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GUIDELINE**

NATIONAL RADIO SYSTEMS COMMITTEE

**NRSC-G203
NRSC IBOC Time and Level
Alignment Guideline
September, 2017**



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FOREWORD

Audible blending artifacts (that is, noticeable differences in time and level alignment between the simulcast analog and digital audio channels of an in-band/on-channel, or IBOC, digital radio signal) are the top complaint from auto manufacturers and consumers regarding the HD Radio listening experience. Most of these problems can be traced back to broadcast stations. The broadcast industry has long relied on manual management of time and level alignment between the simulcast analog and digital audio. However, field experience has shown that stations aligned manually tend to drift over time.

The content in this document was developed by the Time and Level Alignment Working Group (TLAWG) of the NAB Radio Technology Committee (NABRTC), and submitted to the NRSC in April 2017 with the request that the NRSC incorporate this information into an NRSC Guideline.¹ Discussed herein are some of the causes of time and level alignment drift and how stations can implement automated methods to keep this alignment within a specified tolerance.

Many scenarios can cause drift, although the biggest culprit seems to be the separation of the Exporter and the exciter engine (commonly referred to as “Engine”) components over a wide area network (WAN). This Guideline discusses the implementation of various hardware and software configurations to address timing instabilities.

Ultimately, the most effective solution to insure good time and level alignment is automated, continuous, real-time monitoring and adjustment of this alignment so as to reduce or eliminate objectionable blending artifacts. This document describes this solution, among others.

At the time of submission to the NRSC, the NABRTC was chaired by Mike Cooney, Beasley Broadcast Group. The TLAWG was chaired by Roswell Clark, Cox Media Group; committee participants included Paul Shulins and Lamar Smith, Beasley Broadcast Group, Glynn Walden, CBS Radio, Sam Caputa and Jake Robinson, Emmis Communications, Dave Garner, Hubbard Media, Alan Jurison, iHeartMedia, and David Layer, NAB with technical contributions from Ed Allen, Cox Media Group. Much of the material in this Guideline is derived from a paper on this topic written by Mr. Jurison. [1] The NABRTC is grateful to him and to iHeartMedia for this significant contribution.

At the time of adoption of NRSC-G203, the Digital Radio Broadcasting (DRB) Subcommittee was co-chaired by Glynn Walden, CBS Radio and Jackson Wang, E-radio; the IBOC Standards Development Working Group (ISDWG) was chaired by Dom Bordonaro, Connoisseur Media.

¹ The NAB Radio Technology Committee (NABRTC) provides guidance and recommendations to NAB staff and the NAB Radio Board on matters related to current and emerging broadcast media communications, issues, policies and technologies. Members of the NABRTC are radio engineers and radio engineering VPs from NAB member organizations, radio broadcast consulting engineers working on behalf of NAB and/or its members, and NAB Technology department staff.

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NRSC IBOC TIME AND LEVEL ALIGNMENT GUIDELINE

1 SCOPE

This is an informative Guideline document that provides information on the problems associated with time and level alignment of the analog and digital main channel audio (HD1) signals used in hybrid HD Radio broadcasts, and offers solutions for how to maintain proper alignment automatically.

2 REFERENCES

2.1 Normative References

This is an informative specification. There are no normative references.

2.2 Informative References

The following references contain information that may be useful to those implementing this Guideline document. At the time of publication the edition(s) or version(s) indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

- [1] *HD Radio™ Diversity Delay Field Observations: The Need For Automatic Alignment*, Alan W. Jurison, iHeartMedia, Cincinnati, OH; 2016 NAB Broadcast Engineering Conference Proceedings, pp. 34-49, April 2016
- [2] *FM HD-1 Automatic Delay Correction Software Module*, v 1.1, Belar Electronics Laboratory, Inc., 11/18/2015
- [3] *HD Radio Technology – Audio Level Alignment and Time Alignment*, DTS, Inc., <http://hdradio.com/broadcasters/engineering-support/properly-adjust-time-and-level-alignment>
- [4] *HD Radio Time Alignment and the Belar FMHD1*, Ed Allen III, CPBE, Radio Magazine, August 17, 2016
- [5] *A Better Listener Experience: HD Radio Time and Level Alignment*, DTS, Inc., NAB Broadcast Engineering Conference, April 17, 2016 (available online at <http://www.nautel.com/wp-content/uploads/2016/04/Time-Level-Alignment-NUG-2016.pdf>)
- [6] *IBOC Analog-digital Blend Time Alignment Quality*, M. Bergman and J. Kean, 2007 NAB Broadcast Engineering Conference
- [7] *HD Radio Time and Level Alignment*, Brian Beezley, November 18, 2016, <http://ham-radio.com/k6sti/roster.htm>
- [8] *Measure Diversity Delay and Correct for It*, A. Jurison, Radio World Magazine, August 26, 2015 (available online at <http://www.radioworld.com/digital-radio/0014/measure-diversity-delay-and-correct-for-it/336708>)
- [9] *Time Alignment Slip in Flexstar*, Harris Application Note APN-111-WCF, Harris Broadcast Communications Division, April 10, 2007
- [10] *HD Radio Data Network Requirements*, iBiquity Digital Corporation Application Note TX_TN_2040, Rev. 09, October 23, 2006 (available online at http://hdradio.com/sites/default/files/hd_networking_requirements_v91.pdf)
- [11] *HD Radio Networking Implementation Recommendations*, MTM Technologies (developed for iBiquity Digital Corporation), July 27, 2006 (available online at http://hdradio.com/sites/default/files/hd_network_implementation_recommendations1.pdf)

- [12] HD Radio Networking Best Practices, MTM Technologies (developed for iBiquity Digital Corporation), July 27, 2006 (available online at http://hdradio.com/sites/default/files/hd_networking_best_practices.pdf)
- [13] *10 MHz Exporter-to-Exciter Synchronization for HD Radio Systems*, Harris Application Note APN-113-TA, Harris Broadcast Communications Division, November 2007

2.3 Symbols and Abbreviations

In this Guideline the following abbreviations are used.

AM	Amplitude modulation
FM	Frequency modulation
NABRTC	National Association of Broadcasters Radio Technology Committee
NRSC	National Radio Systems Committee
E2X	Exporter-to-exciter
FCC	Federal Communications Commission (U.S.)
GPS	Global Positioning System
IBOC	In-band/on-channel
LAN	Local area network
MPS	Main program service
N/A	Not applicable
RF	Radio frequency
STL	Studio-to-transmitter link
TBD	To be determined
TLAWG	Time and Level Alignment Working Group
VLAN	Virtual LAN
WAN	Wide area network

2.4 Definitions

In this Guideline the following definitions are used:

HD Radio™	Trademark of DTS, Inc, (formerly iBiquity Digital Corporation) for the digital AM and digital FM transmission technology authorized by the FCC. Note that the use of this term in NRSC documents shall be interpreted as the generic term “IBOC” and shall not be construed as a requirement to adhere to undisclosed private specifications that are required to license the HD Radio name from its owner.
Blending	The process whereby an HD Radio receiver transitions between the analog and digital versions of the main channel audio signal. This transition is under the control of the receiver; an example of blending includes during radio signal acquisition, when the receiver captures the analog signal initially, then transitions to the digital signal once digital acquisition is completed (typically on the order of 6-10 seconds in a strong RF signal environment).
Engine	This is a term which means “exciter engine” and describes a particular kind of HD Radio transmission equipment introduced with the 2nd generation HD Radio hardware. An Engine processes baseband inputs (data and audio) and creates a low-level modulated RF signal, which can then be amplified in a transmitter for broadcast. In this guideline, “Engine” and “exciter” are used somewhat interchangeably.

Diversity delay

In the context of this Guideline, “diversity delay” refers to the intentional delay introduced between the simulcast analog and digital audio channels of a hybrid HD Radio signal. This delay provides for time diversity backup of the main channel digital audio signal because the receiver can detect when there are impairments in the digital audio and during that time, switch to the analog backup. The diversity delay needs to be precisely set to ensure seamless switching or “blending” between the digital and analog backup signals.

3 BACKGROUND

A key technical problem facing in-band/on-channel (IBOC) digital radio broadcasters today is maintain time and level alignment of the analog and digital main channel audio in an HD Radio signal. HD Radio receivers blend the main channel audio signal (also known as main program service, MPS, or HD1) from analog to digital upon reception, and then back to analog when the bit error rate of the digital signal exceeds a preset value. Blending can occur frequently, for example, while driving in or out of digital coverage, or along a fringe area of digital coverage.

Ideally, the blend between analog and digital is seamless. However, misalignment between the analog and digital audio channels beyond certain thresholds badly compromises the listener experience. Industrywide off-the-air measurements indicate that time and level alignment continues to be a challenge for many stations, creating a poor listener experience. Misalignment not only reflects negatively on the broadcast industry, but also causes confusion where listeners may think the car radio is malfunctioning, resulting in complaints to automobile dealers, when in fact the problem often lies with the transmission of these misaligned signals.

This document was created to describe the best practices for time and level alignment between HD Radio analog and digital main channel audio signals, and is the result of many months of work by the NAB Radio Technology Committee's (NABRTC's) Time and Level Alignment Working Group (TLAWG). Because broadcasters have control over the parameters that affect time and level alignment, the TLAWG intends to provide a "best practice" set of guidelines for keeping stations both time and level aligned within the researched parameters that have been determined to guarantee a good listener experience during the receiver blends.

Because there are several different manufacturers of HD Radio broadcast equipment and many different configuration topologies for HD Radio transmissions, this Guideline presents several of the most popular basic systems with specific examples of tested configurations that have been demonstrated to provide good blend performance. While it is not possible to provide a guideline for every possible configuration, this document includes those most commonly in use. Please note that while, as discussed below, there are preferred configurations, the suggestions and recommended practices below should prove helpful in improving station time and level alignment performance for both preferred and non-preferred configurations.

3.1 Measuring the problem

The "first generation" (2005-2008) of commercially-available signal monitoring products designed to measure HD Radio main channel audio signal time and level alignment accuracy were primarily focused on "single point in time" measurements. The premise behind these first products was to create an automated extension of the initial manual alignment procedure, which was to put on a set of headphones and, using a receiver in "split mode" with the analog audio on the left channel and the digital audio on the right channel, listen to the audio and adjust the relative delay between analog and digital until they were properly aligned.

That process was acceptable for setting up the 1st- and 2nd-generation HD Radio systems which, because of the architecture then in use, were by and large not susceptible to drifting once aligned. As the industry moved to the 3rd-generation "Exgine" (Exciter engine) platform, this original procedure was no longer adequate because, due to a variety of factors, some internal and some external, time delay was now susceptible to drifting over time. As it turns out, these original, single-point-in-time measurements are not very useful for managing broadcast plants with significant drift problems.

More recently, precision tools have become available to monitor time differences between analog and digital audio channels in real time. With these products, it is possible to monitor time alignment continuously. A further improvement has been the development of logging and graphing tools that display how the delay difference changes over long periods of time. These new capabilities enable broadcasters to better identify the factors that can cause improper time alignment. Even with these advances in knowledge and monitoring, an automated approach to keeping proper time alignment remains a challenge.

3.2 Examples of the problem

Figure 1 through Figure 4 document some research conducted by iHeartMedia on a radio station broadcasting a hybrid FM HD Radio signal during the summer of 2015. These figures show how various configurations of the same equipment produce dramatic differences in time delay stability between analog and digital main channel audio signals. The station in the example measurements implemented a topology that used the Exporter at studio.

Figure 1 shows wide variations in the analog and digital delay shift over time when the Exporter was located in the studio and connected to the exciter across a LAN bridge. In this setup, the Exporter and Exciter were running the latest versions of software, and the Exporter-to-Exciter link was across an Intraplex LAN bridging card on an isolated VLAN network.² Wireshark captures showed the only traffic competing for bandwidth was the Exporter to Exgine (E2X) data.³

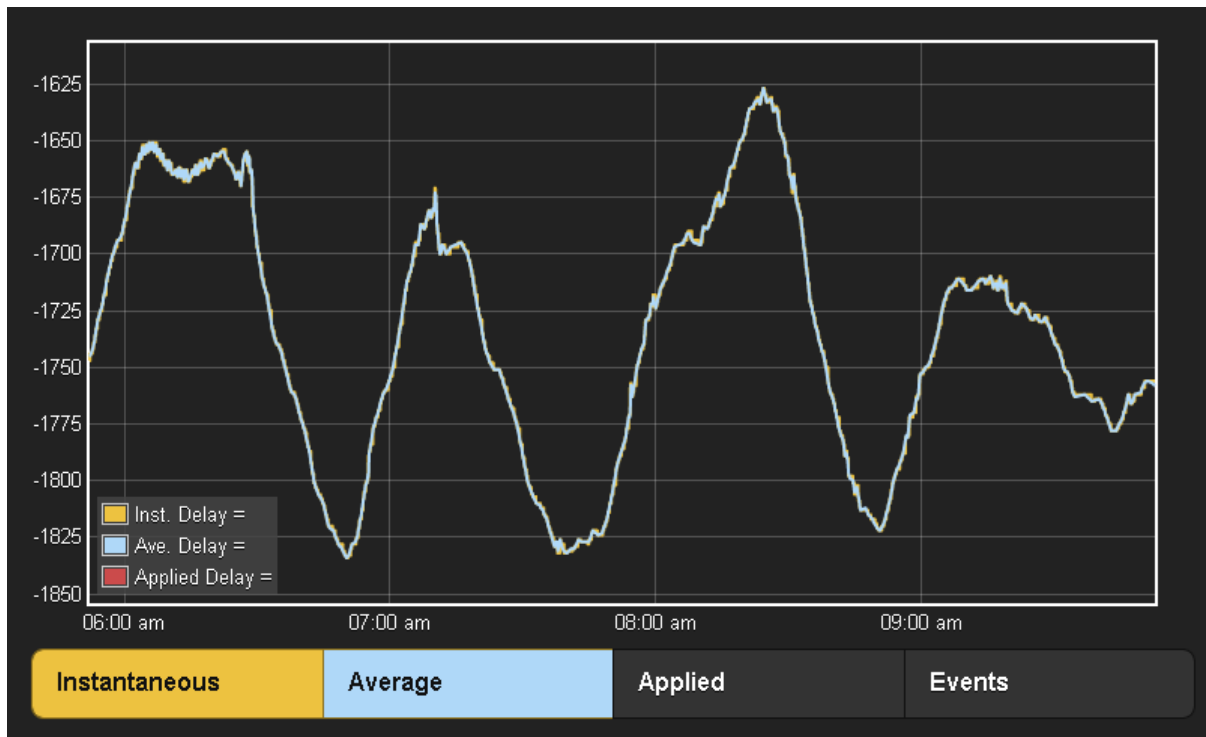


Figure 1. Time delay difference (in audio samples) between the analog and digital audio for the configuration with the Exporter at the studio and the Exciter at the transmitter, connected using an isolated LAN bridge (x-axis is audio samples, y-axis is time).

Careful analysis of this particular system showed that more than a “typical” amount of bandwidth was allotted. Using an E1 media converter, the data was delivered via campus fiber from the studio to the transmitter site. Typically, Intraplex shelves deployed over wired circuits are at T1 speeds (1.544 Mbps) and are configured at 320 kbit/sec, 384 kbit/sec, or 448 kbit/sec. In this case, because of the faster E1 speed (2.048 Mbps) allocated to this link, 512 kbit/second was used.

² Intraplex is a brand of networking hardware made by broadcast equipment manufacturer GatesAir, for more information visit <http://www.gatesair.com/products/transport/audio-contribution-distribution/intraplex-ip-link>.

³ Wireshark is a free network protocol analyzer for Unix and Windows, for more information visit <https://www.wireshark.org/>.

In many similar configurations, this much bandwidth is rarely allocated to the E2X when using wired T1 based Intraplex frames. Despite optimum connections, careful design, and attention to software, etc., stable timing between the analog and digital main channel audio signals was unachievable.

Figure 1 shows measured time delay (y-axis) from 6am until 10am (x-axis), spanning 4 hours. The diversity delay drift on this station was extreme; this would be impossible to maintain in spec by manual means.⁴

In this installation, the network isolation was ideal and the amount of bandwidth allocated on the Ethernet bridge exceeded what many Intraplex installations typically allocate. However, this installation was missing a GPS-disciplined 10 MHz reference source at the transmitter site into the Exciter to assist with clocking.

Use of a GPS timing reference for an Exciter located at the transmitter site when the Exporter is located at the studio is still uncommon. When Engine was first introduced, this was not a standard practice; it was usually implemented after-the-fact, post-installation, to stabilize the delay drift.

Few stations invested the effort and expense to add this 10 MHz reference source. In the case illustrated in Figure 1, this station obtained a loaner GPS unit for testing. This loaner unit had a GPS antenna input and a 10 MHz BNC output, which was brought to the exciter. The exciter was reconfigured to use the external 10 MHz for clocking sync, which resulted in the dramatic improvement shown in Figure 2.

The GPS-referenced 10MHz sample was connected to the Exciter and the Exciter was reconfigured to use this input at approximately 10:20 AM (in Figure 2). Manual diversity delay adjustments to get the delay to center at 0 samples were made around 11:45 AM (in Figure 2).

Figure 3 and Figure 4 show how adding a 10MHz GPS-disciplined source to the Exciter at the transmitter site significantly decreased drift, but it was still is not within spec. Long-term monitoring of this system for well over a month resulted in similar performance each day as what is shown in Figure 3 and Figure 4.

These figures show that coarse timing drift caused by only using E2X Ethernet-based clocking over a LAN bridge can be eliminated, but they also demonstrate that this method could not maintain a ± 3 sample difference between the analog and digital audio with the Exporter at the studio, despite a very clean and adequate network configuration using current, best-in-class equipment.

This data also shows long-term timing drift and clearly indicates that careful attention must be paid to all facets of an HD Radio installation to avoid the resulting consumer complaints. The above example shows that when the Exporter is not co-located with the Engine, it is unlikely that timing will be stable despite careful attention to details.

The information in this Guideline will describe common topologies and some recommendations to help stabilize the HD Radio installations, as well as some tested methods to continuously monitor and correct systems that cannot stabilize because of immutable topology or other challenges within the installation.

⁴ In this Section, "in spec" means that the timing between the analog and digital main channel audio signals is kept within ± 3 audio samples.

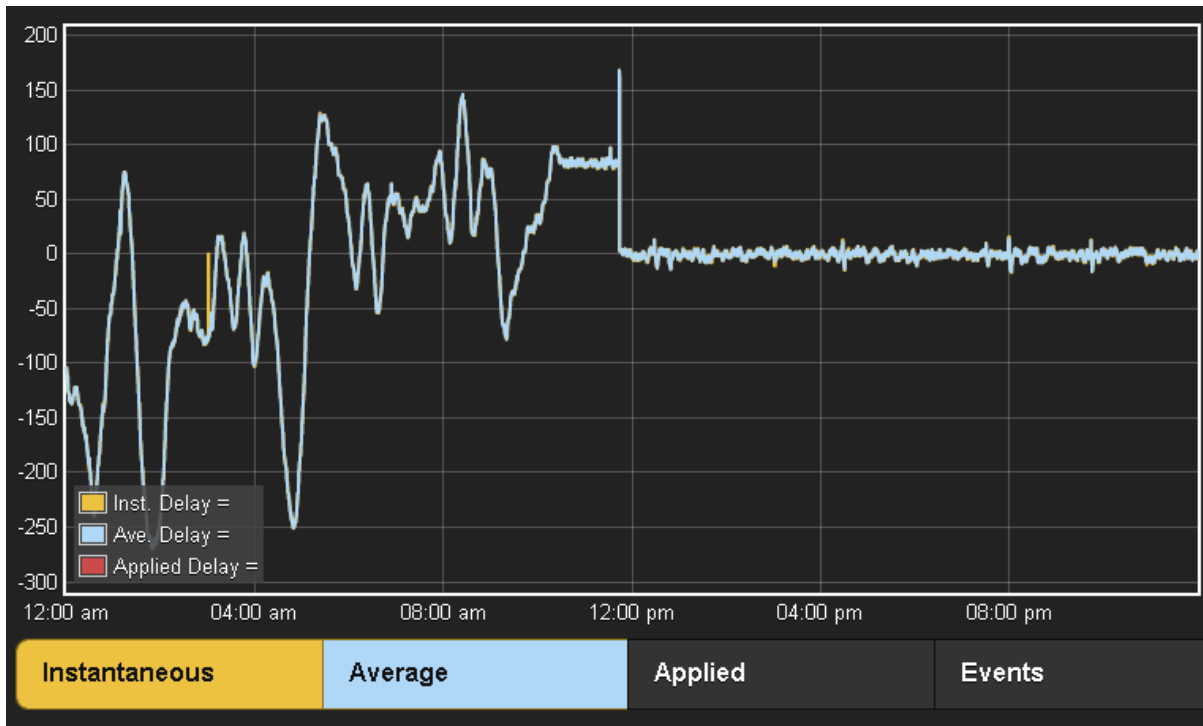


Figure 2. Same configuration as shown in Figure 1 except adding a 10MHz reference to the Exciter (x-axis is audio samples, y-axis is time).

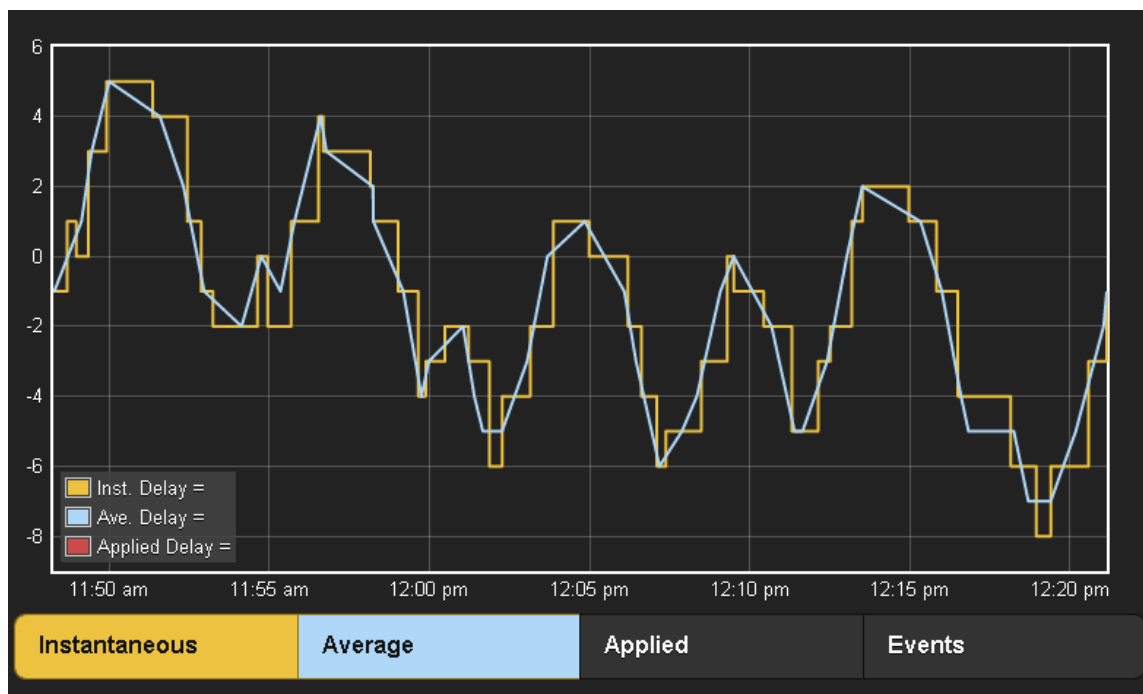


Figure 3. Same configuration as shown in Figure 1 except with 10MHz reference to Exciter (detailed view, ~30 minute scale; x-axis is audio samples, y-axis is time).

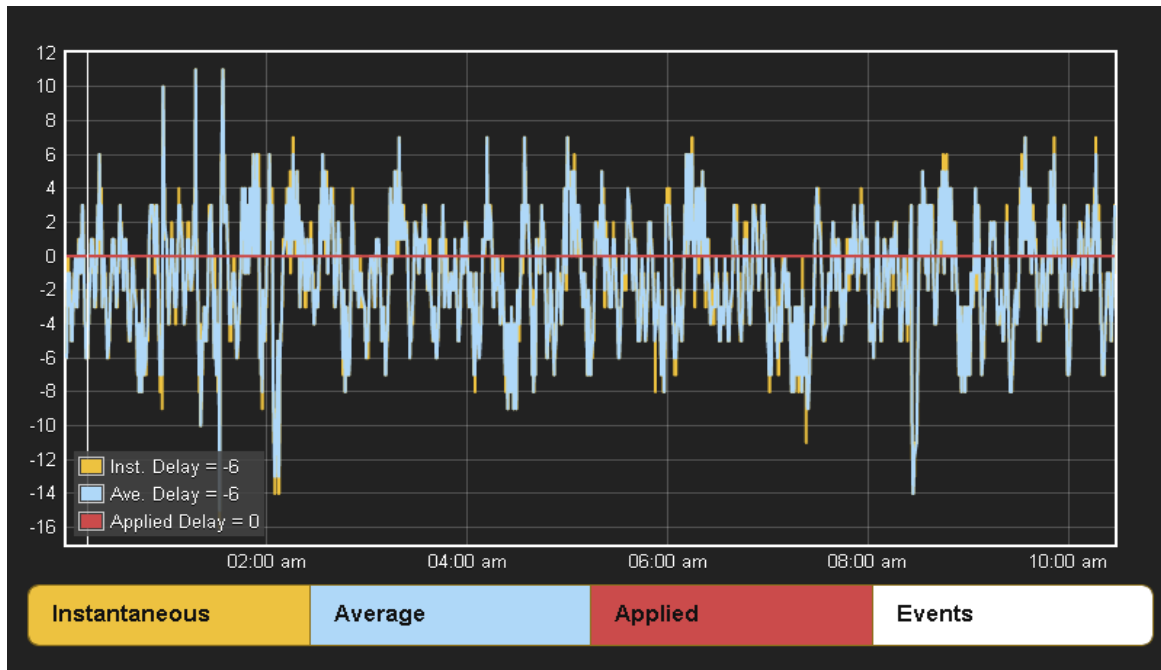


Figure 4. Same configuration as shown in Figure 1 except with 10MHz reference to Exciter (coarse view, ~10.5 hour scale; x-axis is audio samples, y-axis is time).

4 EXAMPLES OF TYPICAL HD RADIO TRANSMISSION TOPOLOGIES

A station's transmission equipment configuration will primarily dictate how easy (or how difficult) it can be to maintain good time alignment. The most commonly used HD Radio transmission topologies are presented in this Section, along with a discussion of the impact of each topology on time alignment. Table 1 summarizes the various configurations discussed.

