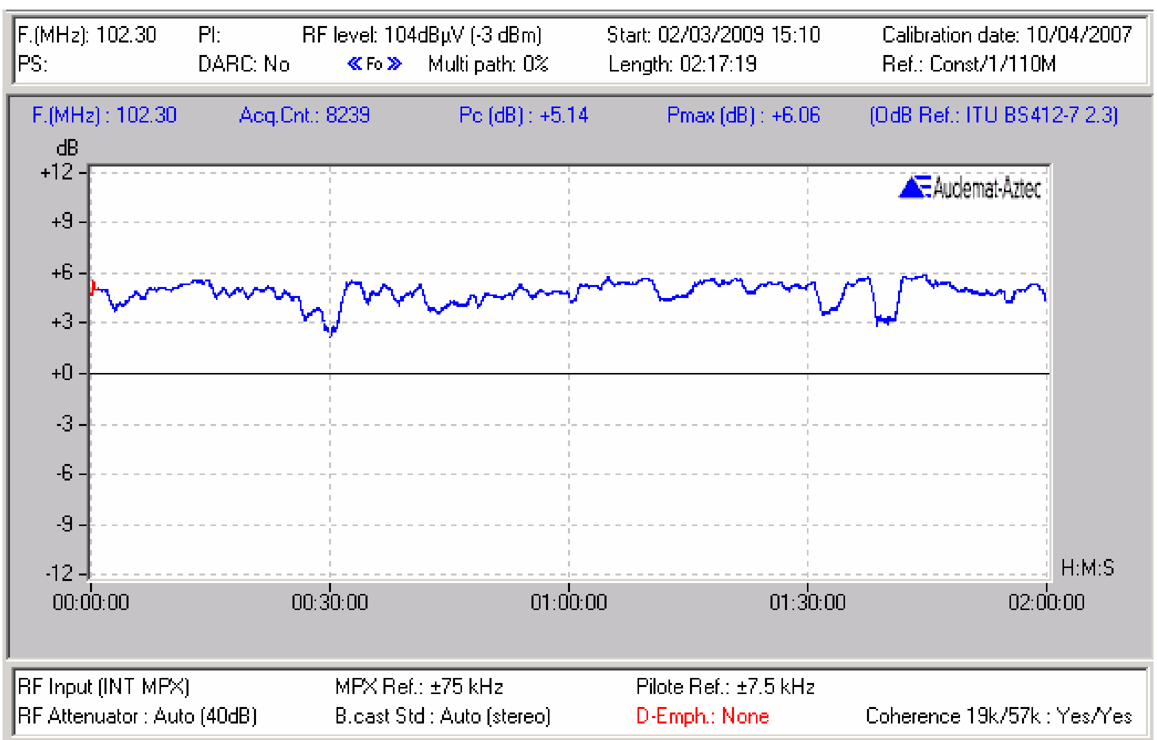


It would be appropriate to state that neither these examples nor our measurements are meant to imply that other methods of MPX Power management are wrong. Rather, we believe that our method is superior *when* management of Multiplex Power is legally required *and* the station doesn't desire additional dynamics-related artifacts when the BS-412 MPX Power control algorithm is in use. These artifacts seem, at least to us, to be in conflict with not just good modern audio processor design, but also in conflict with achieving a great on-air sound that is pleasing and easy to listen to for long periods of time.

MPX Power without the BS-412 Controller

Simply as a point of reference we've included a screen shot of the multiplex power generated by one of our Vorsis processors as measured by our Audemat DFMA02 analyzer when the BS-412 multiplex power controller is not enabled.

Notice not just the measured power level above the "0dB" reference during this two-hour recording, but more importantly, the natural variation in MPX power as the station's program content changes.



This is the 'natural' variation in program density that we mentioned earlier. The job of the MPX Power Controller is not to "fix" this variation, but to leave it alone unless the MPX Power will exceed the reference level set by the BS412 control.

Field Testing and Results

Feedback from four European-based Vorsis BS-412 MPX Controller beta testers during two months of field trials has demonstrated that our algorithm performs as designed and meets current regulatory requirements for FM Multiplex Power control.

Not unexpectedly that feedback also revealed an overall preference for how our MPX Power controller sounds on the air compared to other designs. Users reported (and these are direct quotes) that while other product's designs "…might be a smidgeon louder overall…" the Vorsis algorithm "…is far more natural sounding and completely free of the 'roller coaster' audio levels generated by those processors when their MPX Power controllers are enabled and adjusted in conformance with the spirit of the BS-412 standard…"

When Good is "Good"

During on-air testing one of our beta locations reported what they described as "BS-412 under-control" while the station was using extremely aggressive processing in combination with exaggerated stereo enhancement. The customer had consistently measured a +0.24dB MPX Power excess with his Audemat FM-MC4, and upon our advice found that simply setting his AP2000's BS-412 control to its minus 0.5dB (-0.5dB) setting placed the measured MPX Power precisely within regulatory limits.*

** Two other European beta site customers equipped with similar analyzers had reported BS-412 power measurement deviations of approximately the same magnitude – however, they were in the opposite direction!*

Which is correct? They probably both are…

These field observations fell comfortably within Audemat's published "+/-0.30dB" MPX Power measurement accuracy of the DFMA02 and FM-MC4 family of instruments. Because of the uncertainty of individual instruments' calibration and because small deviations in <u>measured</u> MPX Power can be easily accommodated by using the vernier resolution of the BS-412 control "…to make the customer's MPX Power analyzer 'happy'…" no modifications were made to our algorithm as a result of these reports.

Operating the Vorsis BS-412 MPX Power Controller

In the upper left corner of the Stereo Encoder screen of all Vorsis FM processors is the control associated with the BS-412 MPX Power Controller (see the graphic below).

BS412 Reference Power Threshold Control

The control has 15 possible settings, plus *OFF: +8db, +7dB, +6db, +5dB, +4dB, +3dB, +2dB, +1.5dB, +1.0dB, +0.5dB, 0, -0.5dB, -1.0dB, -1.5dB, and -2.0dB*.

The 0.5dB resolution near the control's zero setting is to allow small adjustments in the MPX Power's reference level to compensate for unusual things a user might do to create his on air sound. Though the MPX Power Controller is not easily fooled we provided a small amount of tweaking near the "0dB" reference level 'just in case'.

Turning the BS-412 Controller On

IMPORTANT!

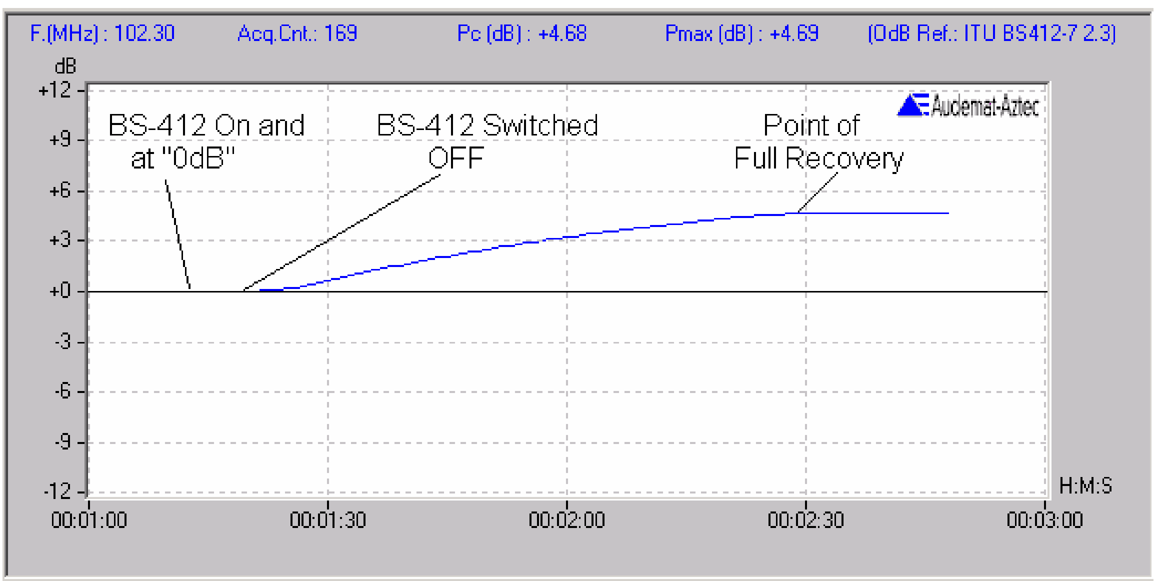
The MPX Power Controller's sole purpose is to reduce loudness and program density. If you are not required to use the BS-412 Controller it should be left in the OFF position because turning it on can cause up to a 5dB loudness loss when the control is set to its "0dB" position.