Please note that while the preferred configurations are discussed below, the suggestions and recommended practices herein should help improve station time and level alignment for both preferred and non-preferred configurations.

Table 1. Commonly used HD Radio transmission topologies. (Note: none of these topologies show automatic correction, this will be covered in Section 6.)

Figure	Analog and digital audio processors		Audio processor and Exporter location		Importer location		Comments
	Separate [†]	Combined	Studio [†]	Transmitter	Studio	Transmitter	
Figure 5	✓			✓	(none)		
Figure 6		✓		✓	(none)		Preferred
Figure 7		✓		✓		✓	Preferred
Figure 8		✓		✓	✓		Preferred [‡]
Figure 9	✓		✓		✓		
Figure 10		✓	✓		✓		
Figure 11	✓		✓	✓	✓		Single Exporter feeding multiple transmitters [†]

[†] Not recommended

[‡] Assumes appropriate data link between Importer and Exporter

Early implementations of HD Radio systems placed the various components required for the creation of the HD Radio signal at the transmitter site; only the audio signal was transported over the studio-to-transmitter link (STL). The Exporter function was built into the HD Radio exciter along with the Exgine.

Later, the Exporter function was separated from the Engine, and could be installed separately from the Engine and communicate with the Engine over a network connection (Figure 5). A separate digital audio processor (that is, separate from the analog audio processor) was required and not all implementations used identical processors for analog and digital audio. The Exporter managed the delay of the analog audio signal, and alignment was managed manually and adjusted as-needed.

Generally, the stability of the timing between the analog and digital audio signals was relatively stable in this basic configuration. although separate audio processors resulted in a more noticeable change in the sound (due to different audio processor settings) during blends between the two signals.

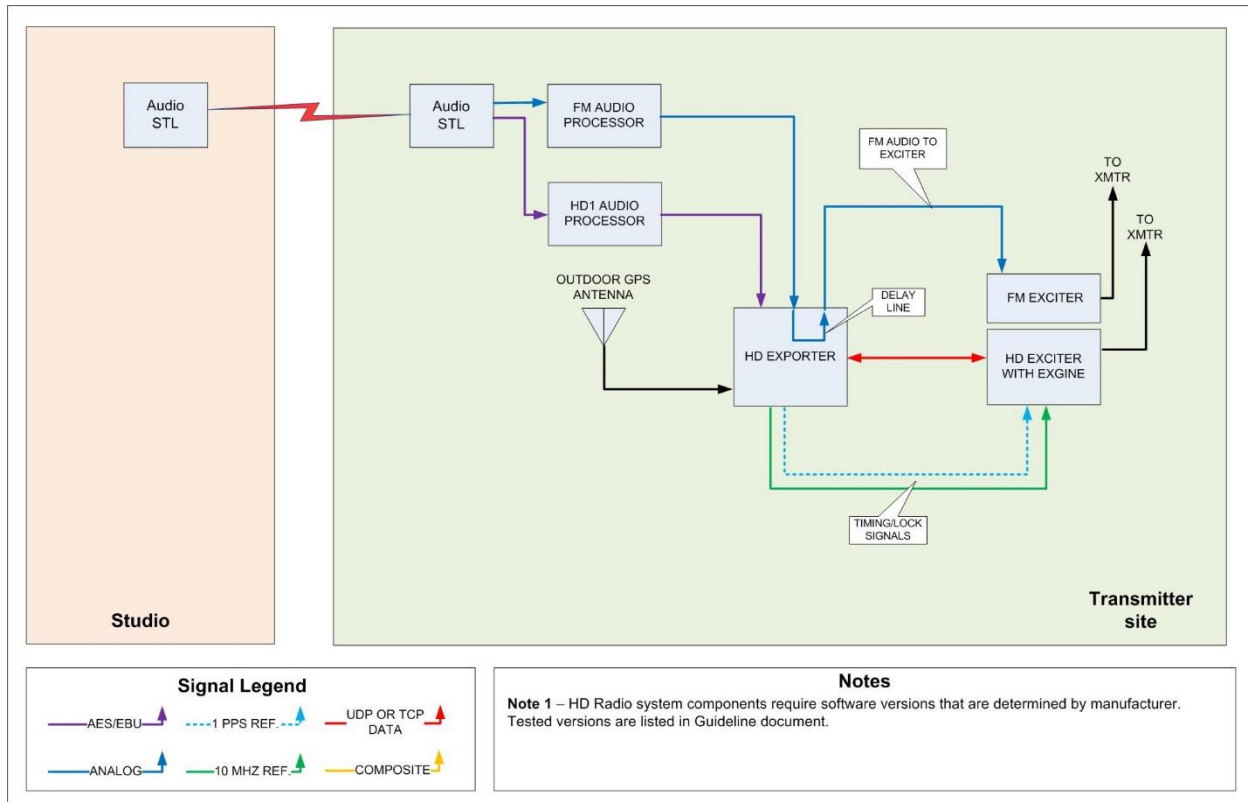


Figure 5. Exporter at transmitter site with no Importer, separate audio processing. (See Figure 16 and Figure 18 for the recommended, automated time-aligned version of this configuration.)

By adding both diversity delay in the analog path and a sidechain dedicated to the digital path (Figure 6), various audio processor manufacturers addressed the artifacts caused by the separate audio processing. This simplifies the air chain for HD Radio stations and decreases the audible change when blending between analog and digital signals.

In this configuration, timing drift is relatively minimal if all components and networking are properly implemented. Timing is still manually adjusted as needed, and restarting any component requires resetting the base time alignment setting.

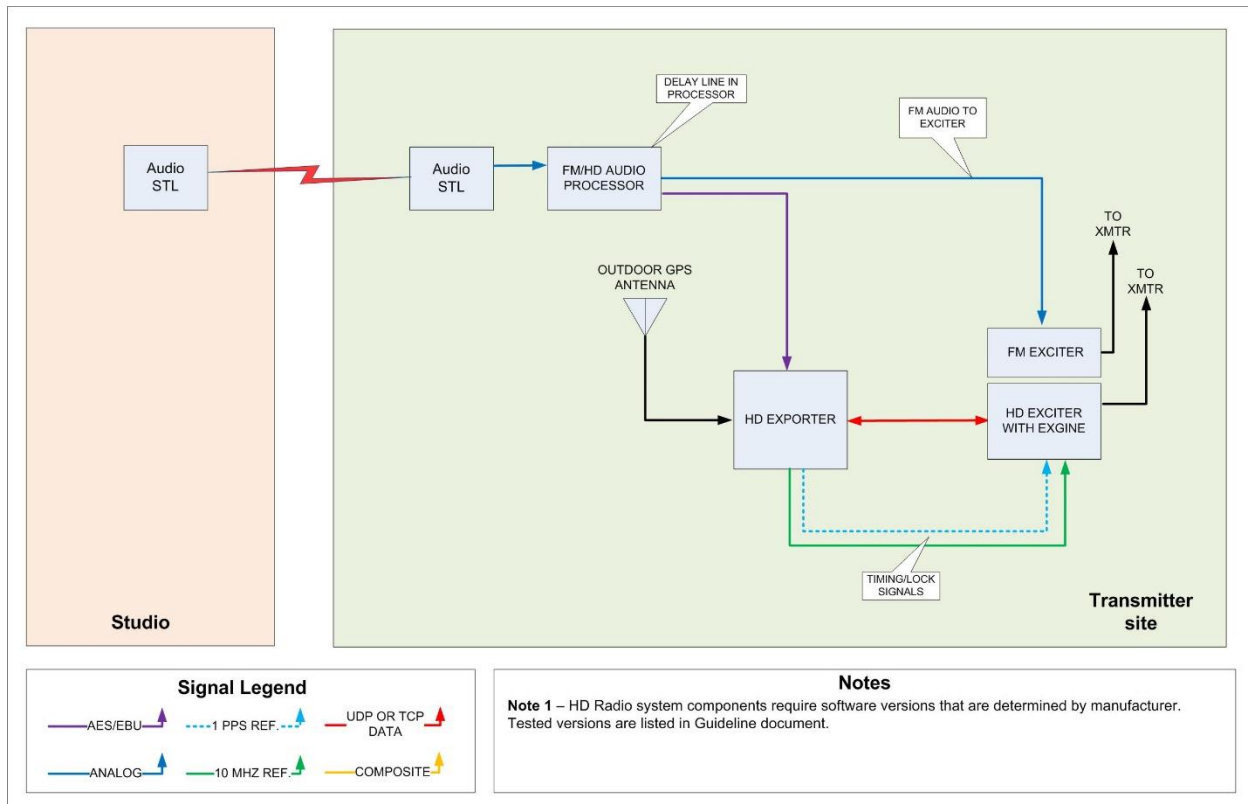


Figure 6. Exporter at transmitter site with no Importer, common audio processing. (See Figure 15 and Figure 17 for the recommended, automated time-aligned version of this configuration.)

In 2005, the introduction of “multicasting” added the Importer to the HD Radio ecosystem. The Importer enables additional audio channels in the HD Radio signal and supports advanced data services that are carried over the HD Radio system, such as traffic information and “Artist Experience” (album art and other audio-related images).⁵

Initially, installation of the Importer occurred at the transmitter site and delivery of additional audio and data channels were accomplished by various means (Figure 7). Although the networking between the various components is more complex in this configuration, analog and digital main channel audio signal timing errors are manageable and generally somewhat stable in this architecture because the Exporter and Exciter are physically co-located. Monitoring and manual time alignment with occasional adjustments is typical, assuming the installations are done properly.

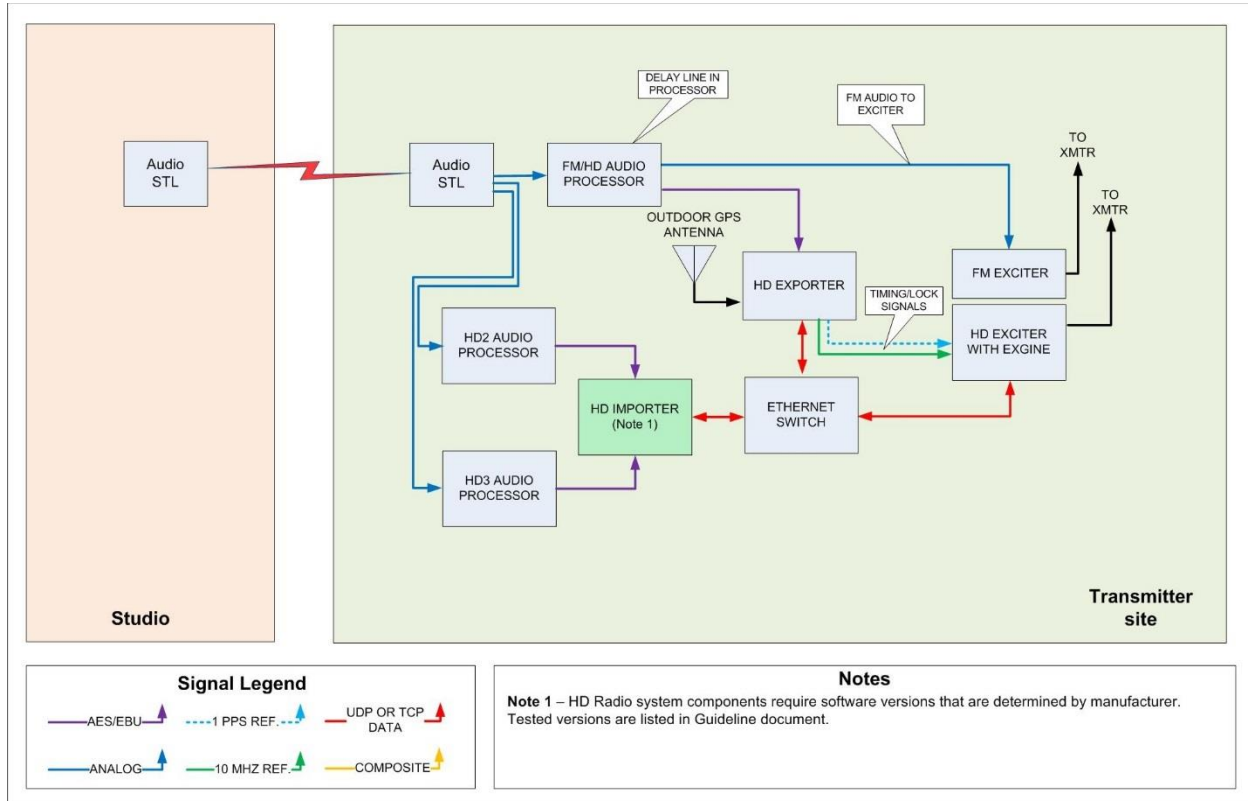


Figure 7. Exporter and Importer at transmitter site with common main channel audio analog and digital audio processing. (See Figure 16 and Figure 18 for the recommended, automated time-aligned version of this configuration.)

⁵ For more information about Artist Experience go to <http://hdradio.com/broadcasters/engineering-support/artist-experience>.

The additional multicast channels and data services often exceeded the capabilities of the legacy STL systems employed at a station, making it necessary to locate the Importer to the studio facility (Figure 8). Establishing a network connection between the studio and the transmitter site made this possible if the network connection was dedicated to this purpose and properly designed. The added network complexity between the various HD Radio system components diminished the stability in the main channel analog and digital audio signal timing, although if the system was properly designed, the ability to make manual adjustments to the timing errors is still manageable.

Assuming a common (*i.e.*, single-box) audio processor is used for the analog and digital audio signals, using separate exciters at the transmitter plant does not affect the timing of the content between the main channel analog and digital audio.

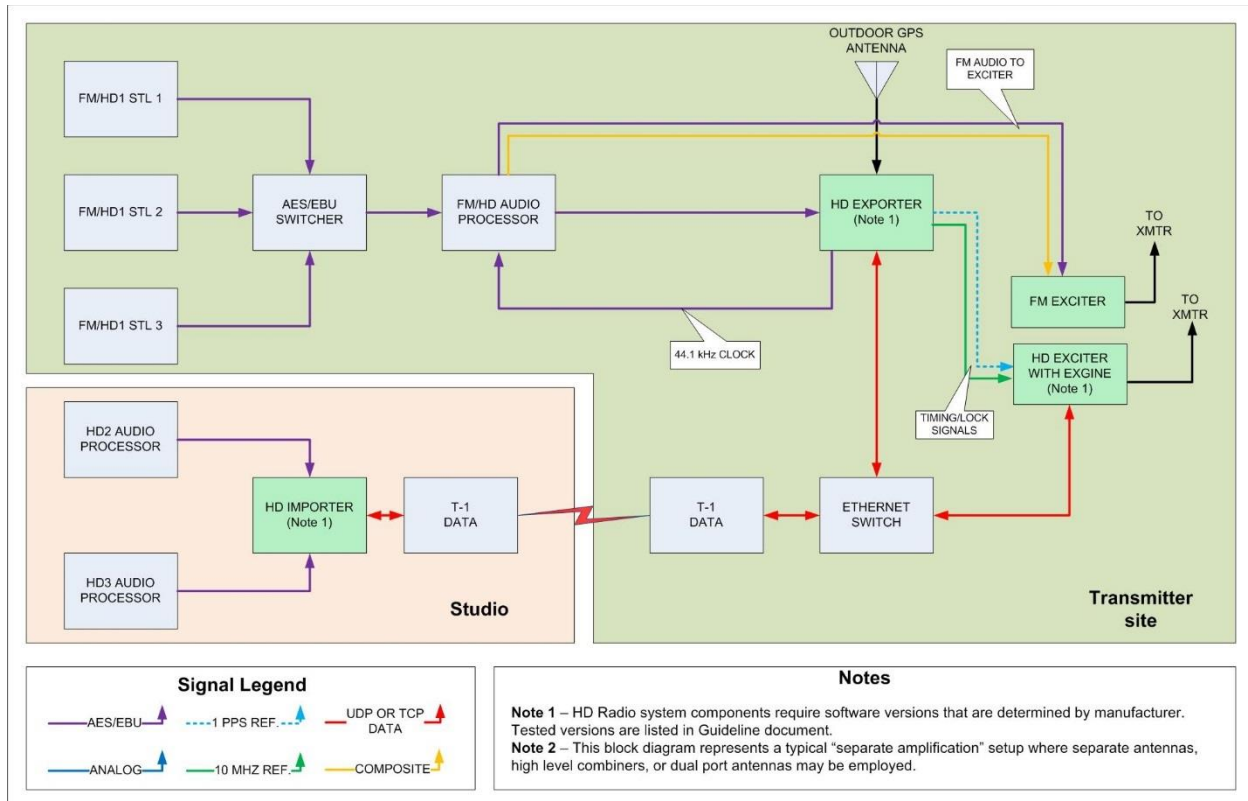


Figure 8. Exporter at transmitter site with Importer at studio with common audio processing. (See Figure 15 and Figure 17 for the recommended, automated time-aligned version of this configuration.)

With a separate Exporter and dedicated data path between the studio and transmitter, it became possible to physically locate the Exporter at the studio (Figure 9). Although this has some advantages, this architecture caused unstable timing between the analog and digital audio signals and contributed significantly to time alignment problems.

The dependency upon the network between the various HD Radio components (in particular, the Exporter and the Engine) results in a constant wandering of the timing (see for example Figure 3). In very carefully designed and managed installations, the timing errors might stay imperceptible to listeners, but these errors are still measurable. Manual timing adjustments can only temporarily correct these errors. Figure 9 shows a separate audio processor for the digital audio, which exacerbates the errors during blending between the two signals.

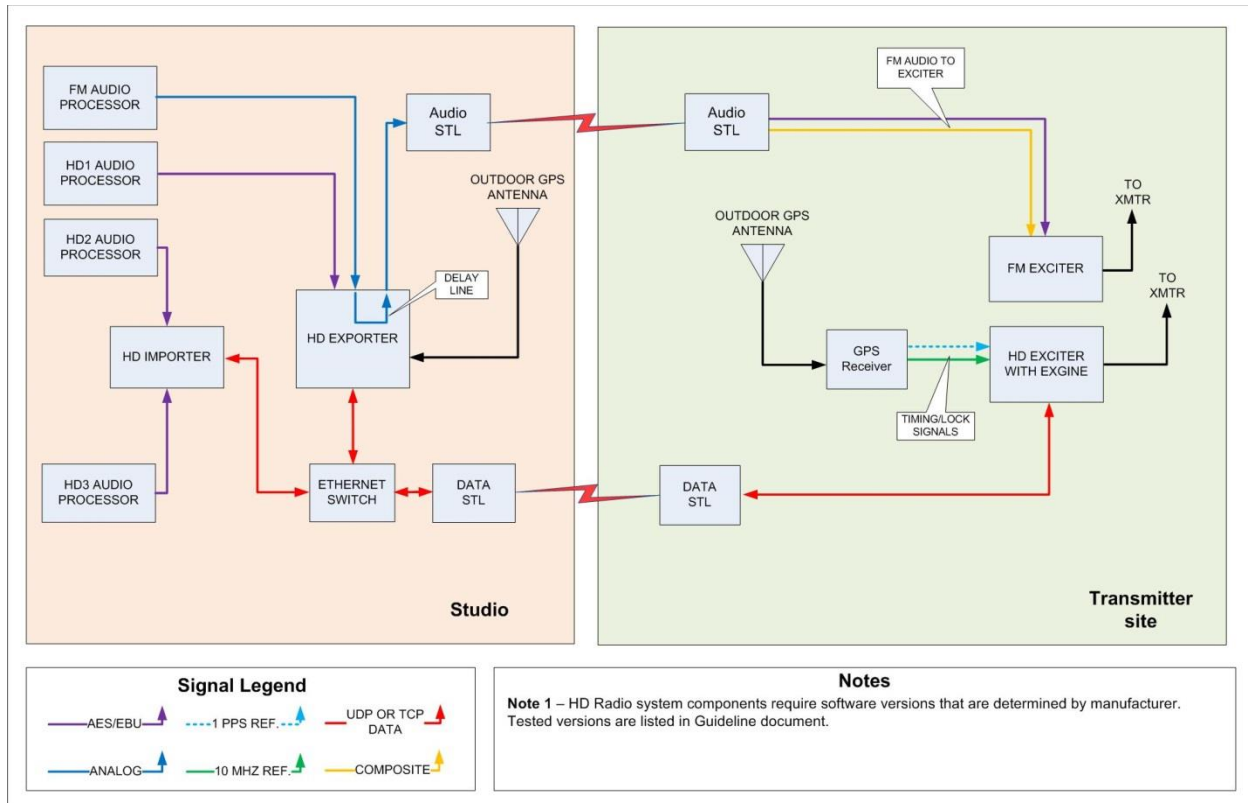


Figure 9. Exporter at studio using data STL and separate audio processing. (See Figure 20 for the recommended, automated time-aligned version of this configuration.)

Using a common analog and digital audio processor, as shown in Figure 10, helps with the blend artifacts even when the Exporter is at the studio, but does not eliminate the timing drift.

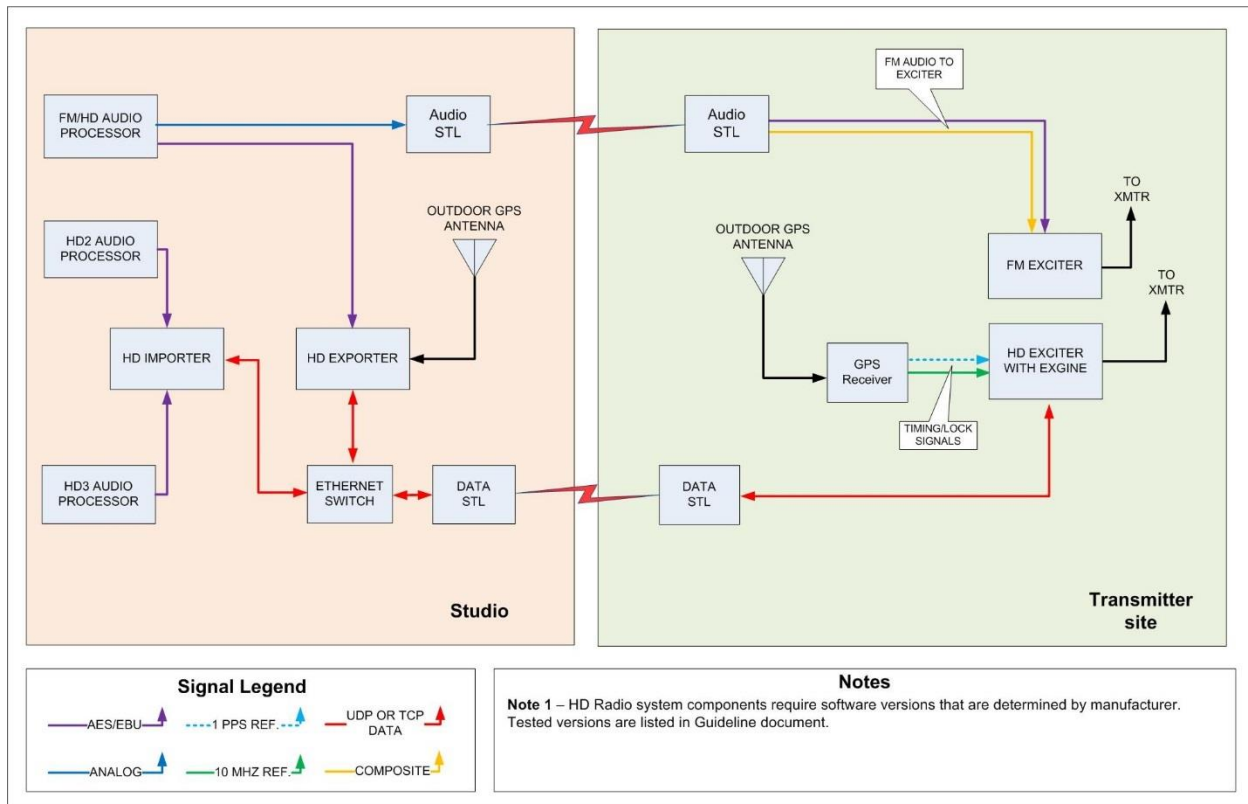


Figure 10. Exporter at studio using data STL and common audio processing. (See Figure 19 for the recommended, automated time-aligned version of this configuration.)

One use case involves a single Exporter feeding multiple transmitter sites as shown in Figure 11. This topology runs counter to the recommendations in this document. The Exporter cannot be co-located with all transmitters in this configuration, and there is presently no way to synchronize the timing of the HD Engine system from Exporter to multiple excitors within the 0 +/- 3 sample specification across multiple excitors in multiple locations. As will be discussed in Section 6.2, this configuration can support good time alignment if the time delay in the analog audio path is automatically adjusted at each transmitter site.

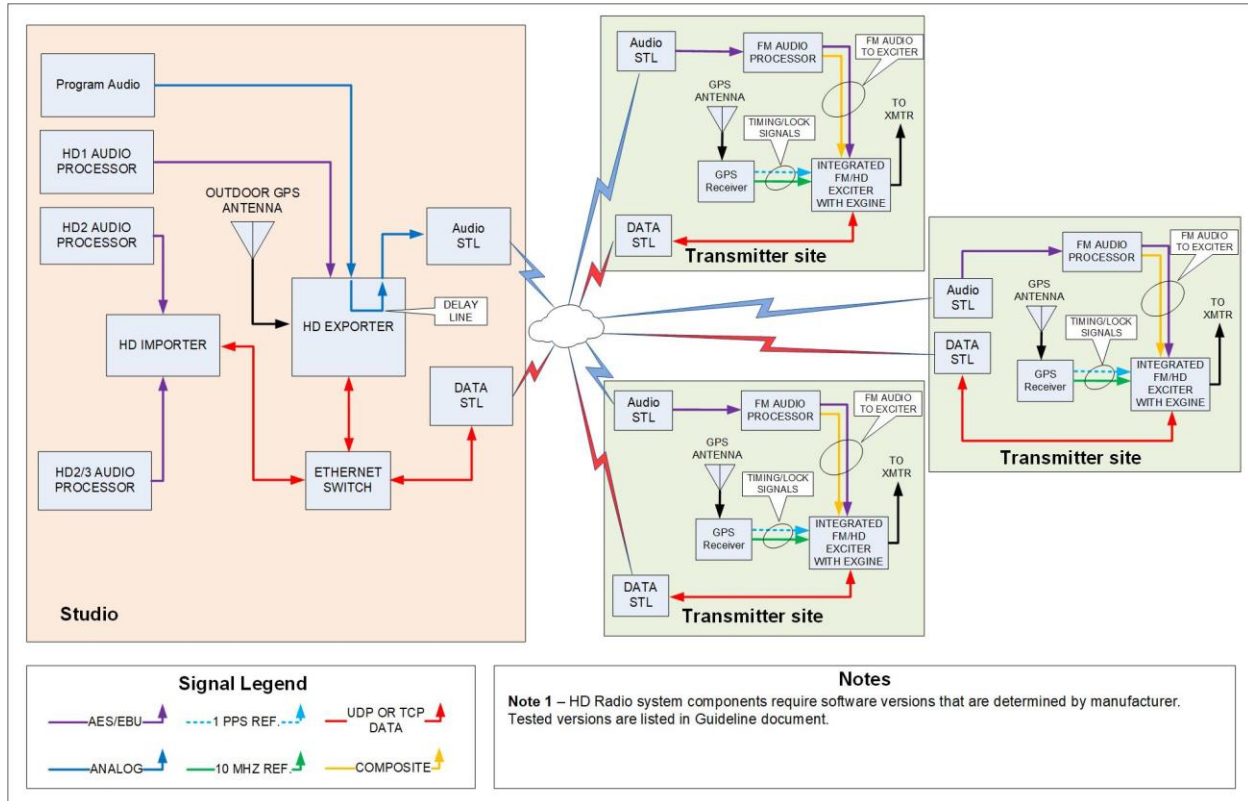


Figure 11. Single Exporter feeding multiple transmitter sites. (See Figure 23 for the recommended, automated time-aligned version of this configuration.)

5 GENERAL GUIDELINES AND BEST PRACTICES

Diagrams and suggestions included in this Section are based upon the hardware and software versions shown in Table 2.

5.1 Best practices for proper FM hybrid HD Radio time, level & phase alignment

The following suggestions are offered as recommendations to broadcast engineers as “best practices” which should be followed to help minimize time and level-delay associated issues with HD Radio transmissions:

- Review and consider the use of currently available time delay auto-alignment devices and procedures (discussed further in Section 5.2);
- Ensure HD Radio subsystems are running the latest software versions as recommended by the manufacturer (see also Table 2 for versions that were current as of the date of this publication);
- Make sure GPS connections are properly installed and operational;
- Co-locate the Exporter physically at the same site as the Exgine/Exciter (in most cases this will be the transmitter site);
- Consider co-locating the Importer with the Exporter and Exgine/Exciter if additional program link channels and LAN extension bandwidth is available;
- Carefully design the network connections between the HD Radio subsystems, including transmission hardware, physical connections, and network IP structure. It is crucial to isolate the network used for the HD Radio transmission equipment via a separate subnet and VLAN, or if your Exporter offers multiple separate interfaces, to use one interface just for the Exporter-to-Exciter network and the other for WAN/LAN/remote access and Importer connection;
- Reference the timing settings for all components according to the manufacturer directions. Pay particular attention to the device including the delay line (exciter, Exporter, audio processor, inline delay), it needs to be synchronized in order to provide stable diversity delay;
- Use an integrated, single-box main-channel analog and digital audio channel processor for setting delay and processing for digital and analog audio signals;
- Place all components on uninterruptible power supply (UPS) power outlets. This includes the exciter(s) which may need to be re-configured to an external UPS;
- Note that if the exciter is located in the transmitter, it unlikely to be operating on a UPS. In that case, use a special UPS power connection. A UPS can minimize exciter rebooting, thereby preventing time-alignment issues that will certainly arise because of the reboot. Modern digital exciters tend to take longer to reboot than other pieces of equipment (including legacy analog exciters), so reducing station downtime requires keeping these exciters on a UPS;
- Note that any interruption on the digital signal transmission path will reset delays to varying degrees. Particularly for non-auto-aligned configurations, it is paramount that the diversity delay is re-calibrated on any Exporter, exciter, for cases of link resets or drop-outs;
- Check the on-air RF signal spectrum waveform to verify proper mask compliance and carrier levels;

Table 2. Current software versions for various HD Radio transmission equipment (July 2017)

Component	Manufacturer	Model/Platform	Software version	Comments
Exciter	Broadcast Electronics (BE)	FXi-60, FXi-250	Exciter Firmware 2.xx.41 (9/17/2007) Exgine Card Firmware 4.03 (4/10/2014)	
	Broadcast Electronics (BE)	STXe 60		
	GatesAir	FAX/Flexiva	A67+ version A316 (October 17, 2016), Exgine Version X.9.29	
	GatesAir (Harris)	HDx Flexstar (Main uP)	8.45 (April 28, 2014)	
	Nautel	GV Integrated	Exgine Server Version 4.5.11_2.6 (Jun 30 2015 - 10:09:05)	
	Nautel	M50	Exgine Server Version 4.3.2_2.3 (May 13 2010 - 15:10:14)	Although newer versions exist, Nautel does not recommend Exgine upgrades above this version in most situations.
	Nautel	NV Integrated	Exgine Server Version 4.3.2_2.3 (May 13 2010 - 15:10:14)	Although newer versions exist, Nautel does not recommend Exgine upgrades above this version in most situations.
	Nautel	VS	Exgine Server Version 4.5.11_2.6 (Jun 30 2015 - 15:10:14)	
	Rohde & Schwarz	TCE900	SW 24.4.0	Updated September 2020
Exciter Accessory	GatesAir (Harris)	HDx Flexstar (DUC FPGA)	20.1 (May 26, 2016)	20.1 (if using P3 partition)
	Nautel	LVDS Adapter	Exgine Server Version 4.3.2_2.3 (May 13 2010 - 15:10:14)	Although newer versions exist, Nautel does not recommend Exgine upgrades above this version in most situations.
	Nautel	Reliable HD Transport (RHDT)	Exgine Server Version 4.3.2_2.4 (Dec 13 2010 - 12:43:28)	Although newer versions exist, Nautel does not recommend Exgine upgrades above this version in most situations.
	Rohde & Schwarz	HDR900	Exgine configuration SW 2.11	Updated September 2020

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Table 2 (continued). Current software versions for various HD Radio transmission equipment (July 2017)

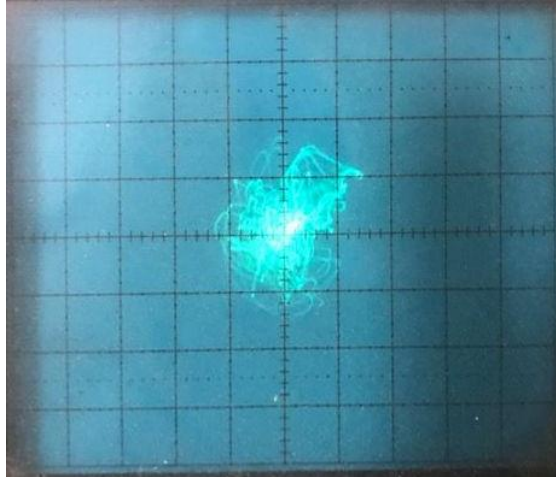
Component	Manufacturer	Model/Platform	Software version	Comments
Exporter	Broadcast Electronics (BE)	XPi 10	4.3.2.1p5 (June 2012)	
	Broadcast Electronics (BE)	XPi 10esp	1.05 (July 30, 2015)	
	GatesAir (Harris)	HDE200	4.4.7.1 (March 5, 2012) 4.4.7.2 (June 5, 2014)	4.4.7.1(or higher for Flexstar) 4.4.7.2 (minimum for FAX)
	Nautel	HD Multicast Importer/Exporter	1.0.0.0 IRSS5.0.4.1	
	Nautel	ExporterPlus (NAE97E)	ExpPlus 1.9.0.1 (June 10, 2014) IRSS 4.4.7.0 Host 1.9.0.1 User If 1.9.0.1 FPGA 2.0.21	
	Rohde & Schwarz	HDR900 Exporter/Importer	SW 2.11	Updated September 2020
Importer	Broadcast Electronics (BE)			
	GatesAir (Harris)	HDI200	4.4.7 (10/30/2012)	
	Nautel	HD Multicast Importer/Exporter	1.0.0.0 IRSS5.0.4.1	
	Nautel	Importer Plus	2.4 IRSS4.4.7	
	Nautel	HD Multicast Importer	2.5 IRSS4.4.7	
	Rohde & Schwarz	HDR900 Exporter/Importer	SW 2.11	Updated September 2020

- If you use a time delay auto-alignment device with variable correction rate, limit its correction rate to 50 samples per second or slower to prevent excessive pitch shifting during correction. This will prevent audible pitch-shift artifacts and will protect the Nielsen Audio ratings encoder watermark, if used by the station;
- Discipline the audio processor or delay line with a GPS-referenced signal, could be Exporter 44.1 kHz word clock.

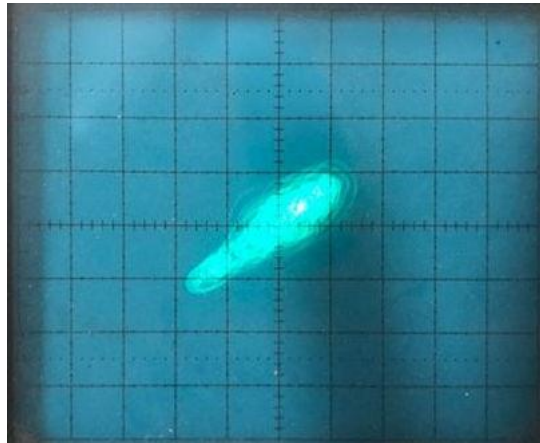
5.2 Suggested procedures for manual hybrid FM HD Radio time alignment

The following suggestions are offered as recommendations to broadcast engineers for manual time-aligning the main channel analog and digital audio signals for hybrid FM HD Radio stations that are unable to use automatic methods. Manual alignment will probably drift so it needs to be checked regularly; just how regularly depends upon the architecture of the radio station:

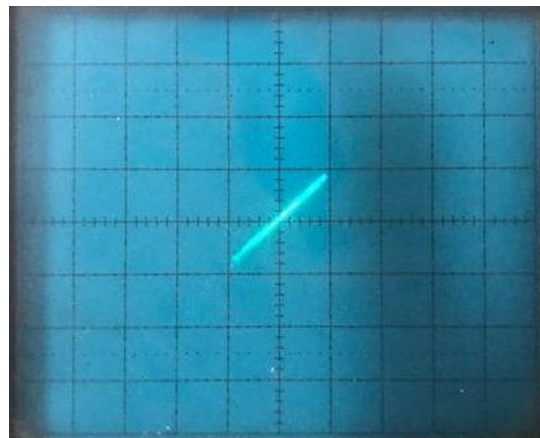
- After rebooting or reconfiguring HD Radio transmission components, wait before adjusting the time delay. This is very important in any configuration that is using Exporter-to-Exciter (E2X) clocking, i.e., when the Exporter is not co-located with the exciter. Most systems take several minutes to several hours to establish a stable delay;
- If available, use a precision diversity delay monitor that can show continuous measurements to detect any drifting before making manual corrections;
- When using an older monitor that provides single-point-in-time measurements, make several measurements over time to ensure the setup is stable before making a manual adjustment;
- Use a receiver in split mode, where one channel output is the analog FM and the other channel is the digital HD1:
 - Connect an oscilloscope to the output of the split tuner in X-Y mode and obtain the proper Lissajous plot (see for example Figure 12 through Figure 14);
 - These figures are showing analog L+R versus digital L+R;
 - Using headphones in split mode is an option of “last resort.”



**Figure 12. Alignment Lissajous pattern showing error of 10 samples (227 μ s).
Display of analog L+R versus digital L+R.**



**Figure 13. Alignment Lissajous pattern showing error of 4 samples (91 μ s).
Display of analog L+R versus digital L+R.**



**Figure 14. Alignment Lissajous pattern showing no alignment error.
Display of analog L+R versus digital L+R.**

5.3 Additional comments on appropriate level of precision for time alignment

The NRSC-5 specification to time align the diversity delay between the FM and HD1 audio to within 68 us (or 3 audio samples) minimizes the audible effects of comb filtering audio frequency content during the blend process.⁶ At a delay difference of 3 audio samples, audio content at 7.3 kHz is affected; at an audio delay of 30 samples audio content at 730 Hz and at intervals of 1.46 kHz beyond this are affected, causing audible artifacts during the blend process.⁷

As the delay difference is increased beyond 100 samples (2.27 ms), the blend artifacts subjectively improve as the two audio streams increasingly become de-correlated. Depending on audio content, blend artifacts are subjectively minimized when approaching about 4 ms (176 samples) of delay difference. The maximum delay difference should be maintained below 10 ms (441 samples) to avoid noticeable audio skips and repeats. Audio listening tests are required to evaluate the impact of the subjectively perceived blend artifacts over varying delay offsets, rate of change of delay, audio content and audio processing; the numbers provided in this section are more “anecdotal” than well-established; additional work would be necessary to better define exact values.

It is best practice to ensure diversity delay alignment always falls within the NRSC specification of 3 audio samples, which realistically can only be achieved by following the recommended guidelines presented in this document, including paying attention to minimizing audio phase differences when processing the FM and HD1 audio. Closed-loop delay buffer management is often a necessary requirement to meet these stringent specifications.

The NRSC is currently discussing these topics and may have a recommendation on some relaxed specifications that would consider these observations.

6 METHODS FOR AUTOMATED TIME AND LEVEL ALIGNMENT

There are several available methods for automating time, level and phase alignment to maintain long-term stability. These methods fall into two categories, “in-line” and “monitor-based,” and will be detailed below. Within each of these two categories, choices are available regarding manufacturer and topology (Section 7 provides a list of currently available alignment equipment).

In-line correction methods (see Figure 15 and Figure 16) adjust time, level and phase of the signals while providing information that facilitates technical analysis of the alignment performance of the overall system. The automated adjustment can be applied to either the main channel analog or digital audio channels. although the suggestion is to insert the device into the digital audio channel because the majority of listening is still analog, and adjusting the delay on-air can cause audible artifacts in some configurations. Moreover, any failure of the device would impact the digital audio channel and thus minimize the impact on the audience.

Monitor-based correction methods (see Figure 17 and Figure 18) can measure and send correction signals to more than one radio station and can send the correction data to either a station’s Exporter or the audio processor (analog, digital or combined). Take into account software versions, equipment compatibility, and placement in the correct networking environment. Typically, a monitor-based correction system adjusts only time alignment automatically, leaving the audio and level adjustments to the engineer to adjust manually. Audio phase and level typically remain stable once adjusted, and because it is possible to adjust multiple radio station signals using a single correction device, the monitor correction system may be the best option. Active in-line correction can only correct one station although it corrects for all three variables.

Table 3 is a summary of the correction methods and station configurations described in this Section.

⁶ See NRSC-5 reference document 1026s, Section 4.3.1, Analog Diversity Delay.

⁷ See Annex 2, Figures 1-3 for an illustration of these artifacts.

Table 3. Correction methods and station configurations described in this Section.

Figure	Correction	Analog and digital audio processors		Audio processor and Exporter location		Comments
	Type	Separate†	Combined	Studio†	Transmitter	
Figure 15	In-line		✓		✓	Preferred in-line approach
Figure 16	In-line	✓			✓	
Figure 17	Monitor-based		✓		✓	Preferred monitor-based approach
Figure 18	Monitor-based	✓			✓	
Figure 19	In-line		✓	✓		
Figure 20	In-line	✓		✓		
Figure 21	Monitor-based		✓	✓		
Figure 22	Monitor-based	✓		✓		
Figure 23	In-line	✓			✓	

† Not recommended

6.1 Automated correction methods for Exporter/Exgine/audio processor at transmitter

Combined with following the best practices described in Section 5.1, an active alignment solution can continuously correct time, level and phase between the analog and digital audio signals. The correction device must receive a clean off-air signal and can be placed into either the analog or digital air chain. Figure 15 shows use of an in-line correction method where a single audio processor is used and where the Exporter and the Exgine are co-located at the transmitter. Figure 16 shows this same configuration except with separate analog and digital audio processors (not recommended). These configurations are also useful for a station that is using space-combining (dual antennas).

It is suggested that the correction device be placed in the digital signal path and that about 1 second of excessive delay be added to the delay line in the processor (or Exporter delay line, if used), allowing the device to adjust the digital signal. Placing the correction device in the digital audio path reduces the risk to the station if the device were to fail for some reason since, at the time of this writing, the percentage of consumers listening to analog is still greater than the digital signal.

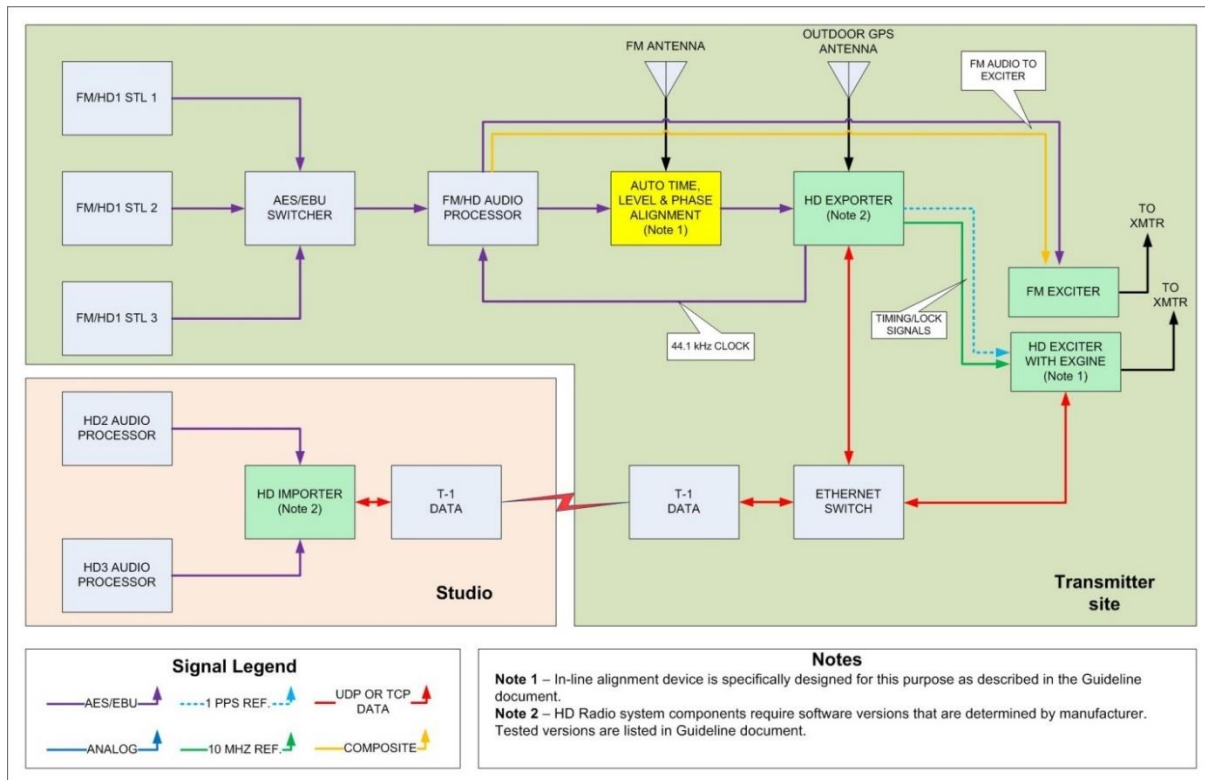


Figure 15. Exporter, Exigne and common audio processor located at transmitter with in-line auto correction.

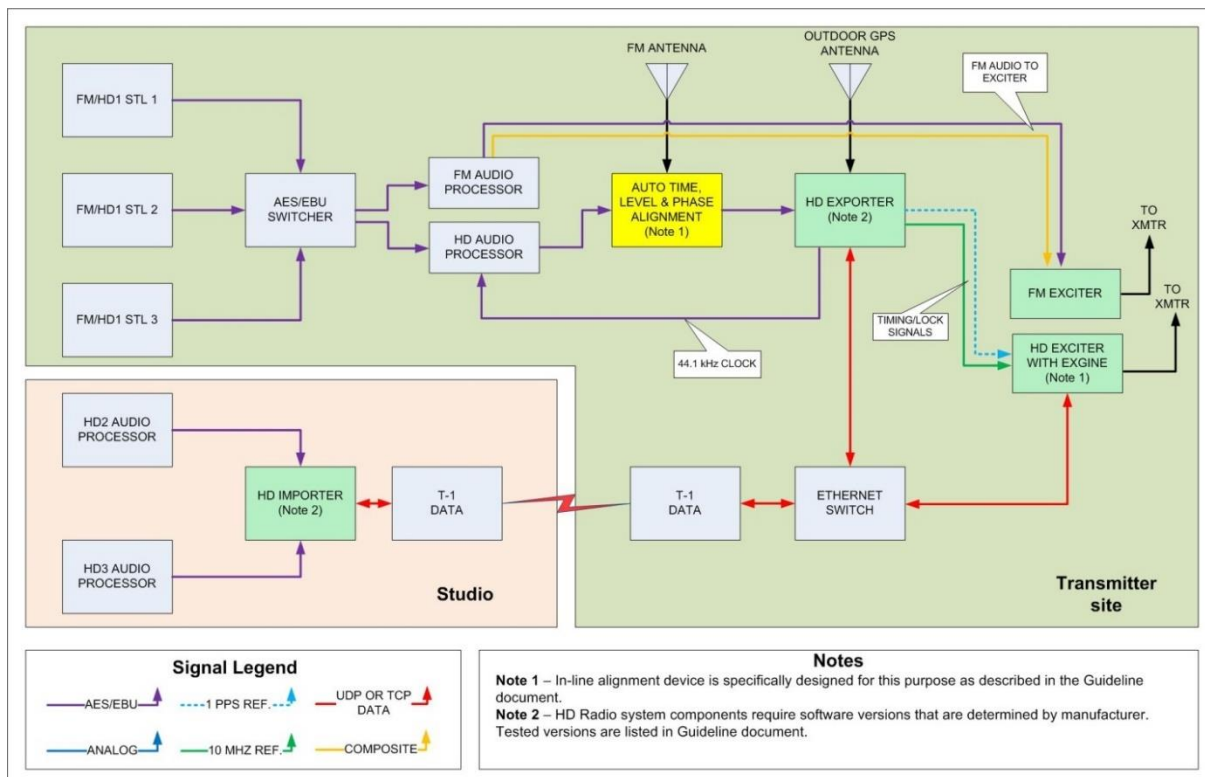


Figure 16. Same as Figure 15 except with separate audio processors. Note that use of separate audio processors is not recommended as it is then harder to achieve good time alignment.

Using a modulation monitor to automate timing correction is another option (shown in Figure 17 with a single-box audio processor and in Figure 18 with separate audio processors). The modulation monitor analyzes the analog and digital main channel audio signals and generates a correction signal that is sent to the device containing the delay line. The delay line can be in either the audio processor or the Exporter.

A benefit of this method is that the modulation monitor can sample and correct multiple stations if the stations' off-air signals and the networking to the delay line device are properly configured. This method only corrects timing errors, not phase or level errors, although phase and level matching are typically one-time adjustments.

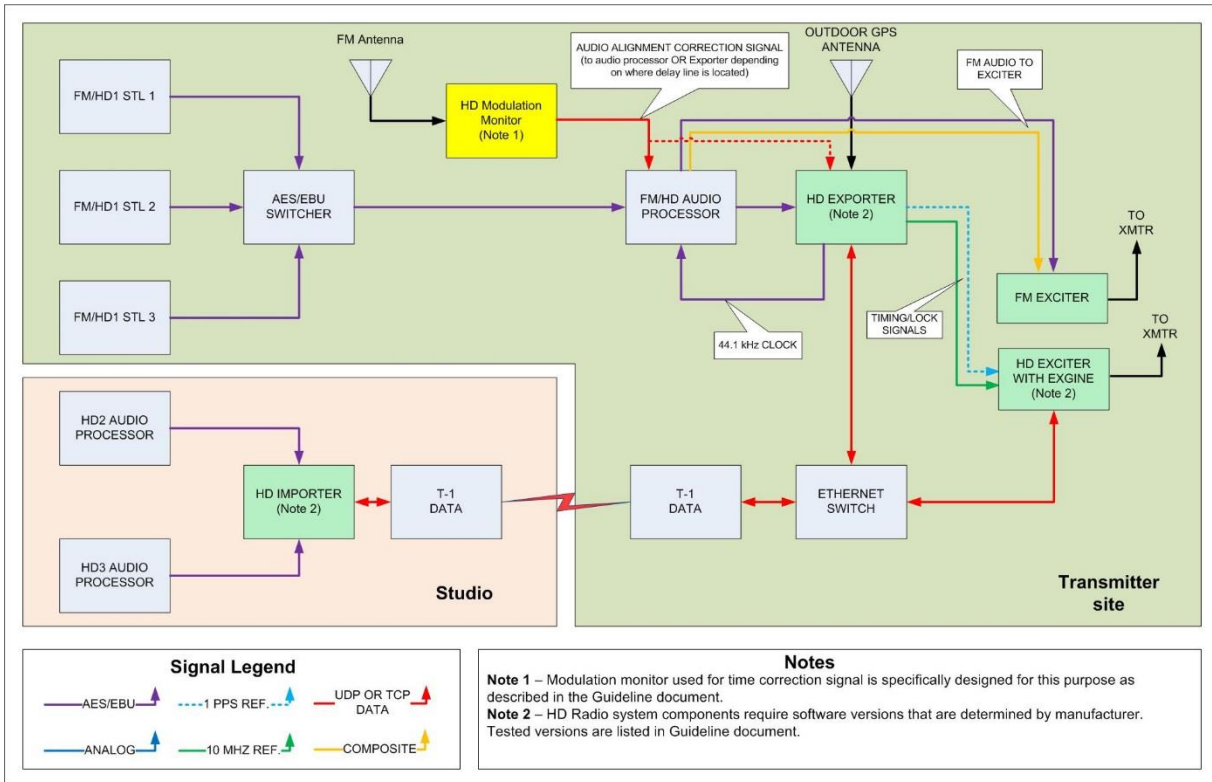


Figure 17. Exporter, Engine and audio processor located at transmitter with monitor-based auto correction.