When the BS412 control is moved away from its OFF position the MPX Power controller is engaged and the algorithm begins measuring and controlling the processor's total MPX power according to the ITU-R BS.412-7 standard. Because the measurement is essentially an average value integrated over a very long time the MPX Power controller will *not* make quick adjustments to the MPX Power when first engaged.

As the controller integrates the MPX energy the drive to the clippers will be modified until the measured MPX power satisfies the reference level as set by the Stereo Encoder menu's BS-412 control. The control's "0dB" setting conforms to the current ITU-R BS.412-7 Multiplex Power standard.

Turning the BS-412 Controller Off

If the BS412 Controller has been on for more than a few minutes and the BS412 control is set back to the OFF position it will take some time for the MPX Power to *return* to an unregulated state. This is because the BS412 controller is not turned OFF by bypassing it (which could cause abrupt changes in output level!), but is instead defeated by raising its MPX Power detection threshold well above *any* conceivable or achievable audio density. The graph below shows how the algorithm recovers after regulating MPX Power at the "0dB" level and is then turned off.



As can be seen above, it may take as much as a full minute for our BS-412 algorithm to recover from a controlled state and return the modulation density to a non-BS-412 multiplex power level.

Once again ... If your station is not required to comply with a Multiplex Power standard where it is licensed to operate the BS412 control should remain in its OFF position!

Just For 'Techies'

(the informal part of this app note...)

We have to admit that we were curious about this BS-412 MPX Power thing, especially its measurement aspects. We could find very little published about 'measuring Multiplex Power' other than what was on the websites of manufacturers offering equipment that measures MPX power and the tiny bit of content there is in the official ITU-R BS.412-7 regulation excerpted below:

> *For the radio-frequency protection ratios given in Fig. 1 and Table 3, it is assumed that the maximum peak deviation of 75 kHz is not exceeded. Moreover, it is assumed that the power of the complete multiplex signal (including pilot-tone and additional signals) integrated over any interval of 60 s is not higher than the power of a multiplex signal containing a single sinusoidal tone which causes a peak deviation of 19 kHz.*
>
> *– and –*
>
> *NOTE – The power of a sinusoidal tone causing a peak deviation of 19 kHz is equal to the power of the coloured noise modulation signal according to Recommendation ITU-R BS.641, i.e. a coloured noise signal causing a quasi-peak deviation of 32 kHz.*