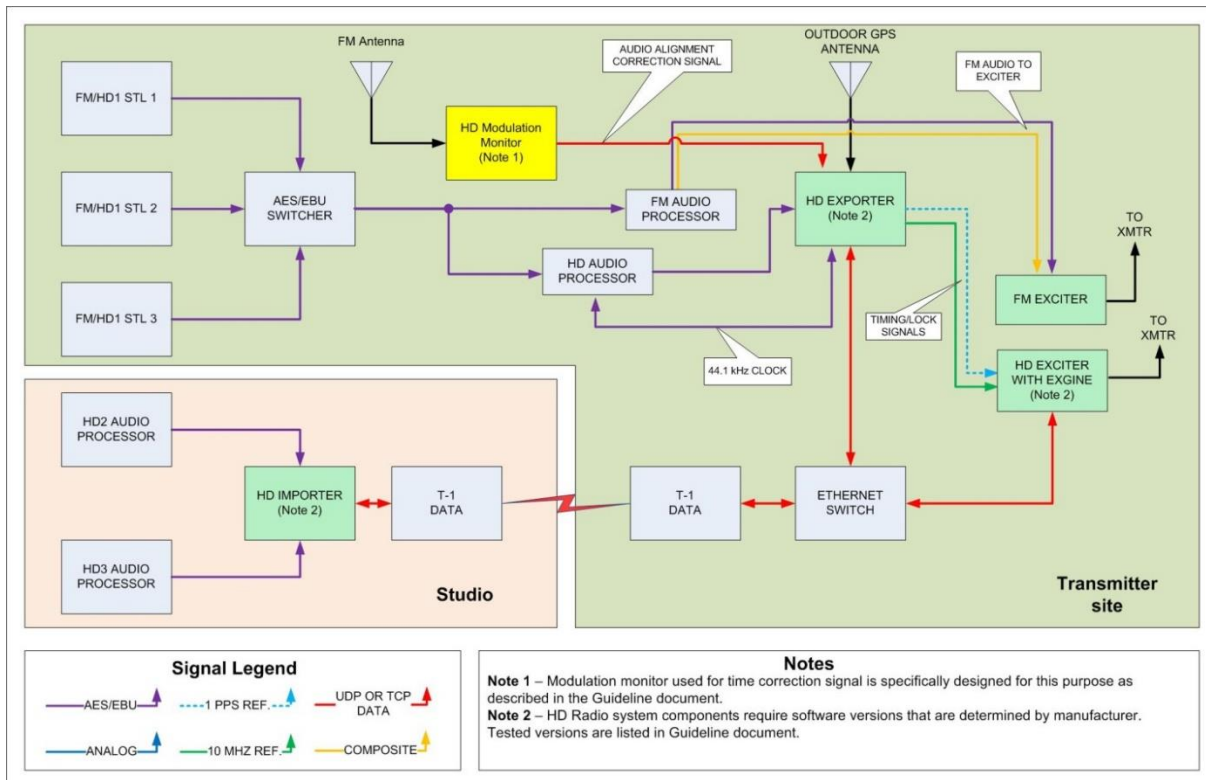


Figure 18. Same as Figure 17 except with separate audio processors. Note that use of separate audio processors is not recommended as this is a more difficult configuration for achieving good time alignment.

6.2 Automated correction methods for Exporter/audio processor at studio

As previously discussed, one of the principal recommendations in this Guideline is to co-locate the Exporter and the exciter (Exgine) at the transmitter. This configuration will provide the best possible analog and digital main channel audio signal alignment. However, for a variety of reasons a broadcaster may have to place the Exporter (and audio processors) at the studio and the exciter (Exgine) at the transmitter, connected by an STL.

As in the case where the Exporter and exciter are co-located, an active alignment solution in the air chain can continuously correct time, level and phase between the analog and digital audio signals if the best practices described in Section 5.1 are followed. The correction device must receive a clean off-air signal and can be placed into either the analog or digital air chain. Figure 19 shows use of an in-line correction method for the situation where a single audio processor is used and where the Exporter and the Exgine are co-located at the transmitter; Figure 20 is similar except with separate audio processors. These configurations are also useful for a station that is using space-combining (dual antennas).

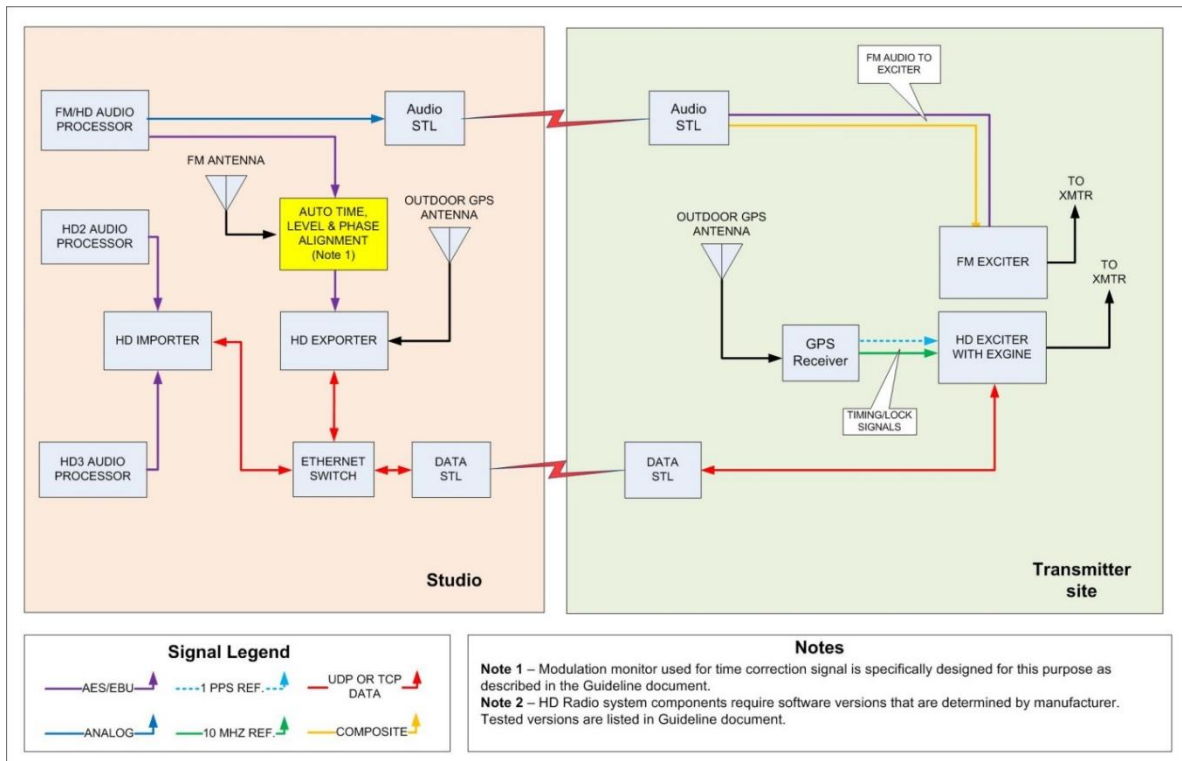


Figure 19. Exporter and audio processor located at studio, Exgine located at transmitter utilizing in-line auto correction.

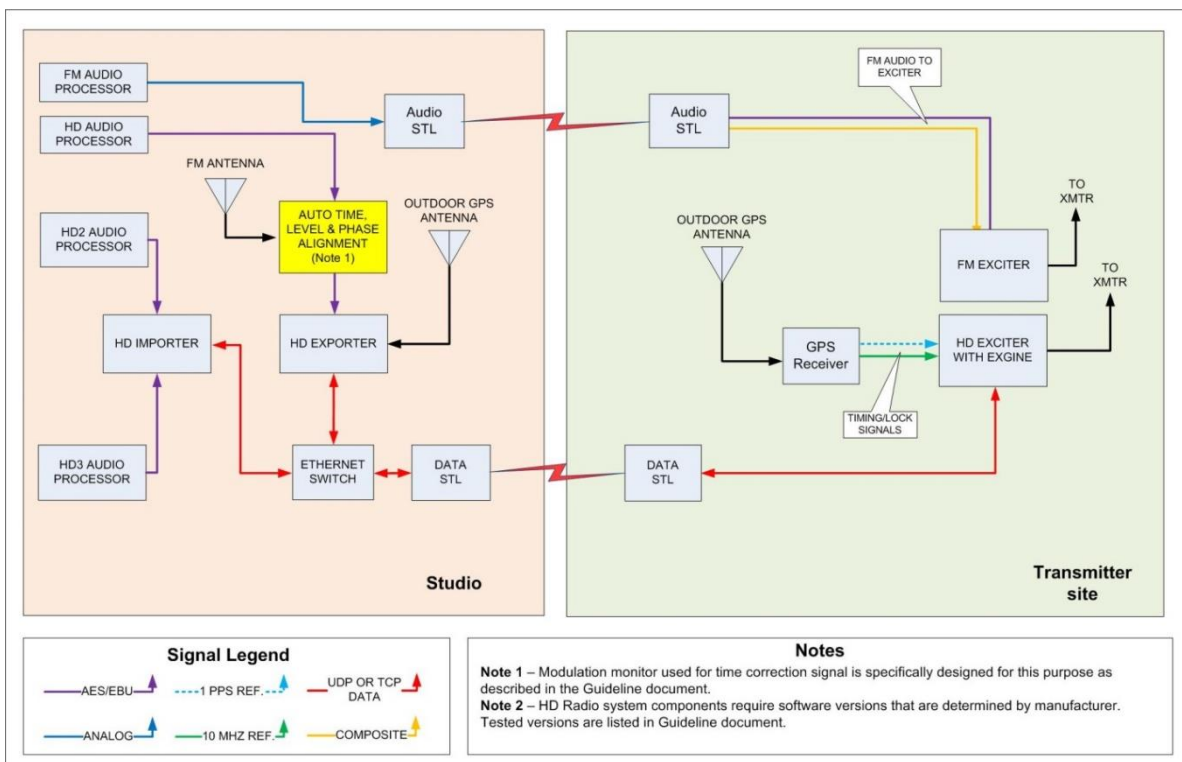


Figure 20. Same as Figure 19 except with separate audio processors. Note that use of separate audio processors is not recommended as it is then harder to achieve good time alignment.

As previously noted in Section 6.1 for the case where the Exporter and exciter are co-located, it is suggested that the correction device be placed in the digital signal path and that about 1 second of excessive delay be added to the delay line in the processor (or Exporter delay line, if used), allowing the device to adjust the digital signal. Placing the correction device in the digital audio path reduces the risk to the station if the device were to fail for some reason since, at the time of this writing, the percentage of consumers listening to analog is still greater than the digital signal.

Using a modulation monitor to automate timing correction is another option (shown in Figure 21 with a single-box audio processor and in Figure 22 with separate audio processors). The modulation monitor analyzes the analog and digital main channel audio signals and generates a correction signal that is sent to the device containing the delay line. The delay line can be in either the audio processor or the Exporter.

A benefit of this method is that the modulation monitor can sample and correct multiple stations if the stations' off-air signals and the networking to the delay line device are properly configured. This method only corrects timing errors, not phase or level errors, although phase and level matching are typically one-time adjustments.

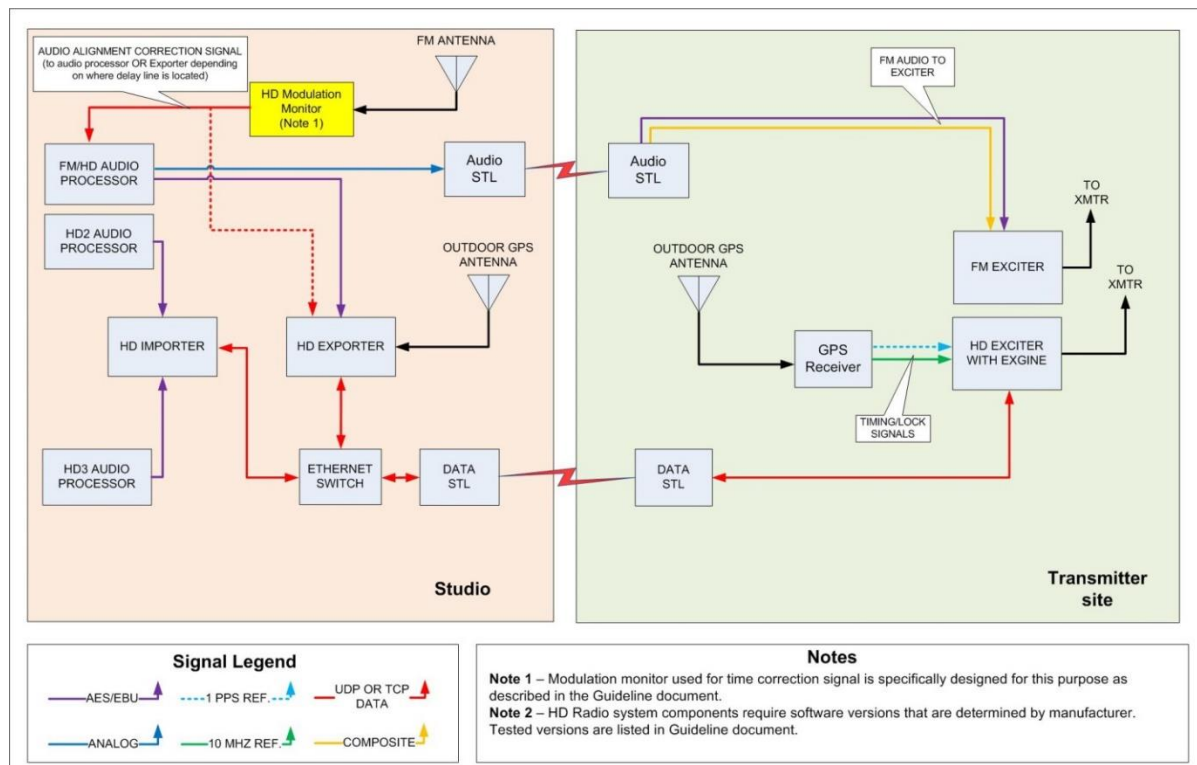


Figure 21. Exporter and audio processor located at studio, Engine located at transmitter utilizing monitor-based auto correction.

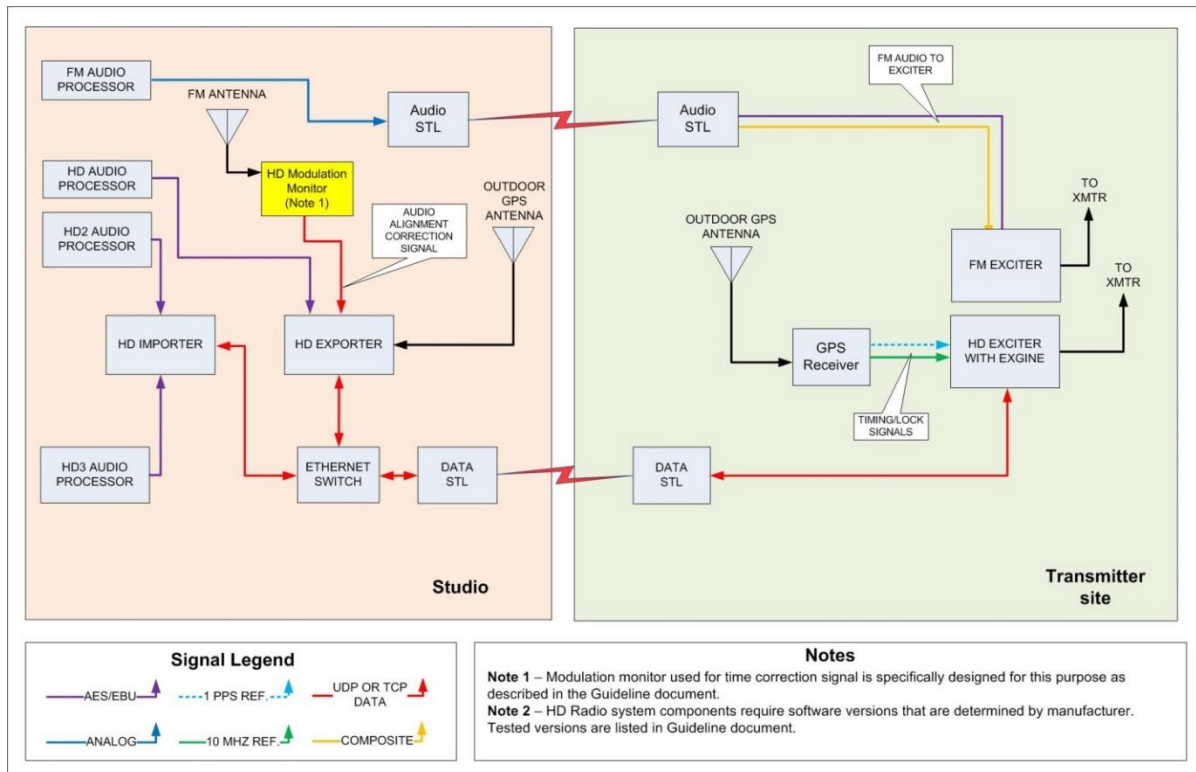


Figure 22. Same as Figure 21 except with separate audio processors. Note that use of separate audio processors is not recommended as it is then harder to achieve good time alignment.

For the single Exporter feeding multiple transmitter locations (shown in Figure 11), providing GPS lock for all the excitors and installing alignment correction devices in the analog audio path at each transmitter site should provide for acceptable time alignment as shown in Figure 23. An improvement on the configuration shown in Figure 23 would be to use a single audio processor (at the studio) and distribute an uncompressed PCM (e.g., AES, note that composite audio would not work here) signal to all of the transmitter sites, to feed the automatic correction devices which then feed the excitors.

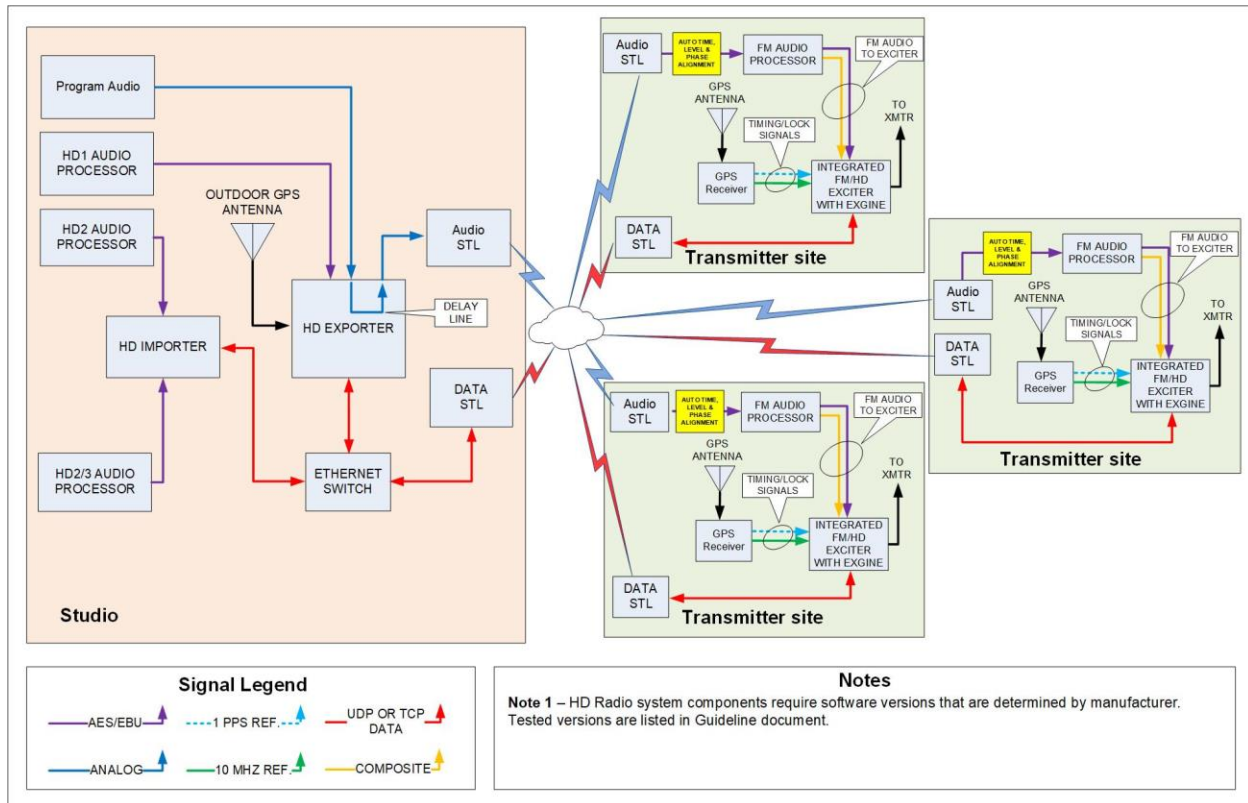


Figure 23. Single Exporter feeding multiple transmitter sites, corrected by placing in-line alignment device in analog audio path at each transmitter site.

7 LIST OF EXISTING MONITORING AND ALIGNMENT SOLUTIONS

Table 4 is a list of auto-alignment products available at the time this Guideline was published. Many of these products have been evaluated by the members of this Working Group (as noted in the column marked "Tested"). Software versions of the various components as released by the manufacturers are also indicated (when available). There will likely be refinements in both equipment and software versions as an ongoing improvement process and it is highly recommended that broadcast engineers check with their equipment suppliers to make sure the latest approved software is in use.

Table 4. Auto-alignment products

No.	Type	Manufacturer	Model	Version(s)	Description	Tested by NABRTC	Comments
1	Monitor	Inovonics	JUSTIN 808	1.1.0.2	In-line corrector	Yes	• Single station, time/level/phase • Continuous graphing with logging http://www.inovonicsbroadcast.com/model/808
2	Monitor	Belar	FMHD-1	6.05, 6.62	Correction signal generator	Yes	• Multi-station time only • Can graph 30 minutes of data http://www.belar.com/FMHD-1/hdradio.htm
3	Monitor	DaySequerra	M4DDC	(not tested)	In-line corrector	No	• Single station, time/level/phase • Can graph 30 minutes of data http://daysequerra.com/Home1.aspx
4	Monitor	DaySequerra	M4.2 TimeLock	(not tested)	Correction signal generator	No	http://daysequerra.com/Home1.aspx
5	Monitor	Worldcast (Audemat)	Golden Eagle HD	(not tested)	Correction signal generator	No	• When paired with 25/7 Precision Delay (no. 6 in this table) • Legacy product, out of production
6	Audio delay	25/7	Precision Delay	(not tested)	Audio delay	No	When paired with GoldenEagle HD (no. 5 in this table) https://www.telosalliance.com/25-Seven/Precision-Delay
7	Audio processor	Omnia	6	(not tested)	Audio processor with time delay	No	• Legacy product, out of production
8	Audio processor	Omnia	7	(not tested)	Audio processor with time delay	No	https://www.telosalliance.com/Omnia/Omnia7FM
9	Audio processor	Omnia	9	(not tested)	Audio processor with time delay	No	https://www.telosalliance.com/Omnia/Omnia9
10	Audio processor	Omnia	11		Audio processor with time delay	Yes	• Tested with Belar FMHD-1 (no. 2 in this table) https://www.telosalliance.com/Omnia/Omnia11
11	Audio processor	Orban	8500S		Audio processor with time delay	Yes	• Tested with Belar FMHD-1 (no. 2 in this table) http://www.orban.com/orban/products/radio/fm/8500s/
12	Audio processor	Orban	8600		Audio processor with time delay	Yes	• Tested with Belar FMHD-1 (no. 2 in this table) http://www.orban.com/orban/products/radio/fm/8600/

Table 4 (continued). Auto-alignment products

No.	Type	Manufacturer	Model	Version(s)	Description	Tested by NABRTC	Comments
13	Audio processor	Wheatstone	AirAuraX3	(not tested)	Audio processor with time delay	No	http://www.wheatstone.com/audio-processing1/on-air-processing/airaura-x3
14	Audio processor	Wheatstone	FM-531HD	(not tested)	Audio processor with time delay	No	http://www.wheatstone.com/audio-processing1/on-air-processing/fm-531hd
15	Audio processor	Wheatstone	FM-55	(not tested)	Audio processor with time delay	No	http://www.wheatstone.com/audio-processing1/on-air-processing/fm-55
16	Audio processor	Wheatstone	AM-55	(not tested)	Audio processor with time delay	No	http://www.wheatstone.com/audio-processing1/on-air-processing/am-55
17	Audio processor	Wheatstone	VP8ip	(not tested)	Audio processor with time delay	No	• Legacy product, out of production
18	Exporter	GatesAir (Harris)	HDE-100	(not tested)	Exporter	No	• Legacy product, out of production
19	Exporter	GatesAir (Harris)	HDE-200	5.0.0.2	Exporter	Yes	• Tested compatibility with Belar FMHD-1 http://www.gatesair.com/products/transmit-radio/fm-transmitters/flexstar-hde-200
20	Exporter	Broadcast Electronics	XPi-10	(not tested)	Exporter	No	• Legacy product, out of production http://www.bdcast.com/products/details/fm-hd-radio-signal-generators/xpi-10
21	Exporter	Broadcast Electronics	XPi-10s	(not tested)	Exporter	No	• Legacy product, out of production
22	Exporter	Broadcast Electronics	XPi-10esp	(not tested)	Exporter	No	http://www.bdcast.com/products/details/fm-hd-radio-signal-generators/xpi-10esp
23	Exporter	Continental	800Exp	(not tested)	Exporter	No	http://www.contelec.com/fm800expembfeatures.htm
24	Exporter	Nautel	Exporter Plus		Exporter	Yes	• Tested with Belar FMHD1 http://www.nautel.com/solutions/digital-radio/hd-radio/
25	Exporter	Rohde & Schwarz	HDR900/R&S HD Sync	SW2.11	Exporter with integrated time delay	No	Added September 2020

8 FUTURE ACTIVITIES

This Guideline was created to help broadcast engineers improve the performance of existing HD Radio stations, hence improving the consumer experience with hybrid HD radio broadcasts. Broadcasters who follow the recommendations contained herein and who invest in the equipment necessary to provide for automated alignment of their stations should usually be able to solve their time and level alignment problems.

While the descriptions and examples included herein are focused on FM hybrid HD Radio, these alignment problems also occur with the AM hybrid HD Radio system as well (but to a lesser degree since the AM hybrid HD Radio architecture is less susceptible to drifting). This Guideline focuses on FM stations since the majority of HD Radio system installations are for FM radio. A future version of this Guideline is anticipated that will expand the discussion to include a more explicit treatment of AM stations and hardware.

The NABRTC is actively involved in helping to develop “next-generation” HD Radio equipment, to insure that this equipment provides for inherent time and level alignment capabilities without relying on external solutions (as is presently the case). Additional goals for this next generation of HD Radio transmission equipment include lower acquisition and operation costs, making the transition to digital radio more desirable and affordable for the many broadcasters who have yet to participate in this transition.

ANNEX 1 – Manufacturer Specific Direct Clocking Instructions

This Annex provides some of the configuration settings required in the engineering user interfaces of some HD Radio exciter products, for setting up direct clocking from 10 MHz or 1pps. Note, not only is a physical connection for the 10 MHz and, when applicable, the 1pps signals required between the Exporter and the exciter, but often the exciter must be configured in order to use these signals, as well.

It turns out that many radio stations have the physical connections made for supporting direct clocking, without properly configuring the exciters to use these connections. Misconfigured exciters could be using an internal oscillator causing a free-run drifting situation, or could be using the Ethernet-based Exporter to exciter (E2X) clocking protocol. Either of these conditions can result in time alignment drifting beyond specification.

The products listed in Table 1 are discussed in this Annex. Please contact the NRSC (nrsc@nab.org) to request inclusion of additional products or any changes or corrections to the information provided.

Table 1. Exciter products included in this Annex

No.	Manufacturer	Product	Date added
1	Broadcast Electronics	FXi 60, FXi 250 FM+HD Radio Exciter	2017-07-24
2	GatesAir	Flexiva Exgine Exciter	2017-07-24
3	GatesAir	FlexStar Exgine	2017-07-24
4	Nautel	Exgine	2017-07-24

Broadcast Electronics (BE) FXi 60, FXi 250 FM+HD Radio Exciter Configuration

- 1) Physically connect 10 MHz output sample of the Exporter to the exciter's 10 MHz input on the rear panel.
- 2) On the front panel, press "FREQ", and ensure 10 MHz reference is set to external.
- 3) If internal, Press "External Reference Button" so that external is shown on the display, as per below in Figure 1.

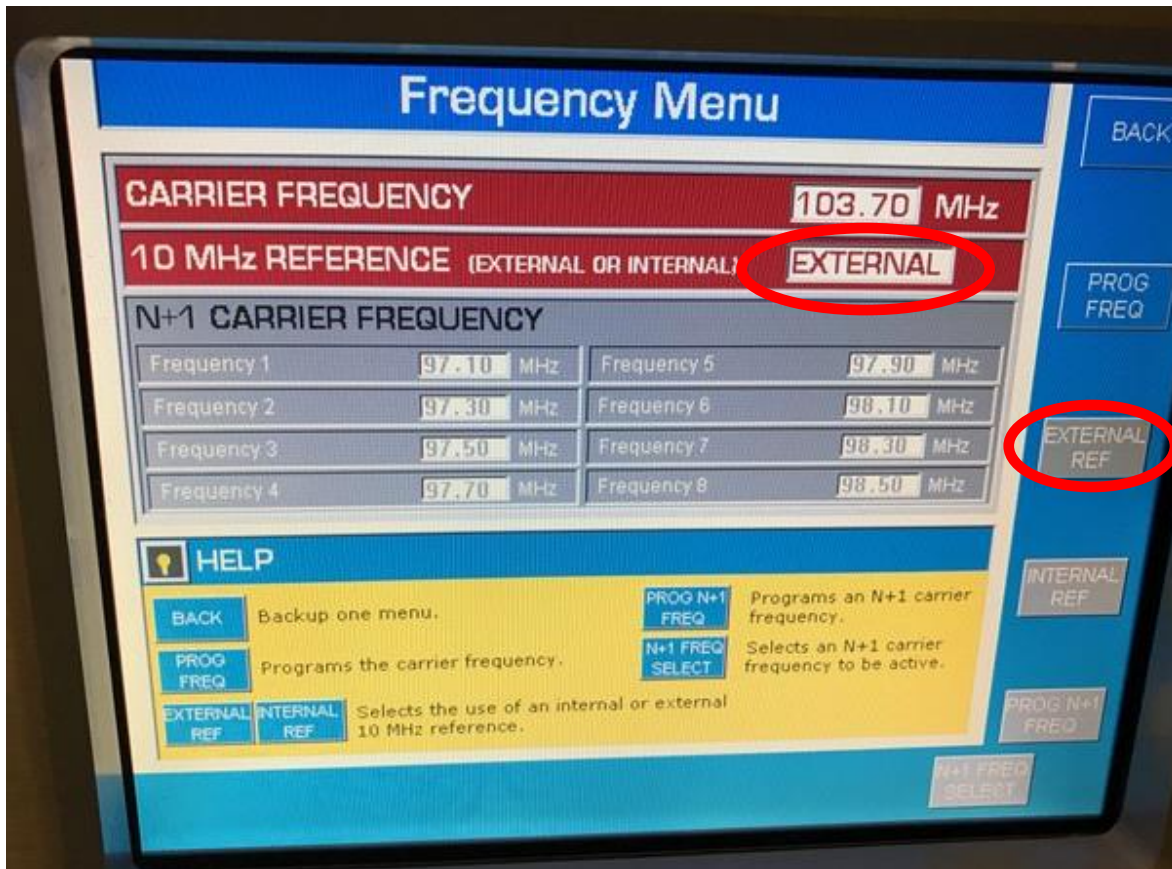


Figure 1. Broadcast Electronics (BE) FXi FM+HD Radio Exciter configuration.

GatesAir Flexiva Engine Exciter Configuration

1) Physically connect 10 MHz output sample of the Exporter to the exciter's 10 MHz input on the rear panel. Note: It has been found [Mini Circuits BLP-10.7+ Low Pass Filter](#) is required for time alignment stability between the Nautel ExporterPlus 10 MHz output and the Flexiva 10 MHz input. It is recommended to place this filter right at the BNC 10 MHz sample input of the Flexiva exciter.

2) When possible, physically connect 1pps output sample of the Exporter to the exciter's 1pps input on the rear panel. (This is possible when connecting the HDE-100 or HDE-200 to the Flexiva, it is not possible if using another brand Exporter, see notes below).

A67+ (October 17, 2016) with Exgine x.9.29 or greater for best time alignment stability:

1) From the web interface, select exciter -> Exgine-> Clock Reference -> Reference -> Exciter (should show locked, see Figure 2).

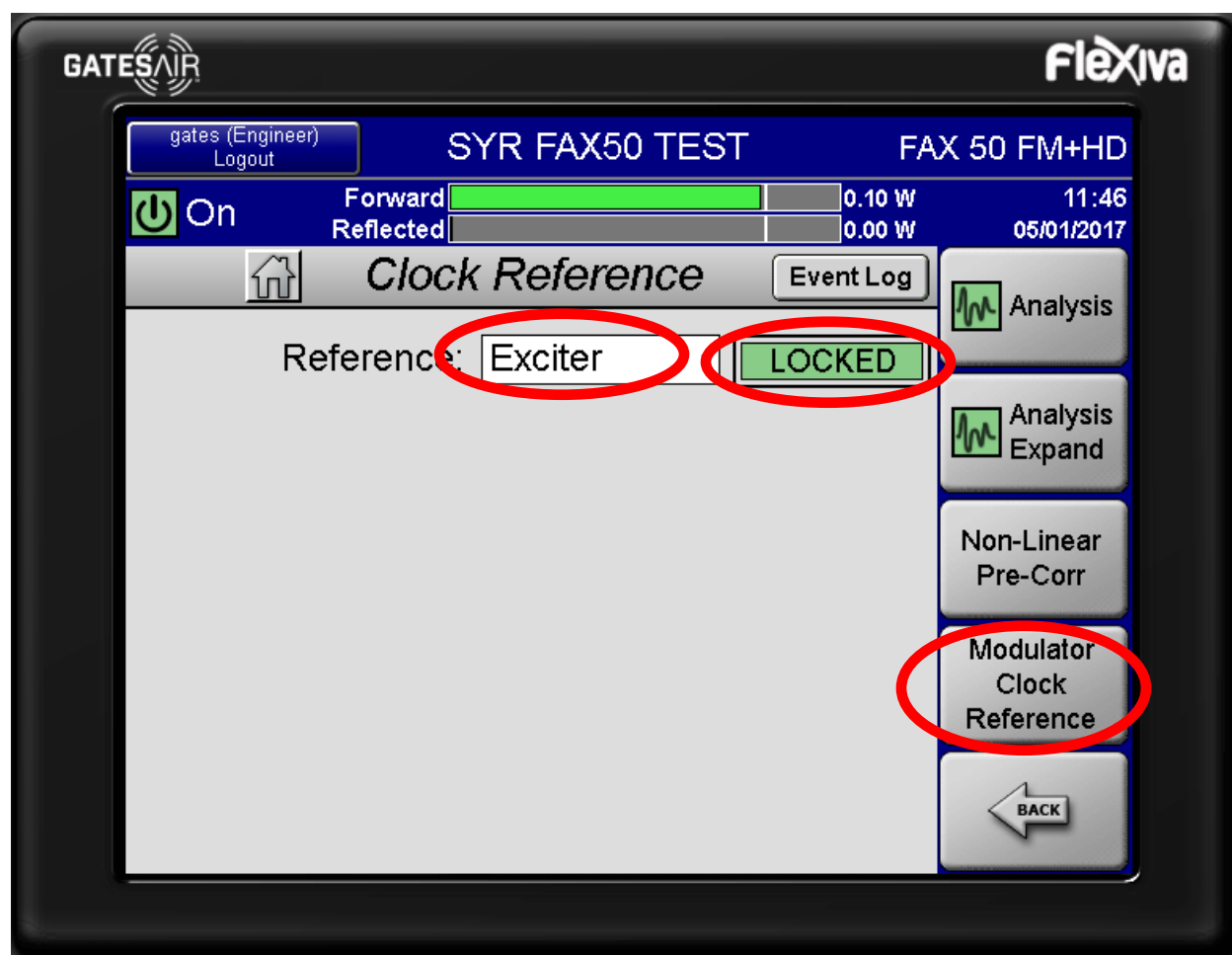


Figure 2. GatesAir Flexiva Engine Exciter Configuration

2) From there, click Modulator Clock Reference

3) From there, click Setup

4) Most Flexiva exciter installations do not include the optional GPS card in the exciter, therefore, with no GPS card installed in the exciter you desire the following settings:

External 1pps: Input
External 10 MHz: Input

5) From there, if you have an HDE-100 or HDE-200 Exporter wired to the Exporter with both 1pps and 10 MHz References:

System Reference: External 1pps
RF Output if Undisciplined: Yes

See Figure 3.

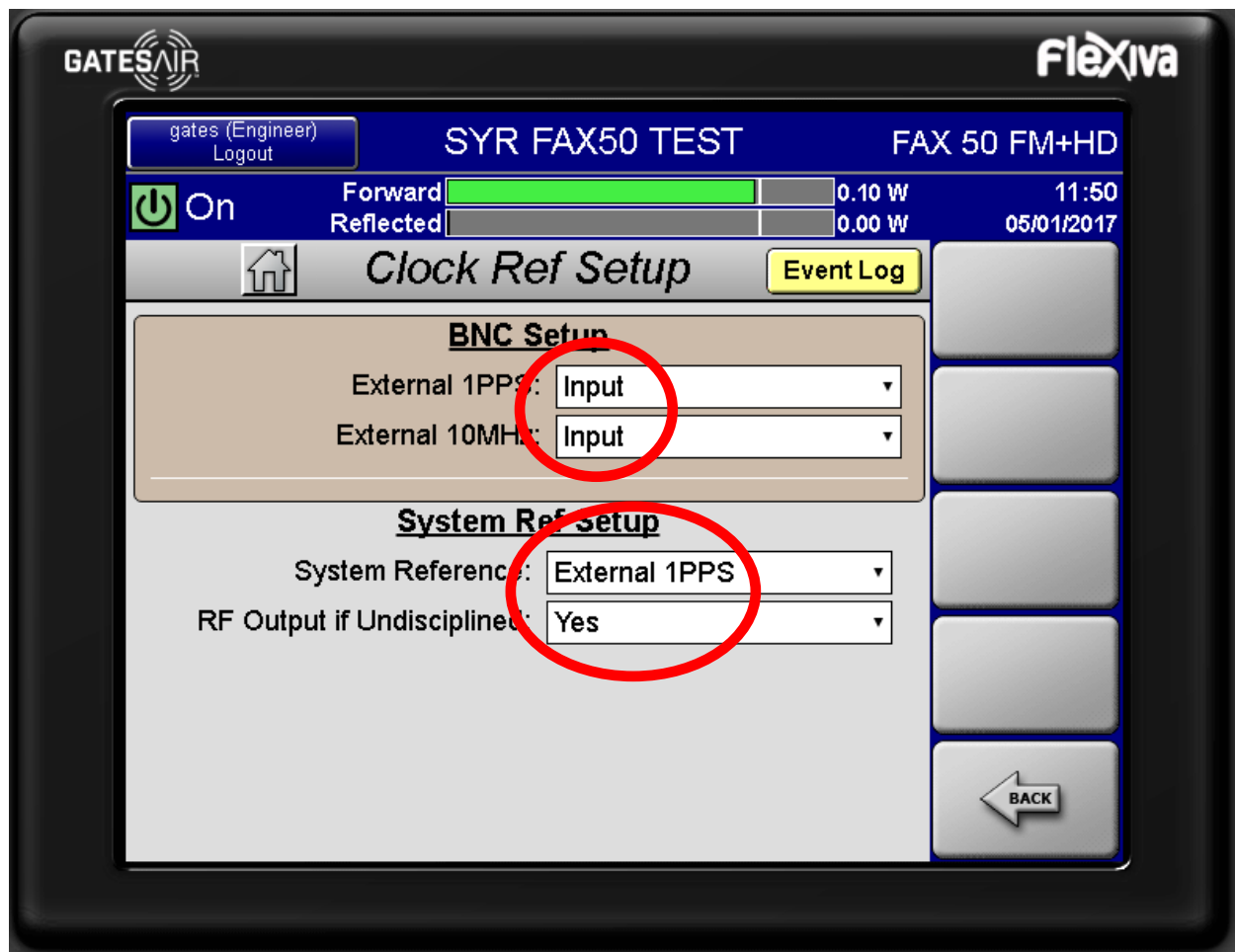


Figure 3. GatesAir Flexiva Engine Exciter Configuration (continued)

6) GatesAir suggests using 1PPS + 10 MHz when available as shown in Figure 4 when using their HDE-100 or HDE-200 Exporters with the Flexiva exciter.

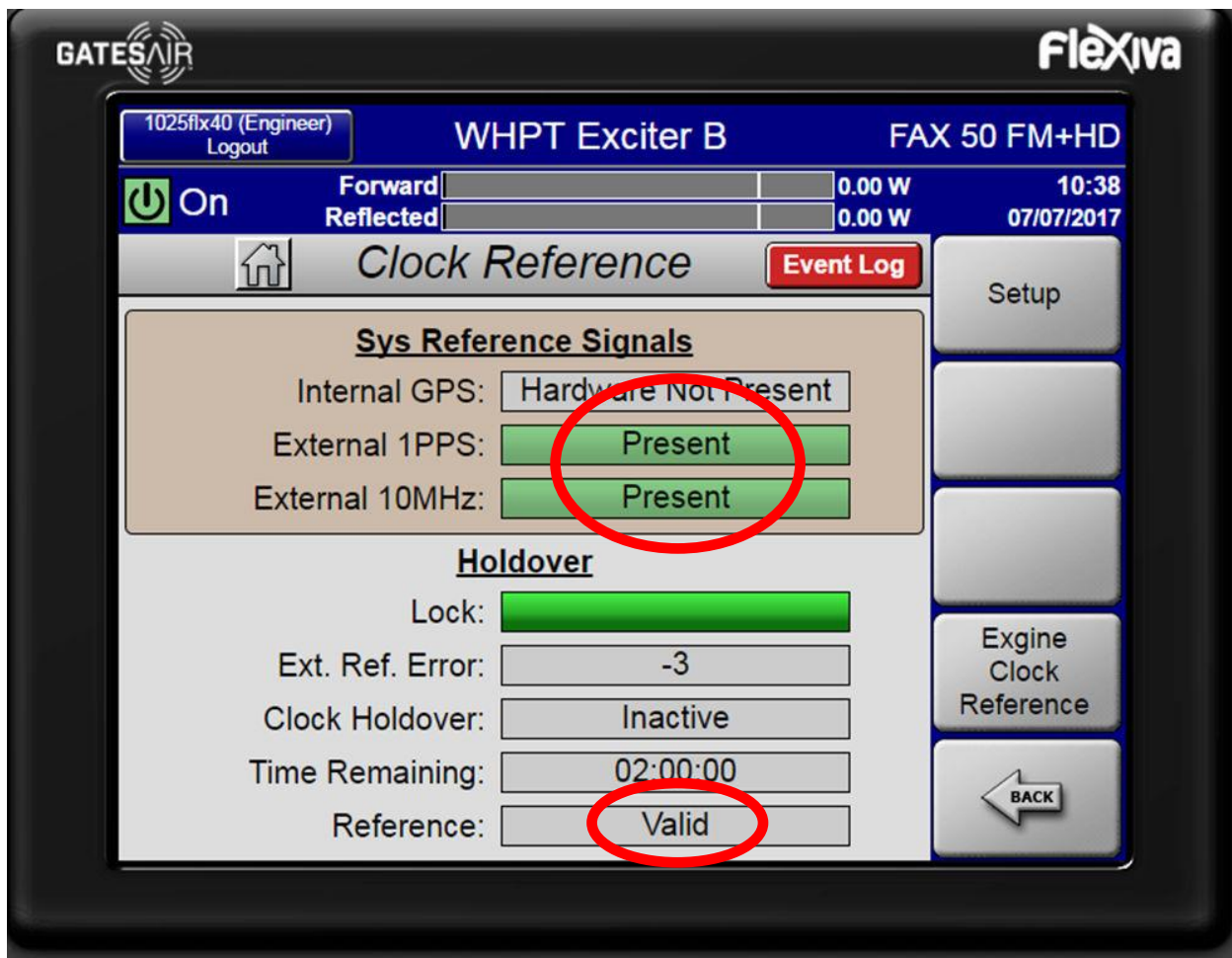


Figure 4. GatesAir Flexiva Engine Exciter Configuration (continued)

7) If you are using another type of Exporter that does not expose 1pps (i.e., Nautel ExporterPlus), use 10 MHz clocking as shown below:

System Reference: External 10 MHz

RF Output if Undisciplined: Yes

When fully configured via 10MHz sampling, the screen should look like Figure 5 and Figure 6:

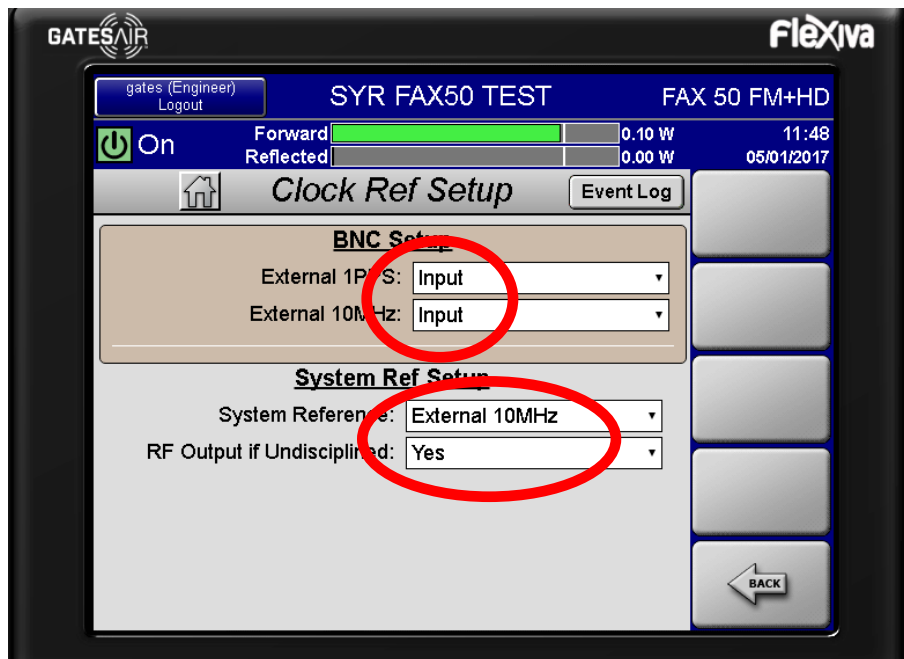


Figure 5. GatesAir Flexiva Engine Exciter Configuration (continued)

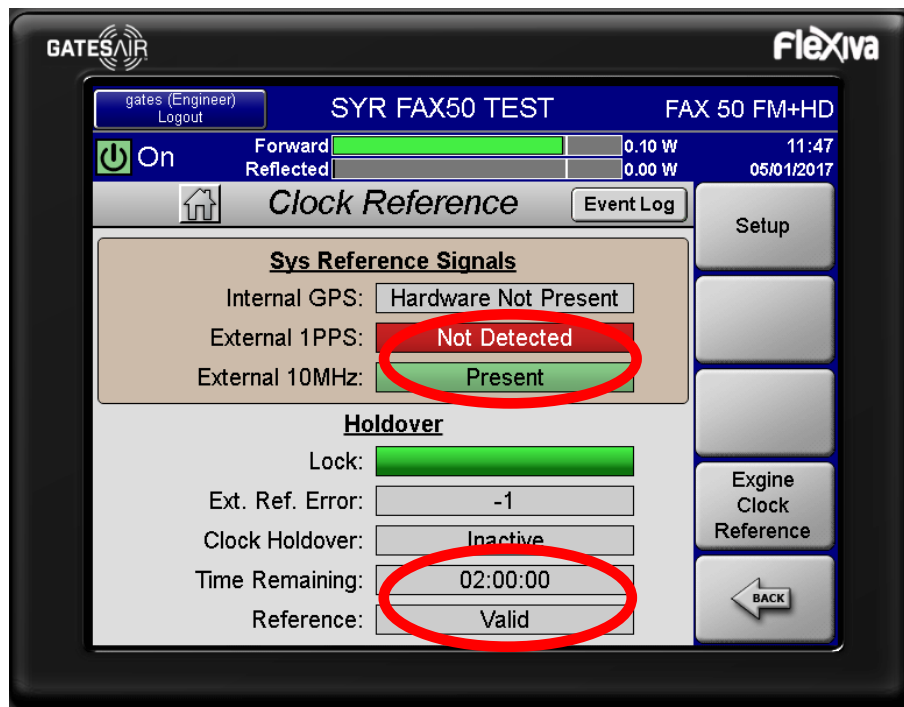


Figure 6. GatesAir Flexiva Engine Exciter Configuration (continued)

GatesAir FlexStar Engine exciter Configuration

1) Main uP 8.45 or greater and Exgine 4.40 or greater is required.

2) From the front panel,

Setup -> More Setup -> Page 2/4 – PLL Sync Control, make sure Ext. 10 MHz is selected

See Figure 7.

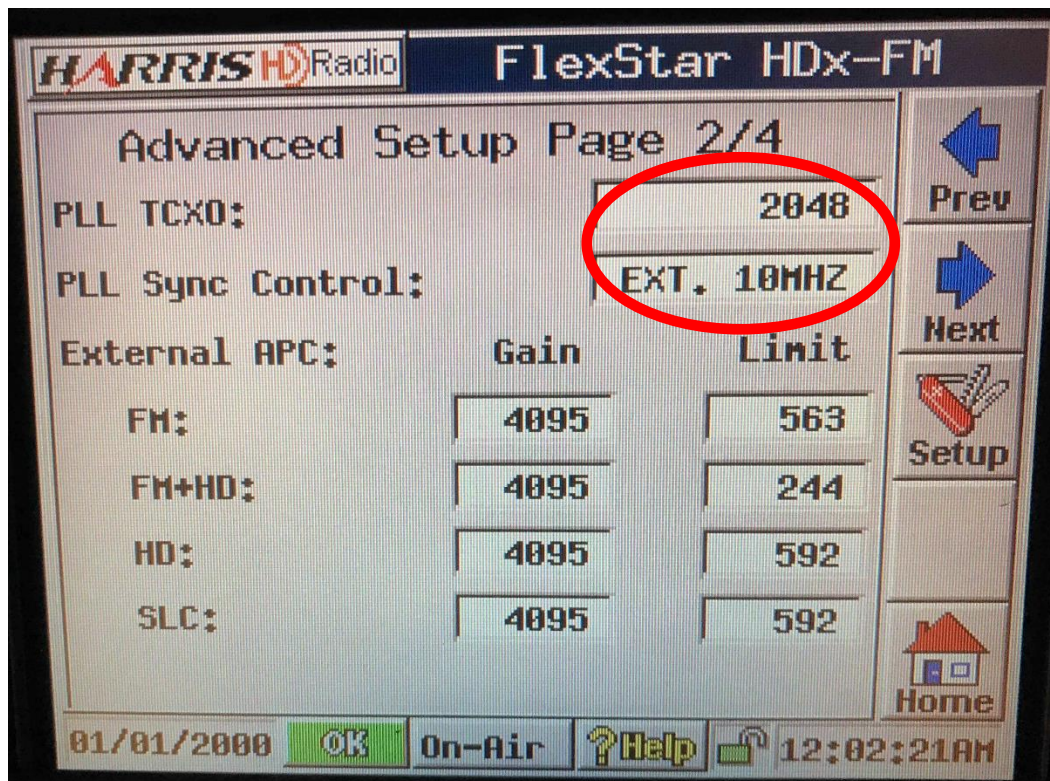


Figure 7. GatesAir FlexStar Engine exciter configuration

Nautel Engine exciter Configuration (M50/VS/NV/GV)

- 1) Physically connect 10 MHz output sample of the Exporter to the exciter's 10 MHz input on the rear panel.
- 2) Menu -> User Settings -> External 10 MHz -> Use External 10 MHz Yes

See Figure 8.