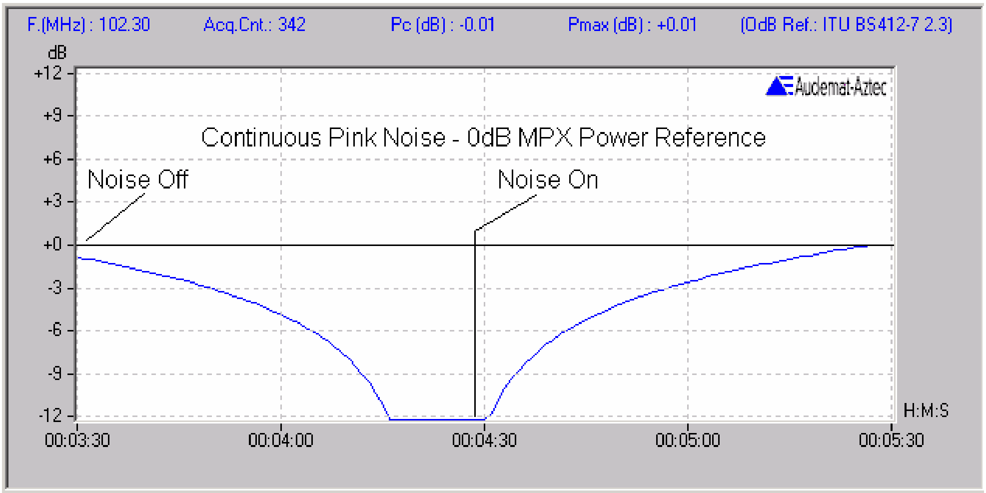
The above excerpt doesn't say anything about *how* they propose to measure a station's multiplex power or what the design requirements *might* need to be concerning what happens inside of the audio processor (other than "control multiplex power...") in order to comply with the BS-412 standard – or at the very least make the instruments happy that measure it...

Lacking a concrete definition of how the MPX Power analyzer actually works we ran some tests on our own (an Audemat DFMA02) to see how its MPX Power measuring scheme responded with easily repeatable stimuli.

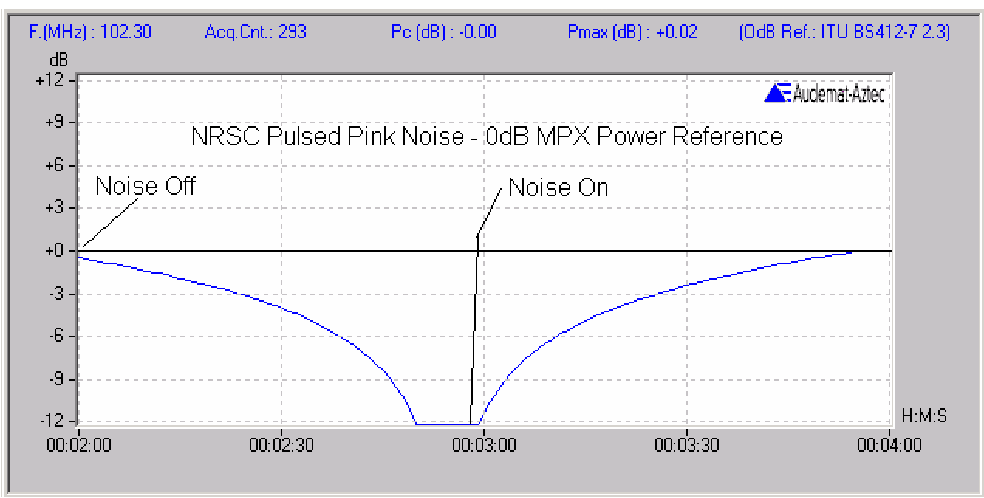
For simplicity we used pink noise generated by a Delta Electronics SNG-1 Stereo Noise Generator because it is equipped with a specified noise burst designed to emulate the crest factor of typical program content. To eliminate stereo pilot/pink noise signal interleaving issues in the non-Audemat part of our lab's monitoring equipment we operated the processor's stereo generator with its 19kHz pilot turned off.

All tests but the BS-412 'mode to OFF' recovery were configured to achieve "0dB" MPX power as measured by our Audemat DMFA02 instrument.

The two graphics below illustrate the results of watching the analyzer adapt to continuous and bursted pink noise at the ITU-R BS.412-7 “0dB” reference MPX Power level.