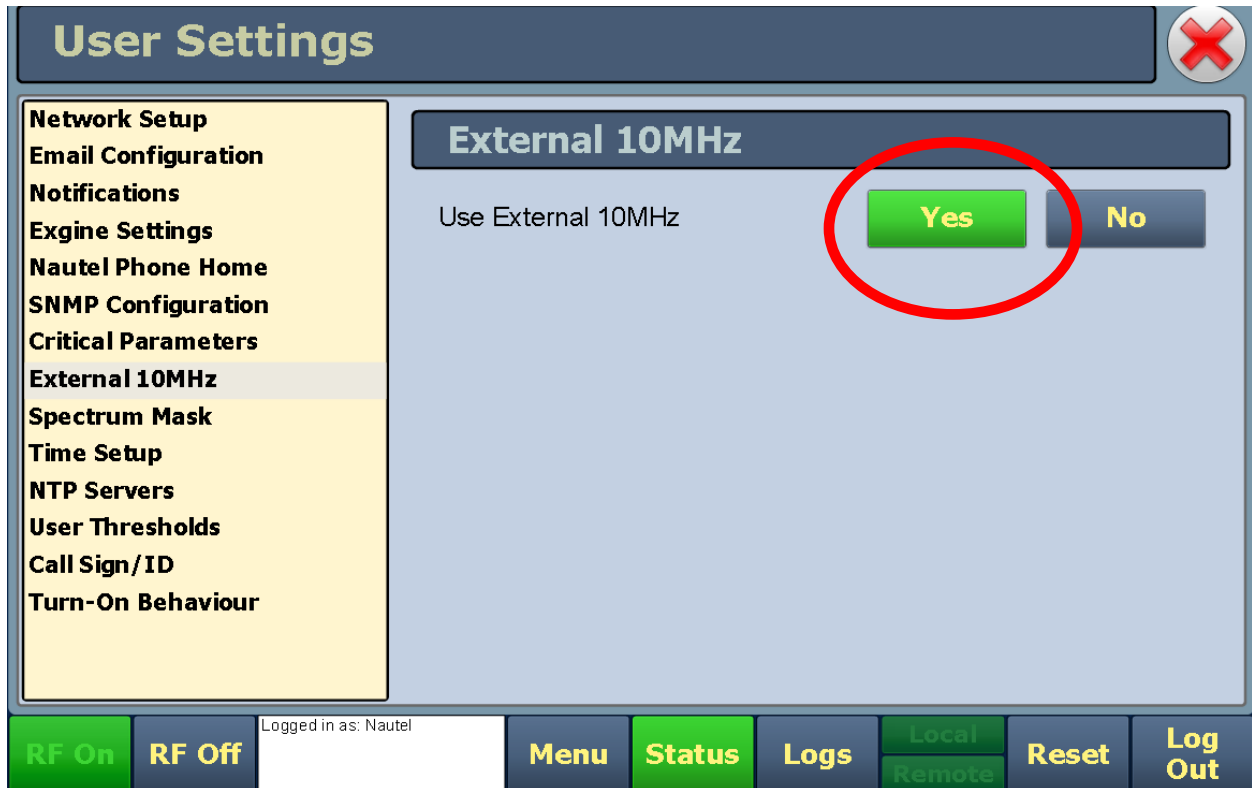


Figure 8. Nautel Engine exciter configuration (M50/VS/NV/GV)

3) Note, the exciter only decides to use External 10 MHz on start up. So if you connected the 10 MHz after the exciter or Transmitter was powered on, it may still be using Ethernet (E2X) clocking. It is best to restart the exciter after making these connections and changing this setting.

4) From the Exgine Interface: <http://exgineIP>, which in this case is 10.10.10.110, select Maintenance -> Restart Exgine **(this will interrupt HD only)**.

See Figure 9.

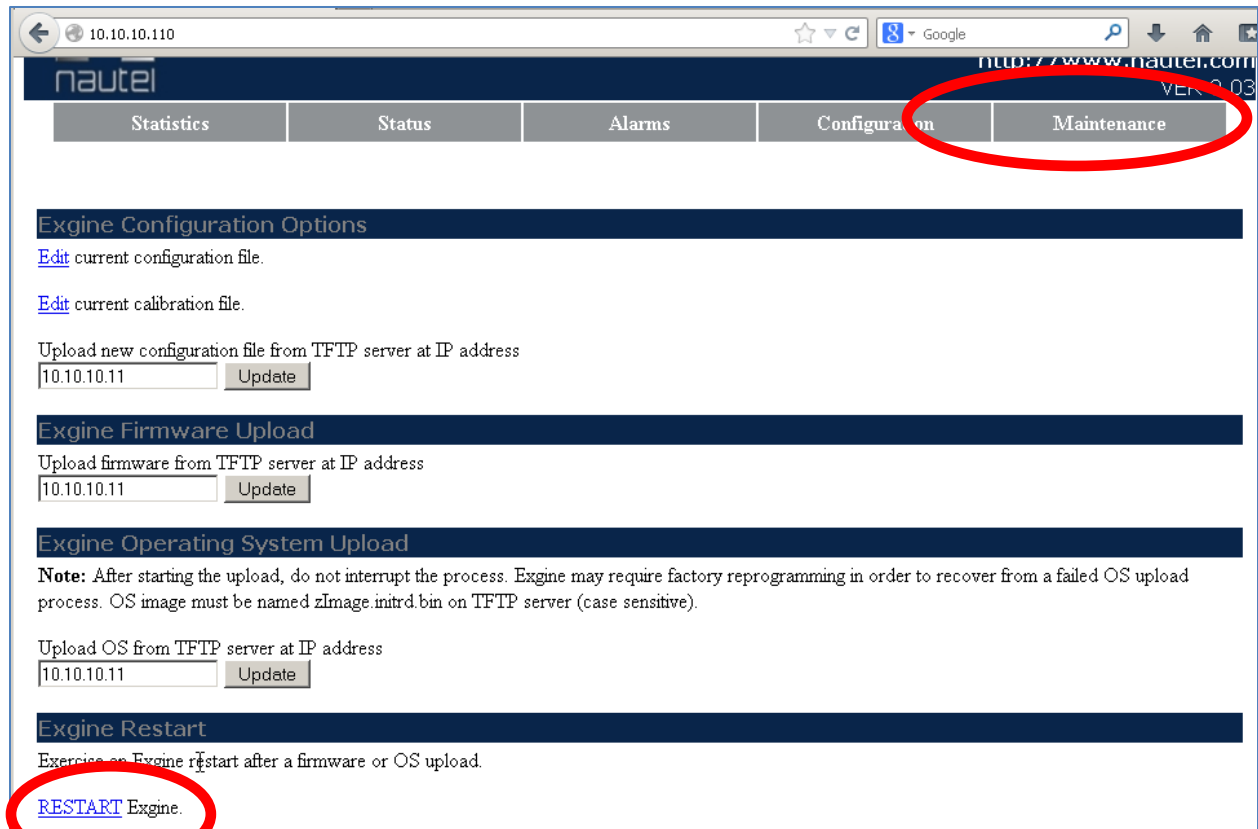


Figure 9. Nautel Exgine exciter configuration (M50/VS/NV/GV) (continued)

5) After the exciter has rebooted, revisit the Engine page and click “Statistics”

6) Look for “DPLL State” it should say “gps dpll”. If it says enet dpll it is still using Ethernet based Exporter to exciter clocking (not optimal).

See Figure 10.

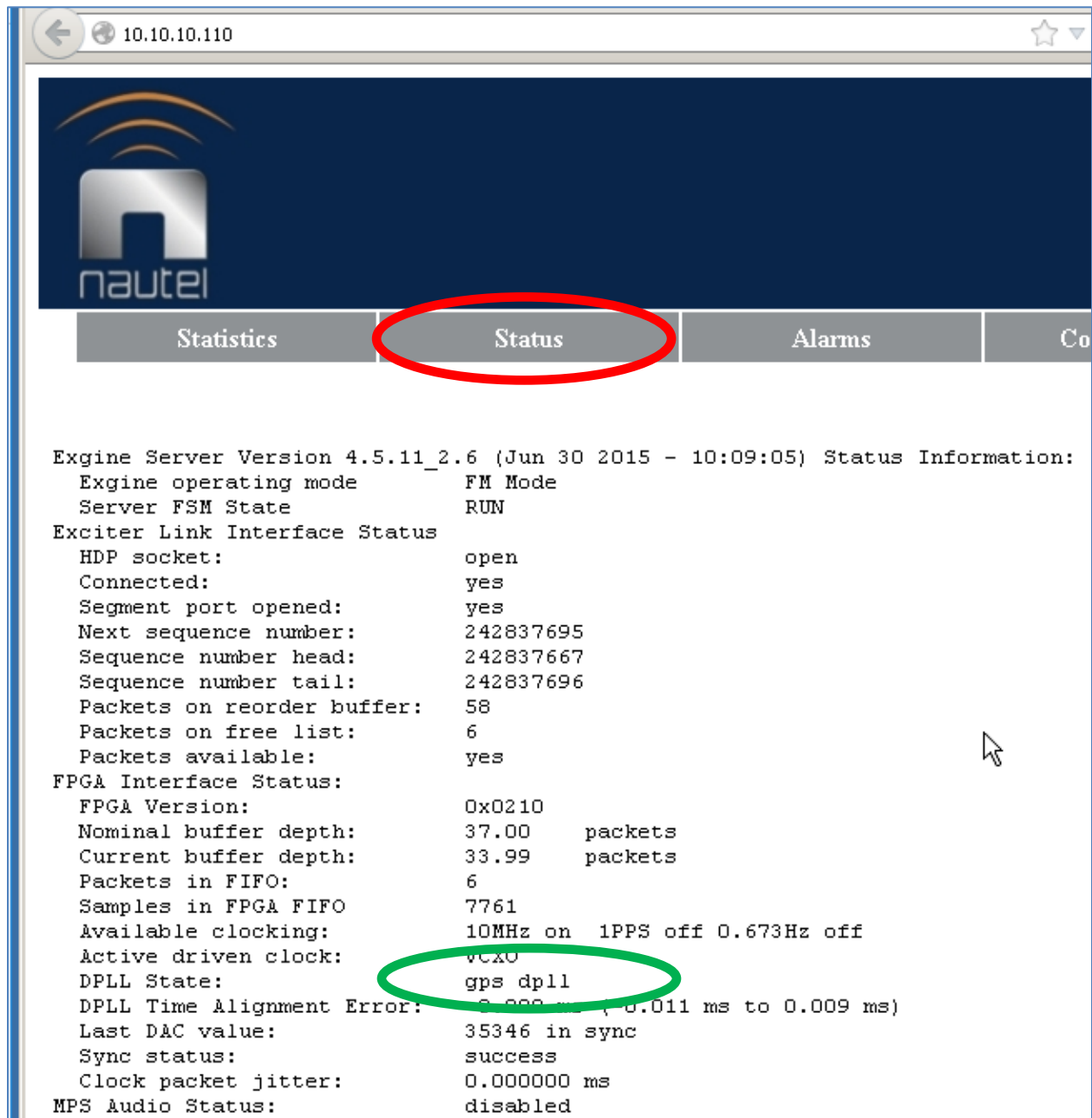


Figure 10. Nautel Engine exciter configuration (M50/VS/NV/GV) (continued)

ANNEX 2 - HD Radio Diversity Delay Field Observations: The Need for Automatic Alignment, (2016 NAB Broadcast Engineering Conference Proceedings paper)

HD Radio™ Diversity Delay Field Observations: The Need For Automatic Alignment

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Abstract - Audible blending artifacts are the top complaint from auto manufacturers and consumers regarding the HD Radio™ experience. The majority of the problems can be traced back to individual broadcast stations. The industry has long relied on manual management of diversity delay and time alignment. However, the results in the field often have shown that stations set manually have been known to drift over time.

This paper will cover some of the causes of drift and how those can be resolved. However, there are a myriad of potential problems that can cause drift which are out of control of any individual device that has been traditionally installed in the broadcast chain. What is needed is a systems approach to this problem. This paper will discuss implementing various combinations of hardware to provide continuous monitoring and adjustment of diversity delay in real-time to reduce or eliminate the objectionable blending artifacts impacting listeners.

Background

The hybrid digital broadcasting solution deployed in the United States, FM and AM IBOC, more commonly known as HD Radio from DTS, Inc, allows simultaneous transmission of broadcast radio signals in both the analog and digital domain. A key component is that receivers can immediately acquire the analog signal and then transition (or “blend”) into the digital signal after it has acquired and buffered. The transition process is called blending.

In order to have this blend be seamless and transparent to listeners, broadcasters employ delays on analog AM and FM signals to time align it to the digital. This delay is typically called “diversity delay” because the HD Radio transmission system uses a variety of techniques and buffering to add redundancy or diversity to the system for signal robustness.

This robustness and signal processing creates significant delays compared to the near-instantaneous analog transmissions, typically anywhere from 6–10 seconds depending on hardware, software, equipment settings, and data links in use. A properly configured AM or FM station broadcasting in HD will have a device in the analog air chain providing this delay.

In the 1st and 2nd generation of HD Radio signal generation hardware, the diversity delay in the HD Radio signal path was in the same device producing the HD Radio signal. Over time, engineers demanded flexibility in

configuration, reduction of hardware costs and reducing points of failure (the first two generations of hardware weren’t particularly reliable).

The Rise of the Exgine Platform

The creators of HD Radio, iBiquity Digital, now DTS, Inc. responded to industry input regarding transmission system architecture with a flexible transmission design called Exgine, which was implemented in 3rd generation HD Radio signal generation hardware and recently introduced 4th generation hardware. These systems rely less on computer-based designs and move most of the encoding into DSP (3rd generation) or FPGA (4th generation) designs. While modernizing the encoding hardware to meet flexibility demands, the encoding was broken up into two pieces. What was a single device became two, the Exporter and the Exciter. These components communicate over common Ethernet using a proprietary protocol called the Exgine platform. The connection between the two is considered the Exporter to Exciter (E2X) link.

Exgine-based 3rd and 4th generation platforms are the most common deployment of HD Radio transmission systems deployed by radio stations. When many FM stations were implementing HD Radio in the 2005-2008 timeframe, 3rd generation hardware was the hardware available on the market at that time. Many FM stations on the original 1st and 2nd generation platforms that deployed in 2003-2005 have upgraded to Exgine based systems due to equipment age, obsolescence and overall improved reliability on the new hardware platform.

As a station-level engineer during that time, ever since I started working with the Exgine system (now in its eleventh year in production hardware), I was challenged to keep the analog diversity delay perfectly aligned with the digital. Consulting with my colleagues, it was apparent that I was not alone. But this was early in production deployment of the Exgine system. These new products were still being worked out, and many of the obvious issues that caused drift were resolved over several firmware updates.

Even after the firmware and configurations matured, some station installations would drift more than others, and the cause for this was often unknown or mysterious to station level engineers, myself included. Part of the problem was the industry did not have sufficient tools to even characterize the problem.



Measuring the Problem

While there were a few commercially-available signal monitoring products on the market during this period (2005-2008) that would measure diversity delay, the measurements being taken were single point in time values. The premise behind these first products was an automated extension of the initial manual alignment process. The initial manual alignment procedure was to put on a set of headphones and put a receiver in “split mode” with the analog on the left and the digital on the right, then get them to match just by listening. As you might imagine, it would take a “golden ear” to get it perfect. Now, equipped with the precision devices available today, I have determined I personally am not very good at setting this delay manually. Or, if I get close, I wasted half my day trying to get it right. The thinking at the time was that the delay was constant, stable, and you just needed to set the compensating delay on the analog channel once and not need to make any further measurements or corrections.

That process may have worked for setting up the 1st and 2nd generation systems, since we now know those platforms did not drift. As the industry moved to the 3rd generation Exgine platform, the methodology this industry used to measure diversity delay was missing a key point: the delay can change after you set it. In the 3rd generation system a variety of factors, some internal, some external could cause the potential for the delay to drift, or change over time. Our single point in time measurements were not very useful for configurations with significant drift problems. We were flying blind. On some installations, every time a measurement was made, the value changed slightly. Many station level engineers, as I was at the time, were perplexed on what to do with this information. Do you ignore measurements that make no logical sense? Throw out the outliers? On some stations, the equipment simply would not measure at all. Many blamed the measurement equipment at the time. It turns out today, the problem was with the measurement equipment, the overall individual station transmission system design and its operating environment.

Precision tools to monitor diversity delay in real-time started arriving on the marketplace in the last few years. These devices were made by well-known manufacturers in the broadcast monitor and receiver business, including Belar, DaySequerra and Inovonics. With these products, we had a value of what the diversity delay was at the exact moment we were observing the reading, as opposed to a single measurement at a point in time. But even equipped with continuous measurement products, the industry still did not have a very good handle on what was really going on.

While we had continuous monitoring, engineers only had a short amount of time to observe the reading, make an adjustment in the system delays, and go about the rest of their daily tasks. What was missing was not only automating the process, but also continuous logging and then graphing of the measurements. Without this information logged and

plotted over time, it was really hard, perhaps impossible to understand what was going wrong. For those of you familiar with how to take RF HD Radio spectrum mask emission readings, it as if we were going with just one sweep on the analyzer making an adjustment and going home.

2015 was a watershed year gaining insight into this problem. All three equipment manufacturers mentioned above implemented various forms of data logging and display of their measurements. Armed with that data, researchers and engineers at these companies, DTS, iHeartMedia, and others started noticing new patterns and trends as we placed these products to monitor various stations and configurations.

What we learned (and frankly, are still learning) is that a laundry list of items can cause a station’s digital transmission timing to change. This list of items continues to grow as we conduct precision research. These problems, in turn, can cause diversity delay drift, which results in blend time alignment problems.

We have learned that it is impossible to keep the station diversity delay perfectly aligned through manual means. Some stations or configurations are more prone to problems than others. But, make no mistake, there does not appear to be a single “set it and forget it” system in existence today.

If you do not have a delay measurement device, it’s also nearly impossible to know the precise amount of delay needed on your station. You should seek a way to measure the delay accurately and correct it automatically. I will get into some of the details of this later on, but before, a bit of background on why this all matters.

Time Alignment Specs

The official specification from DTS is that the analog and digital signals time alignment should be 0 samples, plus or minus 3 samples. So the permitted range is -3 to $+3$ samples, or a range of 6 samples with the center of 0 (0 ± 3). One sample refers to 1 out of 44,100 samples per second in the 44.1 kHz digital audio bit stream.

That is an extreme amount of precision required to get within specification. One sample is 22.7 μsec . 3 samples means within 68 μsec . Many broadcast monitoring products show the measurement in seconds and samples. If you’ve been measuring your diversity delay in seconds from any of these products and been saying things like “...the station is off -0.0001 seconds... close enough,” you have been doing it wrong.

I must admit, I was doing it that way for a long time as well. At four digits beyond the decimal point, that is a resolution of 100 μsec . Any reading that is not zero essentially is out of spec. If the station is off by 3 samples, that equates to 68 μsec , rounded to the nearest 100 μsec , you would get 100 μsec or 0.0001 seconds. Four samples is 91 μsec and would round to 0.0001. So, you could be in spec or

out of spec with that number; there isn't enough resolution. At 2 samples, that will round to 0.0000 sec. Looking at it another way, 0.0001 sec is very close to 4 samples off, but anything between 3 and 6 samples off will round to .0001 seconds.

The best way to avoid these issues is to focus on the number of samples and stop looking at the time. The industry needs to be focused on samples, not seconds. And when you look at it that way, that level of precision is only available consistently if we automate the process.

DTS has provided simulations to visualize what happens during the blend at different blend timing offsets. At 0 samples, the blend is pristine. Figure 1 depicts a near-pristine blend when alignment is at 1 sample offset.

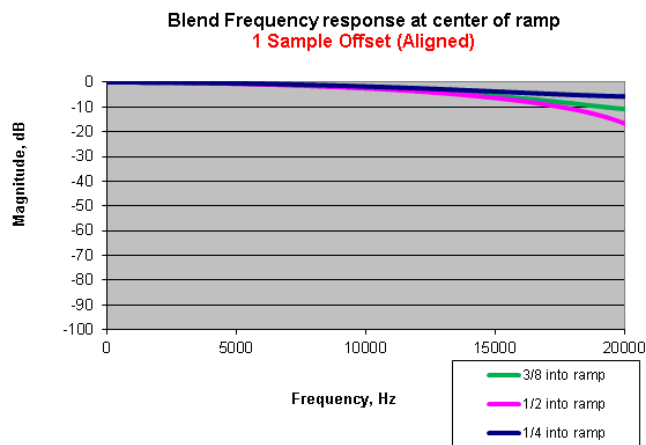


Fig 1 Blending artifacts at 1 sample offset (Courtesy DTS)

Figure 2 depicts the edge of the specification, an offset of 3 samples. Note a deep null halfway through the ramp at 7,350 Hz.

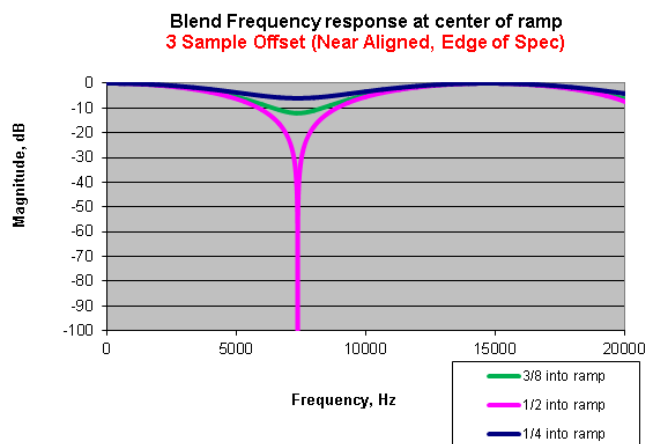


Fig 2 Blending artifacts at 3 sample offset (Courtesy DTS)

Figure 3 shows what is occurring on a station slightly out of specification at 6 samples. Deep nulls exist at 3,675

Hz, 11,025 Hz and 18,375 Hz¹ at the center of the ramp. I think these three figures are extremely helpful to the broadcasting community to understand the importance of maintaining within specification, and why the spec is (0 ± 3) samples in the first place.

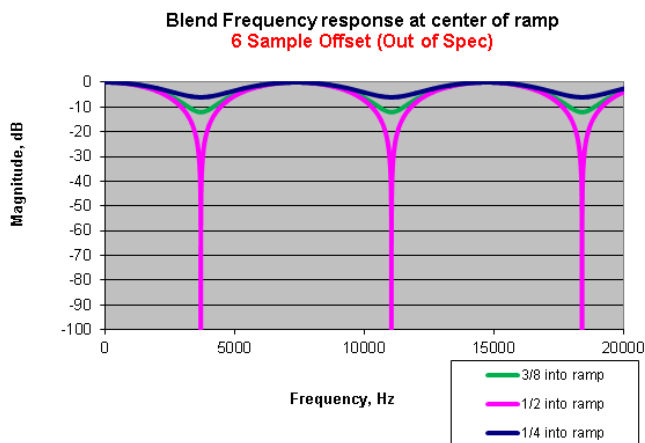


Fig 3 Blending artifacts at 6 sample offset (Courtesy DTS)

Why Does It Matter?

HD Radio is here to stay and growing rapidly. The biggest area of growth is with factory installed radios in new automobiles. Ten years ago the broadcast industry wondered when these digital radios would show up. They are here now; listeners already have them. In 2015, DTS reported that over 35 percent of new automobiles came with HD Radio, standard. In 2013, that number was about 33 percent. This equates to millions of HD Radio receivers being sold and used. And millions more are being added each year.

Each day, more and more listeners have HD Radio receivers. Should trends continue for the rest of the decade, it will be hard to buy a new vehicle without HD Radio in a few years. The digital experience of a radio station is something broadcasters should be paying attention to today. Within a few years, whether listeners are aware of it or not, an HD Radio will become the primary radio they will use.

Market based research conducted by DTS shows that in many of the largest metro areas, 15% or more of vehicles registered on the road are equipped with HD Radio. In a few markets, that number is nearly 20%. Let that number set in. A fifth of the audience could be listening to an HD1 signal instead of the analog FM. Those listeners may not necessarily know that they have HD Radio, or seeking out HD Radio content. But their mere acquisition of a vehicle that came pre-installed with HD Radio now means they are. Buying patterns have changed. Most people are not running out buying a radio and evaluating all the features it has to

¹ The author notes this model does not consider the analog FM only provides audio up to 15,000 Hz, while the HD Radio FM HD1 MPS audio frequency response is up to 20,000 Hz. The model also considers audio processing between these channels identical, which is not likely practical.

offer. They are buying a larger product, like an automobile, which features HD Radio.

If your station is not precisely aligned, all of the time, it makes that transition from analog to digital, or back from digital to analog when the HD Radio digital signal fails, sound bad. How bad it sounds and how objectionable it is to listeners depends on how far off the time alignment is and what type of programming is currently on the station.

My anecdotal experience observing hundreds of stations tells me that music formats with light audio processing or primarily spoken word programming seem to be more susceptible to audible problems even with a small offset in samples. On loud, densely processed music stations the effects of being slightly out of spec can get buried in the program density to a point. But keep in mind, even these stations have periods of less density that are important, such as talk-intensive morning shows and commercials.

Audible Impacts of Misalignment on Blending

The industry is studying this in closer scientific depth. Based on the latest measurement information, many different groups are embarking on answering some of the unknown questions. What exactly is objectionable for an average listener? It may take some time to be able to answer that question.

DTS has performed research, and there are various audible blending effects depending on how many samples the station is off. Figures 1-3 above show the effects of small sample offsets and the impact on the audio, which establishes the need for tight specifications. The aural impact of not being within spec quickly gets out of hand. Figures 4-5 below depict the audible impacts of larger sample offsets. In Figure 4, there are 23 deep nulls created by a 50 sample offset.

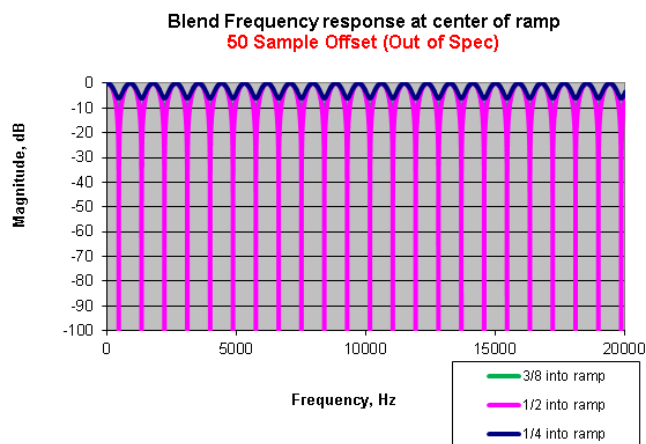


Fig 4 Blending artifacts at 50 sample offset (Courtesy DTS)

Figure 5 shows that at 300 samples, while the magnitude of the nulls may not be as deep, the quantity of them is much higher. There are 272 nulls at -39 dB.

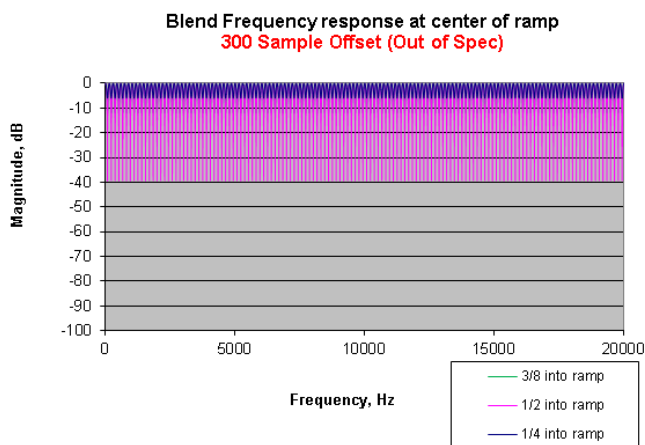


Fig 5 Blending artifacts at 300 sample offset (Courtesy DTS)

During a blend, any misalignment >5 ms (approx. 200–300 audio samples) will be perceptible to a listener as an echo or skipping effect. The two audio sources (analog and digital audio) will sound distinct. Significantly more delay differential than that can cause a situation where you skip a whole word. Depending on the direction of the delay offset, you could skip ahead and miss a word of a sentence, or skip back and hear the same word again.

Even small misalignments (< 200 samples) will produce a filtering effect during a blend. It will sound like one audio source, but will have a “hollow” sound due to a comb filtering effect. The effect is not noticeable if the misalignment is less than 3 samples.

Many broadcasters may think, “Well, the radio blends once 8 seconds after it tunes to the station, so it skips once; why does it matter that much?” Perhaps they think of the blend as an initial acquisition; then you keep digital forever. But that is not always the case. Receivers of all types lose digital lock at some point. We could go into an exhaustive investigation of those situations, but that is a topic in itself.

The easiest way to think about this is in the car. The blend point has traditionally been thought of as occurring when someone is driving out of a station’s market. The listener has coverage, and at some point on the highway, far away from the market core, their receiver loses digital lock, it blends to analog, and eventually as they go out further and further, the signal is gone into noise. But that is not the typical blending experience of listeners. Most listeners do not leave the market and stations’ signal coverage each day.

Think about a station’s 60 dBu coverage contour, which is where many FM band HD Radio stations with digital sidebands at -20 dBc tend to start to lose digital lock. If a listener lives and works in that area, they can experience constant drifting in and out of digital lock. Listeners can run into situations where the radio is blending quite a bit.

Automotive Companies Care

Diversity delay blending issues are the number one HD Radio-related complaint from auto manufacturers. I can independently vouch for this. I work closely with many automotive companies, and I have had emails, phone calls and idle conversations at lunch about this problem with their engineers. I have been in vehicles with these engineers where they hear stations skip and ask me to help fix it.

General Motors temporarily removed HD Radio in some vehicle models to help fine tune their implementation to address consumer feedback about HD Radio blending. [1]-[2] Their customers (and radio listeners) have been complaining to them about this for a long time. But instead of calling up the radio station to complain about it, the customer takes the car back to the dealer and thinks there is a problem with the radio. Listeners are not (and should not be) educated enough on this issue to think to contact the radio station about this annoyance. This customer feedback is not unique to GM vehicles.

Automotive designers are sensitive to this problem, and it is my experience that most of the problems come back to issues on the broadcast side.

Examples of the problem

Research with these new measurement devices on time alignment is really in its infancy. We have only looked at a small percentage of implementations currently. As time goes on, more measurement devices are obtained and deployed, the industry will learn a significant amount of information. Here is a review of some of the things known to cause unwanted drift.

Exporter location and network design

As explained earlier, the industry demanded flexibility in equipment placement and the Exgine system was born. Previously, when all of the encoding of the HD Radio system was located in a single device, the location was always the station's transmitter site. There was little to go wrong here. Those who have implemented and studied more than a few stations have always known that locating the Exporter at the transmitter site seemed to be the most stable. But still many in the industry pushed to move the Exporter back to the studio. The problem is that they lacked tools to effectively measure what they were doing in this process.

Many of the figures below are derived from the latest diversity delay measurement devices. In the instant case of Figure 6, it was rendered by the web browser graphical user interface of the Inovonics JUSTIN 808 HD Radio Alignment Processor. It should be noted, other devices can provide similar outputs for research, as later shown in the paper.

In the diversity delay measurement graphs shown, the Y axis is the line that runs vertically and plots the number of time sample offset between the analog and digital signals.

The X axis is the line that runs horizontally and plots units of time. Some products, such as the JUSTIN 808, provide graphical filters such as instantaneous, average, applied and events to help visualize the data it had recorded. Other navigational features included in products include auto scale ranging which will zoom the Y axis (samples) or X axis (time) to help visualize the information. This allows a user of such a device to analyze data in short, fine time ranges, or broad, coarse ranges, which may be required of the data set.

In this paper, we are only analyzing measured delay differences, or observations. We are not applying any automated delay with measurement correction devices. Thus, most graphs in this discussion will only have the instantaneous and Average indicators illuminated.

Figure 6 below depicts a radio station with the instantaneous and average delays measured by the device at exactly 0 samples (as seen by no variation of the line on the Y axis, or audio samples) for a long duration of time, or from 12:00:00 AM to 11:59:59 PM, or a 24 hour period.

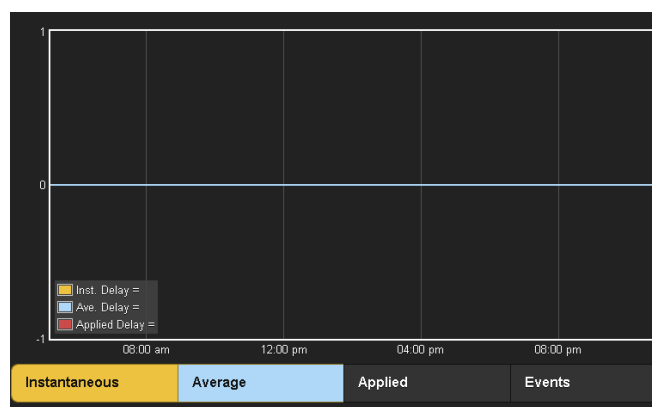


Fig 6 Exporter and Exciter Co-located on Isolated Network. Single Integrated FM+HD Audio Processor

Extensive testing in the last nine months has indicated that Exporter and Exciter hardware, on the latest firmware/software, installed as recommended by their manufacturer and a single integrated FM+HD processor generally leads to compliance with the 0 ± 3 sample spec. An example of this is shown above in Figure 6 where the monitored station had no issues maintaining the 0 ± 3 sample spec. It was at 0 samples for an entire twenty four hour duration. In my experience, these stations are rare unless precision monitors and automated correction are employed. Note, this station, as all stations depicted in this document are configured properly but the delay was set via traditional manual, fixed means. The measurement device is not applying any correction to (and is not even inserted in) the air chain in Figure 6.

Figure 7 through Figure 11 explores some research I conducted with the assistance of a station engineer on a single station during the summer of 2015. In these figures you can see how various configurations of the same

equipment yield dramatic differences in diversity delay stability.

When the Exporter was located in the studio and connected to the exciter across a LAN bridge, we start to see some of the problems that can be introduced, as seen below. Figure 7 shows wide variations in the diversity delay shift over time. In this particular set up, everything was installed in what was considered at the time as accepted industry practice. It indeed was a near perfect configuration, the Exporter and Exciter were on the latest versions of software. The Exporter to Exciter link was across an Intraplex LAN bridging card on an isolated VLAN network. Wireshark captures showed the only traffic competing for bandwidth was the Exporter to Exciter data. Careful analysis of this particular system actually indicated this configuration allotted more bandwidth than what was typical. The station in question was delivered via campus fiber from the studio to the transmitter site and was using an E1 media converter. Most Intraplex shelves deployed over wired circuits are at T1 speeds and the DS-64 bridging cards are configured at 320 kbit/sec, 384 kbit/sec, or 448 kbit/sec. In this particular case, because of the faster E1 speed allocated to this link, the DS-64 card was configured at 512 kbit/seconds. I must tell you, in many similar configurations, allocating this much bandwidth to the E2X is nearly unheard of using wired T1 based Intraplex frames.

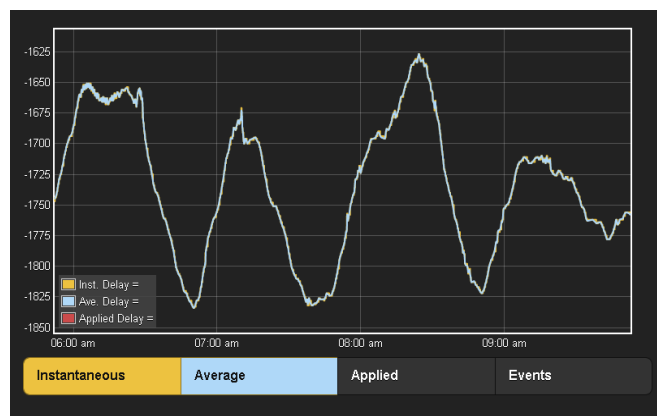


Fig 7 Exporter at Studio and Exciter on Isolated LAN Bridge

Figure 7 is from 6am until 10am, or 4 hours. The diversity delay drift on this station was extreme. Impossible to maintain in spec by manual means.

That being said, while the network isolation was ideal, and while the amount of bandwidth allocated on the Ethernet bridge exceeded what many Intraplex installations typically allocate, there was a major component that was missing in the Exporter at the studio and Exciter at the transmitter site configuration.

This installation was lacking a GPS disciplined 10 MHz reference source at the transmitter site into the Exciter to assist with clocking. If you look around the industry,

adoption of this extra piece of equipment when the Exporter is at the studio appears to be spotty. When Exgine was first introduced, this was not even standard hardware at first, it was usually brought up after-the-fact, post-installation, if an engineer was trying to settle the delay drift down.

I have found very few stations in my travels that actually went forth with the effort and expense to add this 10 MHz reference source. In the case illustrated in Figure 7, this was not initially in use but then the station obtained a loaner unit for this test. It had a GPS antenna input and a 10 MHz BNC output, which was brought to the exciter. The exciter was reconfigured to use the external 10 MHz for clocking sync. You can see the dramatic results of our experiment in Figure 8.

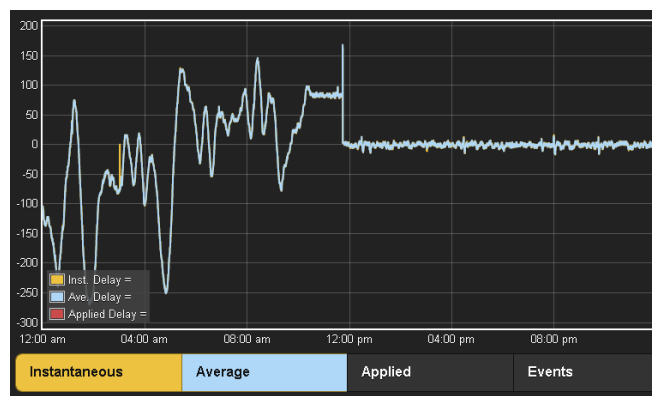


Fig 8 Exporter at Studio Adding 10MHz Reference to Exciter

The GPS referenced 10MHz sample was connected to the Exciter and the Exciter was reconfigured to use this input at approximately 10:20 AM. We observed the stability of the system for a few minutes, and then went to the studio to make a manual diversity delay adjustment to get the delay to center at 0 samples around 11:45AM.

Figure 9 and Figure 10 show adding a 10MHz GPS disciplined source to the Exciter at the transmitter site added significant stability to this station. But, after considering the time and expense it takes to install, it still is not within spec. We monitored this system for well over a month, and received similar results each day as to those shown in Figure 9 and 10.

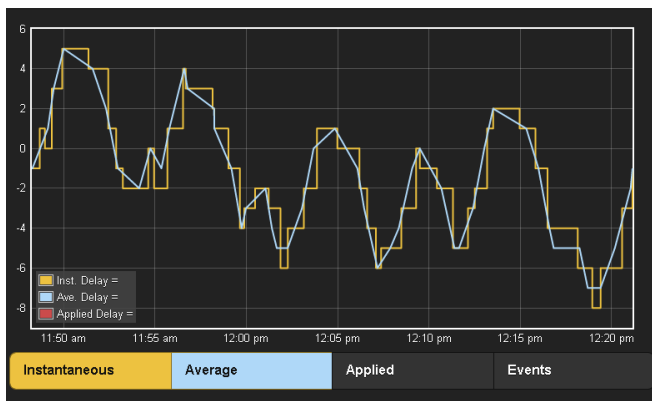


Fig 9 Exporter at Studio with 10MHz Reference to Exciter
(Detailed View, ~30 Minute Scale)

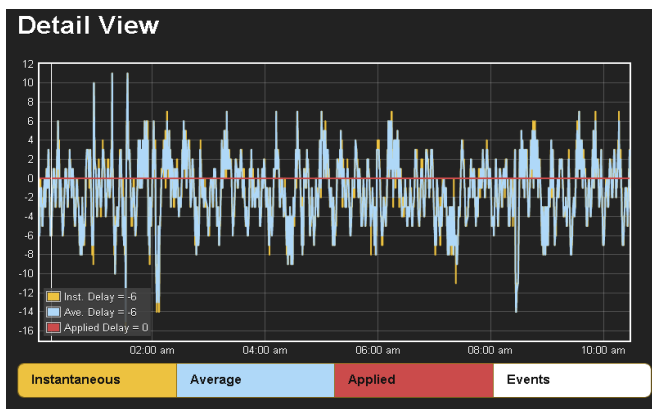


Fig 10 Exporter at Studio with 10MHz Reference to Exciter
(Coarse View, ~10.5 Hour Scale)

The experiment in Figures 9-10 showed that could eliminate coarse drift caused by only using E2X Ethernet based clocking over a LAN bridge. But it also demonstrated that we could not maintain the 0 ± 3 sample spec with the Exporter at the studio.

As a reminder again, this was a close to ideal network, using the popular Intraplex bridging product. It was a fully isolated network and at 512 kbit/sec, offered 202 kbit/sec more bandwidth than I have seen more common with Intraplex wired T1 based configurations.

Figure 11 (right) shows you the end of our experiment. A month later, it took bringing the Exporter up to the transmitter site, putting it on the exact same network as the exciter to get us within spec. At this point, with the Exporter co-located with the exciter, the Exporter's internal GPS receiver was used and the 10 MHz was connected from the Exporter to the exciter directly. The additive GPS unit used in Figures 8-10 was no longer needed.

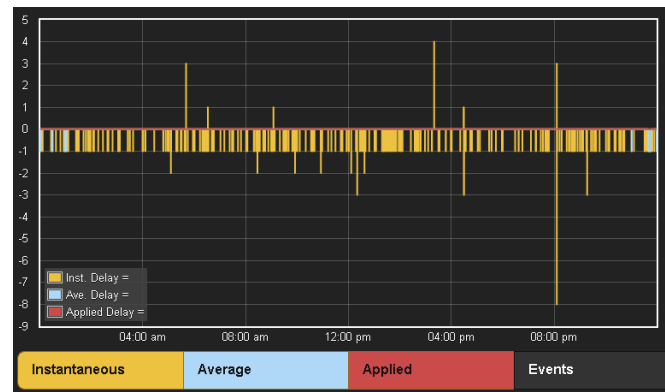


Fig 11 Exporter Re-located to Transmitter Site
(Coarse View, 24 hours)

For this particular station, there was no reason why the Exporter had to be at the studio initially, it was just a matter of design preference when the station enabled HD Radio over a decade ago. In 2015, without any additional equipment expenses, the Exporter was relocated at the transmitter site with all of the existing components to bring the diversity delay within spec.

This option may not be the available for all stations in all situations. If an Exporter is at the studio, and a bidirectional Ethernet bridge connection from the studio to the transmitter site is available, to the station may benefit by moving the Exporter to the transmitter site for best stability.

Placing the Exporter at the studio puts broadcast engineers in the position of having to design a high availability Ethernet network. The industry at the time (and still today) has struggled with understanding the networking best design practices for the Engine system. Simply put, broadcast engineers need to become IT network engineers to better understand this issue and address some of the most common problems related to drift, the network design.

Many of the networking products the industry uses to extend the LAN from the studio to the transmitter site do not have the adequate specifications required to keep the E2X link in pristine form. Many stations employ various Ethernet bridging products from the studio to the transmitter site from known broadcast manufacturer companies. Popular products in use are the 900MHz unlicensed spread spectrum radios (*i.e.*, Moseley LANLink, Ubiquity 900 series), T1/E1 multiplexing shelves bridging products using telco provided circuits, or extending them from the studio to the transmitter site using wireless licensed or unlicensed solutions (*i.e.*, GatesAir/Harris Intraplex, Moseley Starlink SL9003T1) or unidirectional digital STLs in the licensed 950 MHz Broadcast Auxiliary spectrum available to broadcasters (*i.e.*, Mosley Starlink SL9003Q-4SLAN, GatesAir /Harris Intraplex HD Link).

I have not monitored each bridging solution named above with the new delay measurement devices. Several of the ones I have analyzed, by collecting Ethernet statistics

and performing network captures with Wireshark, indicate that they provide less than precise delivery of the Ethernet network (LAN) it is extending (or bridging). Many of the implementations above do not perform as well as the station seen in Figures 7-10, so it is possible the drift seen there could be worse across other LAN bridges.

All Ethernet networks have inherent jitter, and the Exgine system was designed to tolerate some of it, but many of the LAN extension products implemented have variable jitter characteristics that cause the packet timing on the receiving end to be variable. Also, many of these systems have insufficient bandwidth to adequately pass the L1 framing packet every 1.48 seconds. Many of the links were designed with the minimum bandwidth of 200-300 kbit/s in mind. The minimum dedicated link bandwidth to clear the nearly 20 kilobyte L1 packet is approximately 1.5 Mbit/s. Nautel has performed research and data modeling as shown in

Figure

12.

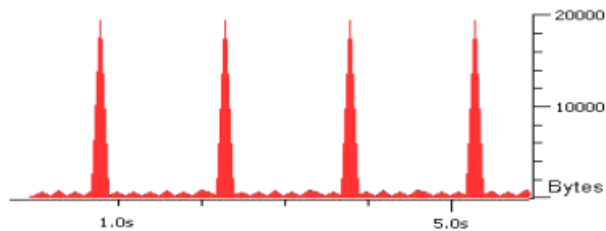


Fig 12 HD Radio Mode MP3 E2X Bandwidth Utilization
(Courtesy P. Schmid, Nautel) [3]

Many of the commonly used bridging products have less bandwidth allocated than 1.5 Mbit/s. This results in critical packets being fragmented and creating an oversaturation condition on the link temporarily. The packets are received sometimes out of sequence. This also impacts the smaller clocking packets sent every 92.8 ms. Depending on what other traffic is passing through the link, the throughput (transmission delay) of the clocking packet can vary as well [3]. Wireless links are prone to packet loss and variable latency depending on RF channel conditions. The variable latency on these links generally creates Ethernet jitter conditions far beyond the jitter design tolerances of the E2X Exgine system.

Recently I became aware of periodic latency changes on wired T1 circuits leased via a telco. While we like to think the delay on these types of links as fixed once the telco installs the circuit, the reality is, over time, they re-engineer some of these circuits. They may take different paths, and may replace the encoding equipment along its journey from the studio across one or more central offices, to the transmitter site. Any delay changes that occur within the telco network can impact your HD Radio diversity delay on the air. While this problem may be static, *i.e.*, only change when the telco makes a change, if you do not have any automated measurement and correction equipment to compensate for it, when they make these changes, your station can become out of spec.

Another related issue plaguing the industry is that many of these extended Exgine networks are not properly isolated. In some of my research I have discovered networks where the Exporter and the exciter are also on the same network with many different devices. Some networks even had automation systems and standard end-user workstations on the same subnet as the Exporter at the studio and the exciter at the transmitter site. A Wireshark analysis of these networks will show you that your E2X is competing with broadcast traffic that is inherent on large networks, like the Address Resolution Protocol (ARP). I have seen some networks so large attached to these bandwidth limited LAN bridges that the remote connection is nearly saturated with just broadcast traffic alone.

Many broadcast engineers do not understand some of the core concepts of Ethernet network designs and think that a good Ethernet switch helps isolate the traffic across these links. Ethernet switches help break up collision domains and isolate unicast traffic, which is indeed important. But it is not enough when isolating the Exporter to exciter link, particularly when it is extended across a bandwidth-limited LAN bridging product. The proper network design must also include isolating that traffic from broadcast and multicast traffic, and you cannot accomplish that with a standard Layer 2 switch.

The Exgine network should be isolated on its own subnet. There are several ways to accomplish this; one is by creating a physically different network for the E2X link that just has these two components on it. Ideally, this would consist of just the Exporter and an exciter connected via a single CAT5/6 cable. However, in some Exporter designs that is physically impossible (single NIC design), and secondly, if the Exporter is being located at the studio, there are often other devices in the path, like the LAN bridge or an Ethernet switch, or both. If you need access to that network, add an Ethernet switch and then connect it to an interface on a router. The more advanced method (and more commonly accepted practice with larger corporate network environments) would be to create a separate VLAN for this network and use a virtual router in a Layer 3 switch.

Other ways to mitigate these issues could be to look at the available next generation Ethernet bridging products. These are not usually broadcast industry branded products, but rather IT products. When HD Radio was being implemented, getting 256, 512, or 1024 kilobits per second to the transmitter site was difficult. Today's newer bridging products can handle tens or hundreds of megabits per second. So, if you must insist on keeping your Exporter at the studio, you should consider updating your link to a newer product.

Also of note, Nautel developed the Reliable HD Transport (RHDT) system which encapsulates standard E2X into what is designed to be a more robust, buffered platform to send E2X over data links with questionable quality. [3]. I myself have used this product suite in a handful of

applications where the Exporter could not be located at the transmitter site and it has seemingly worked well. That being said, a note of caution: I have not had an opportunity to monitor the stations I implemented this on with today's precision delay measurement tools, so proceed with some caution. I found the RHDT worked very well for eliminating HD Radio dropouts caused by the network. I have not measured the diversity delay stability of this product suite with precision devices.

The reality is, in present day 3rd and 4th generation hardware the Exporter belongs at the transmitter site if you want to remain in spec with 0 ± 3 samples. You may wish to invest time, money and resources to segment or isolate the LAN bridge onto its own subnet, switching infrastructure or VLAN. You could replace the LAN bridge with newer technology, etc., but the results you get may or may not be in spec. I urge stations insistent in keeping their Exporters at the studio to start monitoring them with precision diversity delay measurement and correction products. Proceed with caution, and do share your experiences with the industry.

As a side note, I have found many of these Ethernet bridging products, while not precise enough for the Exporter to Exciter (E2X) link are often quite good for the Importer to Exporter (I2E) link. For best results, use Importer and Exporter DTS (iBiquity) IRSS 4.4.7. The I2E link is TCP-based, so traditional unidirectional Ethernet extension products that use the 950 MHz channel cannot be used for this application. But, if you have a bidirectional link, as long as the packet loss is low (under ~1%), latency is typically low (~100 ms or lower), and link reliability and saturation is acceptable and managed, this typically works well for many stations for I2E. So, my general advice would be to keep the Importer at the studio, and Exporter at the transmitter site under the current 3rd and 4th generation products for best performance.

Exporter or Exciter Reboot

3rd and 4th generation HD transmission hardware is far more reliable than the earlier generations, so the need to reboot due to a hardware or software lockup is typically lower compared to the past. That being said, there are things that can cause reboots, such as power interruptions to the Exporter or exciter. These can be mitigated during power failures or switchover from utility power to generator and vice versa by installing an Uninterruptable Power Supply (UPS) to increase reliability. However, UPS systems are known to fail themselves as they age and are particularly vulnerable when the batteries get old. Monitor and maintain the UPS. Note, that in some transmitter designs the Exporter or exciter power may be switched or split off the transmitter's electrical power distribution system. In these cases, unless you have a large UPS capable of running the entire transmitter, it may be worthwhile to reconfigure the power distribution for the exciter and/or Exporter mounted inside a transmitter to place these components on a more moderately sized UPS. Additionally, hardware failures of the

Exporter or exciter can cause unexpected reboots. Status monitoring of these two components is an important part of eliminating drift.

The Exgine system in its current design does not have deterministic startup. At every reboot, the transmitting Exgine in the Exporter can start at a different time reference, and even the receiving Exgine interface in the exciter can come up within a time window, not an exact time. The manufacturers have worked with DTS on this issue to some degree, but it is not perfect.

Below are graphs from the latest diversity delay measurement devices on the market. These graphs were generated at the same time on a single test station. Both the exciter and Exporter are co-located at the transmitter site and properly synced. The Exciter is rebooted to generate the graphs for analysis.

As you can see in Figures 13-15 the products show a ~425 sample drift when the exciter was rebooted with their graphing interfaces. This type of precision analysis is what is required to measure the diversity delay stability of your system. Do not focus on the 425 sample number specifically for a reboot, the number will vary depending on factors such as manufacturer, firmware, network, and clocking methods in use. The same exciter or Exporter can be rebooted many numbers of times, and the delay will usually come back at some slightly different number than the previous state.

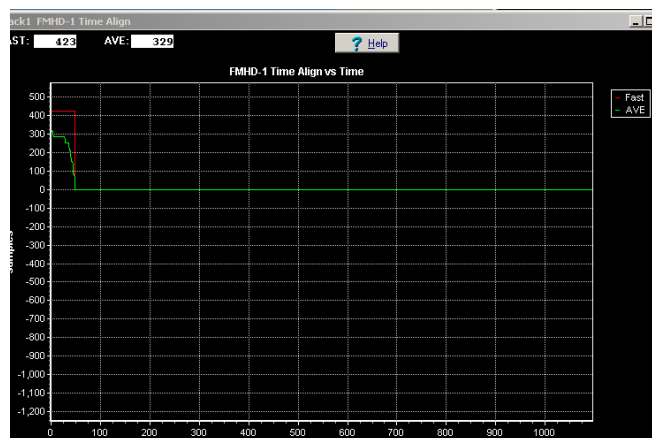


Fig 13 Belar FMHD-1 Real-time Plot of Exciter Reboot

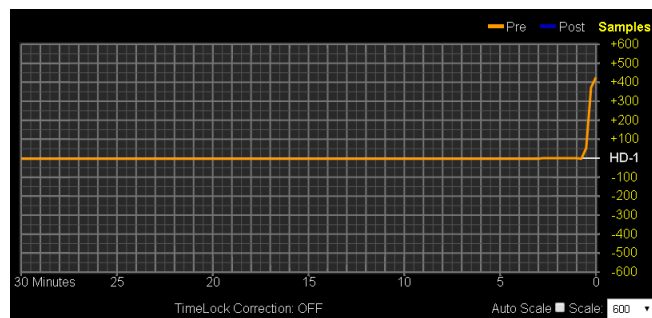


Fig 14 DaySequerra Real-time Plot of Exciter Reboot

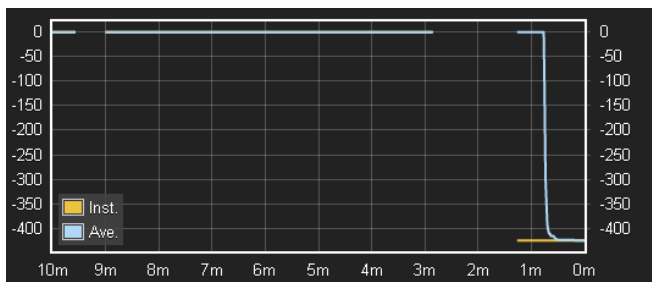


Fig 15 Inovonics JUSTIN 808 Real-time Plot of Exciter Reboot

There are discussions among the manufacturers and DTS about adapting the Engine core for HD Radio Single Frequency Network (SFN) systems, commonly known as on-channel boosters. Broadcasters should encourage research and development in this area, as it would add deterministic startup to Engine as a requirement at the core of both the Exporter and exciter. This deterministic startup would be essential to sync a single Exporter with multiple SFN HD Radio exciters in a station's coverage area. While it is unclear how many stations would implement such networks, once the work has been performed, the basics of deterministic startup could be applied to the more common single Exporter to exciter topology used by most stations today. This could be supported in later 4th generation and 5th generation hardware easily. The viability of updating existing 3rd generation hardware to support this would be a separate research effort.