(The resulting <u>peak</u> modulation during BS-412 “0dB” MPX Power with *continuous* pink noise was 56%)

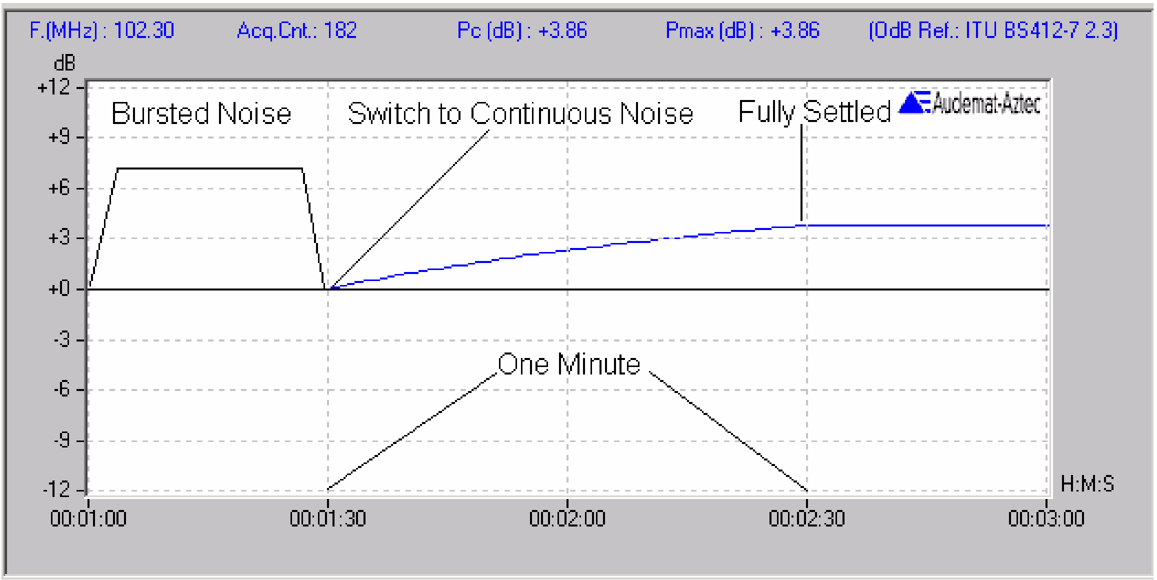


(The resulting <u>peak</u> modulation during BS-412 “0dB” MPX Power with NRSC *bursted* pink noise was 90%)

It was interesting to note a visually identical trajectory of the instrument’s detection curve to and from the BS-412 “0dB” MPX Power reference whether the pink noise modulation was in continuous or in burst mode. It was also curious that there appeared to be a pause of a few seconds before the instrument indicated an increase in MPX power. Perhaps it’s not pause at all, but simply the time it takes for the measurement to become un-bottomed-out from the bottom of the scale?

Another experiment we performed involved observing the behavior of the analyzer when transitioning from bursted pink noise once the analyzer had fully settled at the "0dB" MPX Power level to a new MPX Power level caused by switching the noise generator to its continuous pink noise mode.

The graph below shows the analyzer's behavior as it settled to this new power level, noting that it took exactly one minute (00:01:30 to 00:02:30) for the analyzer to settle to the new and higher MPX Power value (+3.86dB) – precisely the integration time specified in the standard.



Armed with this data we embarked on designing a multiplex power controller that would comfortably meet the BS-412 Multiplex Power standard. Our 'research' into the behavior of the MPX Power Analyzer's measurement behavior - which we will readily admit is 'simplistic' in purely scientific terms - gave us valuable insight on how to design a MPX Power control algorithm that could meet the requirements of the regulation and yet have minimal impact on desirable program dynamics.

The Vorsis BS-412 Multiplex Power Controller is now a standard feature on the following Vorsis FM processors and software versions:

AP2000	Version 1.62 and later
FM2000	Version 1.62 and later
FM-10HD	Version 1.40 and later
VP8	Version 1.91 and later

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