Improper Clocking Configuration

It would be impossible to cover every Exporter and exciter clocking configuration in the scope of this paper. Therefore, make sure you follow the proper configuration for your Exporter and exciter installation as recommended by your manufacturer and your configuration. Make sure you are on current known stable firmware and software builds from your manufacturers. Improperly clocked systems have a distinct visual step pattern on today's precision diversity delay monitoring graphs. For example, in a ten minute plot in Figure 16, the station has slipped from 63 samples to 59 samples.

In Figure 16, this was an Exporter and exciter co-located at the transmitter site. The exciter was a GatesAir Flexstar on the latest 8.45 firmware with Engine 4.40. In that configuration, a 50 ohm BNC cable from the Exporter to the exciter provides the best E2X stability. This cable was in place. All the physical connections had been done, but a simple software configuration setting in the exciter was set to use "Internal" sync as opposed to "Ext. 10 MHz".

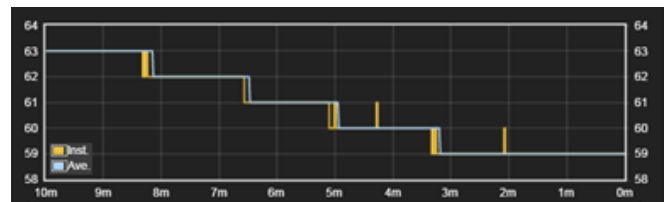


Fig 16 Exciter Clocking Error: Ext. 10 MHz not selected (Detailed View, 10 Minutes)

Figure 16 was one example of a misconfigured GatesAir Flexstar, but clocking issues can occur with Exporter or Exciter designs from any manufacturer if either the physical installation or software settings are not configured properly. Figures 17 and 18 below show a clocking problem that can occur on the Nautel platform. As you can see, in approximately 12 minutes after the manual diversity delay setting of 0 was set, the station has gone from 0 samples to 6 samples. And a little over 3 hours and 15 minutes the station had drifted to over 100 samples.

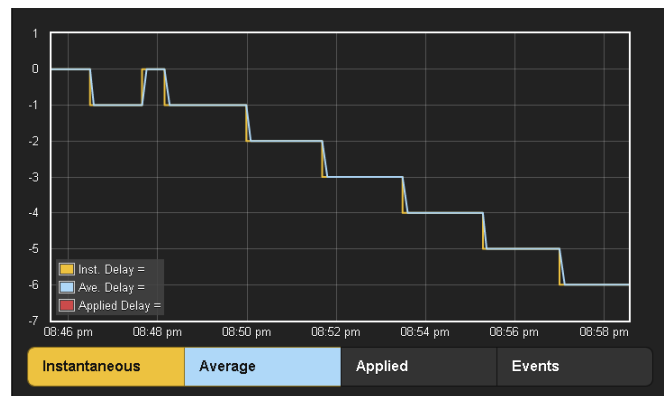


Fig 17 Exciter Clocking Calibration Issue (Detailed View, ~12 Minutes)

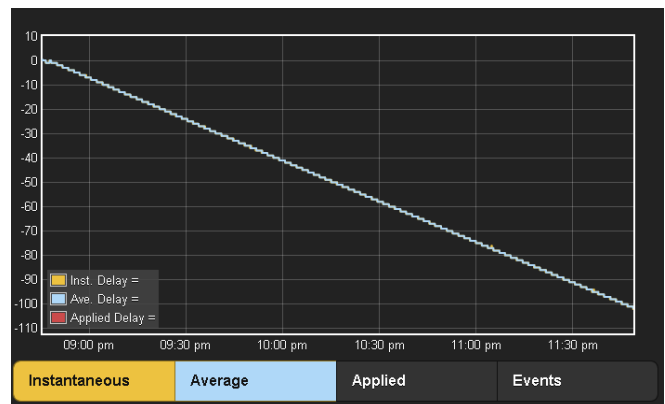


Fig 18 Exciter Clocking Calibration Issue (Coarse View, ~3 hours and 15 minutes)

In Figure 17 and Figure 18 above, this was an Exporter and Exciter co-located at the transmitter site. The exciter was an integrated Nautel exciter in a new GV transmitter. In this configuration, Nautel has typically recommended connecting the Exporter's dedicated Engine eth0 port to the

Exigine interface of the exciter with a single CAT5/6 cable and relying on E2X clocking. When ordering a new transmitter and Exporter together, Nautel calibrates both at the factory. But in the instant case, the Exporter on the station was re-used from a previous installation, and it was approximately 3 years of age. While GPS referenced, its Exigine reference system needed to be calibrated to the new GV exciter. Nautel has a technical bulletin regarding this issue with calibration procedures². Regardless of manufacturer or configuration, without the latest diversity delay monitoring hardware and their powerful logging engines, clocking problems may be hard to identify or isolate, but a distinct stepping pattern as shown in Figures 16-18 is likely evidence of a clocking issue.

GPS Sync

It was demonstrated earlier in Figures 7-10 that GPS on the receiving Exigine exciter is important when the Exporter is not located at the transmitter site. It goes without saying; the Exporter at the studio must also be synced to GPS to gain the benefits of improved diversity delay stability.

However, a common misconception or myth that exists among broadcast engineers that if the Exporter is located at the transmitter site, GPS synchronization is optional. This couldn't be further from the truth. GPS-disciplined oscillators are really a requirement for long-term stability of the station to maintain the 0 ± 3 sample spec.

Also, many exciters and Exporters use the GPS reference to make sure their oscillators, sampling and 10 MHz subsystems are disciplined and fall within acceptable operating tolerances. If a component in these circuits fails and the hardware is not GPS synced, you may not be given any warning of a problem.

Hardware Failures or Defects

Also difficult to fully address in the scope of this paper are each manufacturer's various clocking and sampling systems. Sometimes components in these systems fail or need to be recalibrated due to age. These can be tricky to troubleshoot in the field without experience with the hardware. Often times, loaner or spare Exporter or exciters can be used to help troubleshoot the issue in the field. Or sometimes it could be best to send them back to the factory for analysis.

As mentioned above, if an Exporter is not GPS disciplined, it may be hard to learn of a hardware failure or out-of-tolerance conditions of the internal oscillators and timing systems. One telltale sign is perfect GPS reception statistics being recorded by the Exporter or GPS receiver, but a GPS/timing or 10 MHz fault noted by the hardware. If

the GPS is not installed, the GPS reception is intermittent, or a GPS antenna or coaxial cable has an issue, then an important safeguard in the system design is missing.

Separate Audio Processors for FM and HD

It is now becoming clear that the once-embraced tactic of implementing a separate audio processor for analog FM and the HD1/MPS digital audio has been causing blending headaches that this industry may not have imagined over thirteen years ago.

When FM stations were first converting to HD Radio, the need for separate audio processors was apparent. Analog FM channel processing requires the use of very aggressive techniques to increase apparent loudness and program density to help overcome the analog channel impairments of multipath effects, noise, etc. Also, the use of pre-emphasis was required, the analog FM was limited to 15 kHz of audio frequency response, and various encoding techniques were employed to optimize the separate mono L+R and stereo multiplex L-R decoding by receivers.

In comparison, the new FM HD1/MPS audio channels are pristine, near CD quality (depending upon the bit rate used), free of channel impairments, required no pre-emphasis, offer 20 kHz of audio frequency response and discreet left and right channel encoding/decoding. When configuring processing for the HD Radio digital audio channel, a broadcaster might not need to be as aggressive with the audio processing because the channel was pristine.

Because of these differences, separate processing was encouraged as a best practice for the initial stations adding HD Radio broadcasts. It was not until later, 2005-2006 that the audio processor manufacturers started offering processors with FM+HD processing integrated in a single device. These single box processors became the more accepted practice on how to install HD Radio on a new station after they became available. But it has been found through market scans with diversity delay devices and interviews with broadcast engineers that many stations that employed HD Radio before single processor solutions were available have remained on separate audio processors.

While performing research with these newer delay measurement devices, it became apparent that some stations would correlate audio between the analog and digital as expected and stay locked and consistent. On other stations, there were mixed results. At some stations these devices could never obtain a correlation value of the delay difference between the analog and digital. Some could, but not 99% of the time, perhaps only 10 or 20% of the time. Even more perplexing, four different products could be tuned on the same station and result in different diversity delay readings. These readings could be different by a few samples, or in some cases, many tens or hundreds of samples.

iHeartMedia brought this to the attention of DTS and each of the manufacturers of the devices. After extensive

² Contact Nautel and inquire about Information Sheet IS14002 Exigine VCXO Clock Crystal Recalibration if you believe you have similar symptoms. They can help you diagnose the issue further and provide the instructions if they feel this is applicable.

research and testing on numerous stations, many deep investigations, we stumbled upon the separate audio processor issue.

Summarizing our findings, it was determined that the monitor manufacturers were doing their correlation sampling differently. Depending on the audio frequency bands being analyzed, sampling duration, and averaging, we were seeing different results. The most dramatic measurement differences were noticed when the analog audio was processed differently than the digital audio. This occurs when separate audio processors are employed on a station.

Looking at it on a wideband basis, *i.e.*, 0Hz-15kHz, one could visualize what appeared to be instantaneous delay swings or differences between the analog FM and HD Radio digital audio of anywhere from 1 to 300 samples per second as shown in Figures 19-21.

Upon further research, it was found that stations implementing single, integrated FM+HD processors on most platforms, on a wideband analysis were only seeing diversity delay measurement differences of ± 1 sample, well within spec. See earlier in Figure 6 for a depiction of this.

But those stations employing separate processors, in particular those using completely different separate processor architectures, could experience wideband “drift” measurements of ± 300 samples per second. *i.e.*, we found in our market scans stations that had an Omnia 11 on the analog, and an Omnia 6 on the digital. Or, an Omnia 11 and an Orban 8500 pairing. These combinations represent quite different techniques in audio processing implementations, and that is why we were seeing wideband measurements of ± 300 samples in some cases. Figure 19 depicts the values we were seeing. Notice the instantaneous readings of +200 and -150 samples, indicating a perceived 350 sample swing.

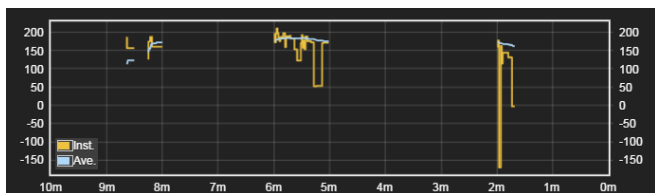


Fig 19 Exporter and exciter co-located on isolated network. Separate processors Omnia 11 FM, Omnia 6 HD (detailed view, 10 minutes)
Wideband analysis, no longer available in products

Narrowing it down to the same architecture, *i.e.*, an Omnia 6 on the analog and a separate Omnia 6 on the digital, if the same firmware/software is in use, we have found that dissimilar presets can cause a wideband measurement of ± 150 samples, as shown in Figure 20.

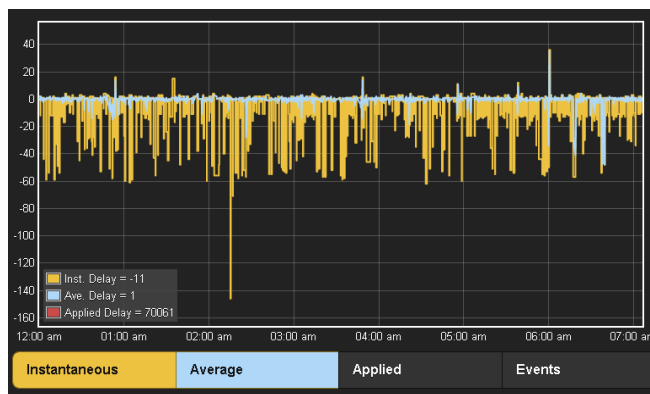


Fig 20 Exporter and exciter co-located on isolated network. Separate Omnia 6 processors, dissimilar presets (coarse view, ~7 hours)
Wideband analysis, no longer available in products

Copying the preset in use from the analog FM Omnia 6 to the separate HD Radio digital audio Omnia 6 and then making minor adjustments tends to keep the audio within ± 1 sample for the majority of the day with a wideband reading. See a depiction of this below in Figure 21.

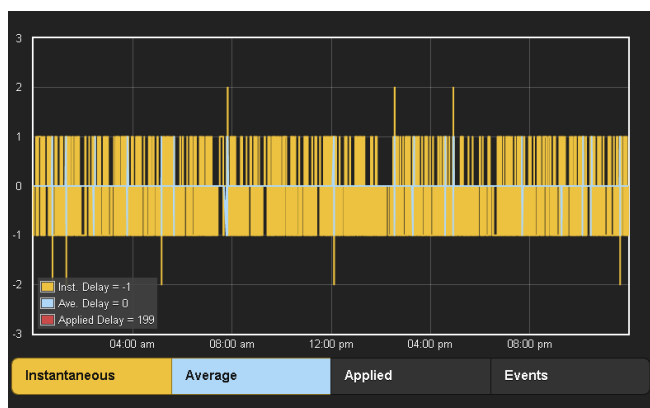


Fig 21 Exporter and exciter co-located on isolated network. Separate Omnia 6 processors, similar presets (coarse view, 24 hours)
Wideband analysis, no longer available in products

Through extensive research, DTS discovered a frequency band, filtering, and averaging techniques which seemingly could eliminate this “drift” we were seeing in wideband measurements. This information was shared with the measurement device manufacturers, and their engineers were able to employ these new specifications in their products.

Today the active time delay measurement products in development from manufacturers, including Belar, DaySequerra and Inovonics, use the guidance provided by DTS. Our preliminary findings on both complex separate and single processor setups we can typically achieve measurement results within ± 10 samples. Stations must upgrade to the latest firmware for best results. This will allow automatic alignment products to be able to measure the diversity delay of stations with complex dissimilar dual

processor configurations in coarse fashion with seemingly great accuracy over time. Only time will tell how well this will work as these techniques appear in more products and in use across a wider selection of stations. Of note, the ± 10 sample range is not within the spec of 0 ± 3 samples. DTS continues to test these latest methodologies with the measurement device manufacturers and I think we will see additional findings in the future as a result of this research.

What we are finding is that, while a station may have a perfect alignment with no drift whatsoever, when separate processors with dissimilar presets or a completely different architecture are used, the blends between analog and digital often do not sound good. We theorize this is because each processor, particularly those with different hardware designs, has different throughput, sampling, and processing delays. Phase rotation and other techniques are in use and may vary significantly from one device to another dissimilar device. Even when on separate processors but identical hardware, if different presets are in use, the presets may be processing audio in different frequency ranges of the multiband processor differently. The theory is that when dissimilar processors are in use, if not near identical, that the blend may never be able to sound good enough.

Ultimately, the industry may find that it must eliminate separate audio processors for analog and digital, and implement integrated processors to achieve blends that are not objectionable to listeners and automotive companies. Or, as depicted in Figure 21, perhaps stations with separate, but same model processors can mitigate the differences and manage this issue with education and care. Only time will tell how this will pan out, I expect a very robust analysis of this topic by many industry engineers in the coming years. One thing is for sure, we will likely learn things we never knew before about diversity delay, audio processing, and blending.

DTS is scheduled to presenting more in-depth findings and research at the 2016 NAB Broadcast Engineering Convention (BEC) presentation in April 2016 entitled “*Audio Processing Configuration and its impact on HD Radio Blending.*” [4]

Audio Phase Differences

While commonly known, it bears mentioning, the audio in the analog FM and digital HD1/MPS should be in phase. In some early hardware designs the audio phase was inadvertently flipped 180 degrees. Also, there was a small school of thought initially that the out of phase condition might be better for blending. When the audio is perfectly synchronized with similar processing, an out of phase condition causes a brief mute or fade to complete cancellation on blend, which can be very fatiguing.

Many products now offer the ability to invert the audio phase in the digital or analog chains. This is common in most audio processors and the Exporter designs, spanning

over a decade. One thing to be mindful of is to make sure the setting of each of these devices in the broadcast chain is known, otherwise there may be an inadvertent phase flip.

The broadcast monitors of last decade detected phase issues relatively well. And the new monitors on the market today also detect this as well. Some solutions can even automatically correct the problem. The digital and analog audio should always be in phase.

Audio Level (Gain) Differences

The DTS spec is that the analog and digital audio are to be within 1 dB of each other at all times. Broadcasters will want to make sure that the level is matched between these two different air chains. Differences beyond 1 dB can be audible and cause fatigue. The measurement devices from a decade ago offered this ability, as do the current product offerings. As discussed below, the single device solutions, when inserted in the digital HD1/MPS audio path can measure and adjust the digital audio to maintain a constant level between the analog and digital chains.

How to Address the Problems

For years, broadcast engineers have been working with DTS and transmitter hardware manufacturers to resolve the alignment problems discussed in this paper. Progress has been made, and some of the many common issues that cause drift have been addressed. As I have transitioned from a traditional broadcast engineer to an HD Radio implementation specialist for iHeartMedia, I have discovered there are just too many variables beyond the control of all the individual parties involved. The above items are just some most common issues that can cause drift.

There needs to be an industrywide push for updated, precision and continuous diversity delay measurement systems and automatic corrective systems. iHeartMedia and other broadcasters have been asking for products and solutions in this area, and we have seen the industry respond in the last few years. At the April 2015 NAB Show in Las Vegas, we saw a large collection of solutions being introduced to the marketplace. Moving forward, many new products and integration efforts continue to be introduced.

Below, I have compiled a roundup of products that can help stations monitor and manage diversity delay. Note that I have not personally tested each solution, and the list should not be construed as a product review or endorsement. Also, this is an evolving space. Some vendors are working on additional integration efforts and refinements with other products; and there may be other offerings available by the time you read this paper. Check with each vendor about pricing and delivery schedules for the implementations you are considering.

Implementation Strategies Available

Create a two-piece system. Consider pairing a monitoring receiver that can measure the diversity delay offset and send a correction offset to a device that is active in the analog air chain (an audio processor, delay unit or Exporter). If the station has some of these products already, this could make a lot of sense. By upgrading firmware on existing devices, it may be possible to put together two pieces of hardware to come up with an automated hardware solution.

Single-box solution. Some stations may choose to implement devices that measure and correct the diversity delay in a single device. This is also helpful for larger companies looking for standardization of delay solutions from station to station. The single devices below can be inserted into either the analog or digital air chain to make delay adjustments and have an integrated receiver to make the measurements of delay offset. A simple antenna can be used on these units, or coax off an RF sample (in FM+HD installations) with the appropriate amount of attenuation and the device.

Many engineers I have spoken with are most comfortable about having these devices right before the Exporter, so that any adjustments it is making to delay are contained to just the digital audio and the analog plant remains exactly the same as it does today. In that implementation, the existing diversity delay in the analog chain can be increased to a larger number than needed today. Then, these devices will make up the difference in the digital chain. For example, if the analog processor is performing the delay at eight seconds now, this could be increased to ten seconds. Then, the automatic correction device in the digital chain would add two seconds of additional delay to the digital chain to now match the larger delay in the analog chain. The advantage of going in this direction is that the devices can then correct the digital audio level and provide level alignment between analog and digital. The disadvantage to it being in the digital chain is that it would not work for any station that has to eliminate all delay for live programming and enter what is commonly referred to as “ballgame mode.” Luckily, the products are easily configured to work in either chain. Both products on the market today have delay ramp controls and can also jump to correct delay as desired.

Solutions Available (as of February 1, 2016)

Belar

FMHD-1 This broadcast monitor receiver makes a variety of HD Radio related measurements, and it can measure diversity delay continuously. Not only is this helpful when trying to manually align a station, the correction offset can be sent to a variety of devices in this list, such as products from GatesAir, Nautel, Omnia, Orban, 25-Seven and Wheatstone below. For devices which jump to the correction delay value, the FMHD-1 has an optional ramp function which sends the correction in user defined incremental steps.

In a recent software release (version 6.0 dated October 8, 2015) the device can now scan up to six station presets and send correction codes to supported delay devices. The latest versions implement the most recent measurement filtration techniques developed in Fall 2015 by DTS. Belar is actively releasing new software for this device, so look for the latest version when starting integration efforts.

For integration with audio processors, the delay is changed in the audio processor in the analog chain. For integrations with GatesAir or Nautel Exporters, the station may be configured in two different methods. You can employ the traditional Exporter delay model, configuration option “GatesAir FM” or “Nautel FM” where the analog air chain is looped through the Exporter, providing the full analog diversity delay (7-10 seconds). Or, there is a newer configuration with options “GatesAir HD” and “Nautel HD” where there is a fixed analog delay in another device, i.e., an audio processor in the analog air chain at a high fixed value (i.e. 10 seconds), and then loop the HD1/MPS digital input through the Exporter’s delay to then increase the HD1/MPS delay 1-3 seconds to match the HD1/MPS to 10 seconds on the analog.

Broadcast Electronics

XPi10 esp Exporter This Exporter has a built-in diversity delay alignment feature. If the Exporter is provided with audio of the analog and digital from a receiver running in split mode through the unbalanced audio inputs, when configured, it will measure and maintain diversity delay. Note that the station must be configured to have the analog diversity delay fully provided by the Exporter for this feature to be useful.

DaySequerra

M4DDC This is a single-box solution that can do the measurement and delay adjustment in a single device. It inserts in your AES stream of either the analog or digital air chain and can make the corrections necessary for time alignment, level alignment and phase reversal correction. It has a Web GUI and can alarm via GPIO, SMTP (email alarms), and also has an SNMP interface. The Web GUI also does data collection and can show you how the device is working over time graphically. Delay history in .CSV format is also available via FTP. The latest versions implement the most recent measurement filtration techniques developed in Fall 2015 by DTS. DaySequerra is actively releasing new software for this device, so look for the latest version when starting your integration efforts. This is an FM-only device; an AM version with slight hardware variations is expected in the future.

M4.2 TimeLock This broadcast monitor receiver makes a variety of HD Radio-related measurements, one of which is that this product can measure diversity delay continuously, helpful for aligning stations manually. In addition, this product supports automatic diversity delay correction with

many of the Nautel, Omnia and Wheatstone audio processing products listed below. Support for delay controls in the GatesAir HDE-200 Exporter, Nautel Exporter Plus, and Omnia 11 audio processor is planned soon but not yet available. The latest versions implement the most recent measurement filtration techniques developed in Fall 2015 by DTS. DaySequerra is actively releasing new software for this device, so look for the latest version when starting your integration efforts

GatesAir

HDE-200 Exporter can receive correction outputs from the Belar FMHD-1. Future support for the DaySequerra M4.2 TimeLock is expected, but not available yet at time of publication. With Belar's latest software, the Exporter's delay corrections can be placed in either the analog or digital chain.

Inovonics

JUSTIN 808 This is a single-box solution that can do the measurement and delay adjustment in a single device. It inserts in an AES stream of either the analog or digital air chain and can make the corrections necessary for time alignment, level alignment and phase reversal correction. It has a Web GUI and can alarm via GPIO, SMTP (email alarms), and also has an SNMP interface. The Web GUI also does data collection and can show how the device is working over time, both graphically and in .CSV format. The latest versions implement the most recent measurement filtration techniques developed in Fall 2015 by DTS. As of this writing, development of the Inovonics firmware is stable, new features are being considered. The product may be modified based on customer feedback and suggestions, so it is best to check for the latest firmware before proceeding. This is an FM-only device; there are no current plans to make an AM version. However, should the industry show interest in such a device that may change.

Nautel

Exporter Plus can receive correction outputs from the Belar FMHD-1. Future support for the DaySequerra M4.2 TimeLock is expected, but not available yet at time of publication. With Belar's latest software, the Exporter's delay corrections can be placed in either the analog or digital chain.

Omnia

Omnia 7, Omnia 9 and Omnia 11 audio processors can work in conjunction with the Belar FMHD-1 to automatically adjust the analog diversity delay. The Omnia 11 requires version 1.6 firmware or higher. At the time of this writing, the DaySequerra M4.2 TimeLock integration was available with Omnia 7 and Omnia 9 processors, with support for the Omnia 11 in the near future.

Orban

The Orban 8600, 8600S, 8500, 8500S, 5700, and 5500 audio processors can work in conjunction with either the Belar FMHD-1 or the DaySequerra M4.2. Orban notes that even the non-HD versions of these processors make diversity delay available for stations running separate analog FM and HD Radio digital audio processors.

25-Seven

Precision Delay can be inserted in the analog air chain to achieve diversity delay and supports automatic correction adjustments from either the Belar FMHD-1 or the Worldcast/Audemat Golden Eagle HD.

Wheatstone

AirAuraX3, FM531HD, FM-55, AM-55, and VP8ip audio processors can work in conjunction with the Belar FMHD-1 or the DaySequerra M4.2 TimeLock.

Worldcast/Audemat

Golden Eagle HD is a broadcast monitor receiver makes a variety of FM and HD Radio related measurements, one of which is that this product can measure diversity delay. It can work with the 25-Seven Precision Delay for automatic diversity delay correction. Also, it can be configured to monitor diversity delay alignment and send alerts if alignment (or other parameters) are out of specification. All alignment measurements are available via SNMP for use by third party equipment.

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