IMPROVEMENTS TO FM AND IBOC SIGNAL QUALITY THROUGH THE USE OF PRE-EQUALIZATION

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ABSTRACT

FM HD Radio™ transmission, whether pure digital or hybrid (FM+HD), requires the use of a linearized transmitter to minimize the generation of intermodulation products during amplification of the HD signal. Even these transmitters have limitations to their linearity so to further reduce spectral regrowth, pre-correction techniques at the exciter level have been employed. With the hardware now available in these modern exciters coupled with their linear transmitter, it is also possible to add corrections for amplitude and phase variances introduced by the transmission system.

The objective of this paper is to demonstrate improvements that can be achieved to the FM broadcast signal, both analog and digital, by the use of pre-equalization at the exciter stage.

BACKGROUND

Due to limited real estate and tower locations the FM broadcast plant, especially in urban centers, can house several transmitters each producing its own carrier frequency. These signals are usually combined at the base of the tower in order to have a single feeder line to the antenna. The combining technique employed can vary but usually utilizes bandpass or bandstop filters to provide the necessary isolation between the carrier signals. It is the presence of these filters that adds undesired frequency response and variances to group delay in the transmission path.

The traditional FM channel bandwidth is 200kHz but that has now been increased with the addition of HD Radio. Systems that use a common radiating element (antenna) for both the analog and digital portions of the signal now require a channel bandwidth of 400kHz placing even a greater strain on the channel combiners to provide an adequate response.

The mathematical relationship between frequency response, group delay and the degradation to the FM hybrid signal is beyond the scope of this paper but can be observed by three figures of merit: stereo separation; AM synchronous noise; and spectral analysis of the HD carriers to verify proper amplitude. Note as well, the iBiquity requirements from SY_SSS_1026s states total gain flatness of the transmission signal path to be flat within ±0.5dB while differential group delay variation of the entire transmission path to be within 600nS from F_c- 200kHz to F_{c+} 200kHz.

BASELINE MEASUREMENTS

Equipment was set up as shown in Figure 1. AM synchronous noise using the standard test tone of 400Hz was measured to be 53.5dB. Frequency response, group delay, and stereo separation were then measured.

A narrow bandpass filter and line stretcher were then added as depicted in the narrowband path. Network measurements as well as the three figures of merit were repeated at several different settings of the line stretcher to verify consistent transmitter response.

Synchronous AM noise was measured to be 36dB in the narrow band path while the remaining results are shown in the following figures.

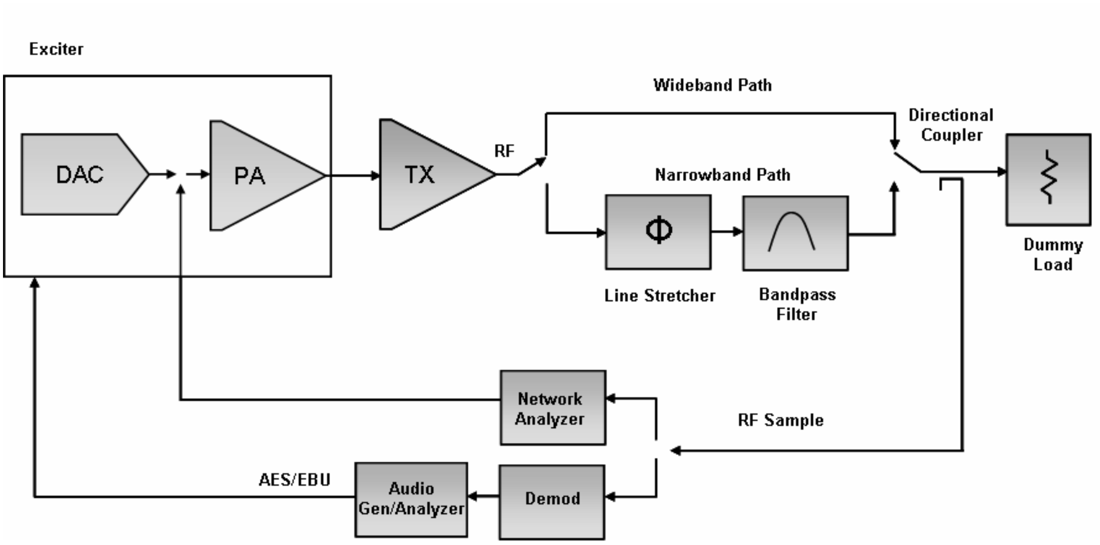

Figure 1 – Baseline Measurement Setup

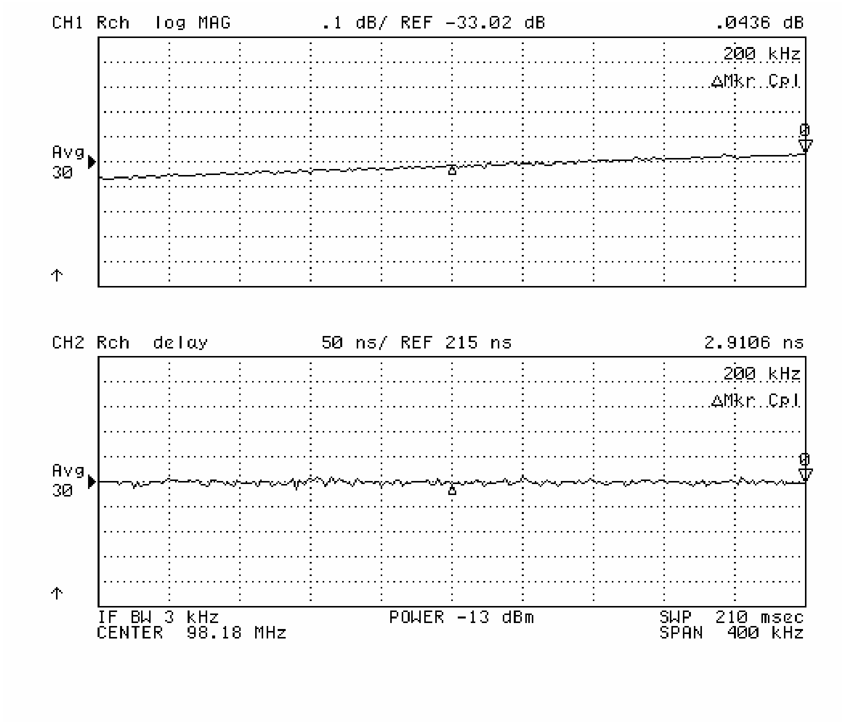

Figure 2 and 3 – Transmitter Response and Group Delay for Wideband Path

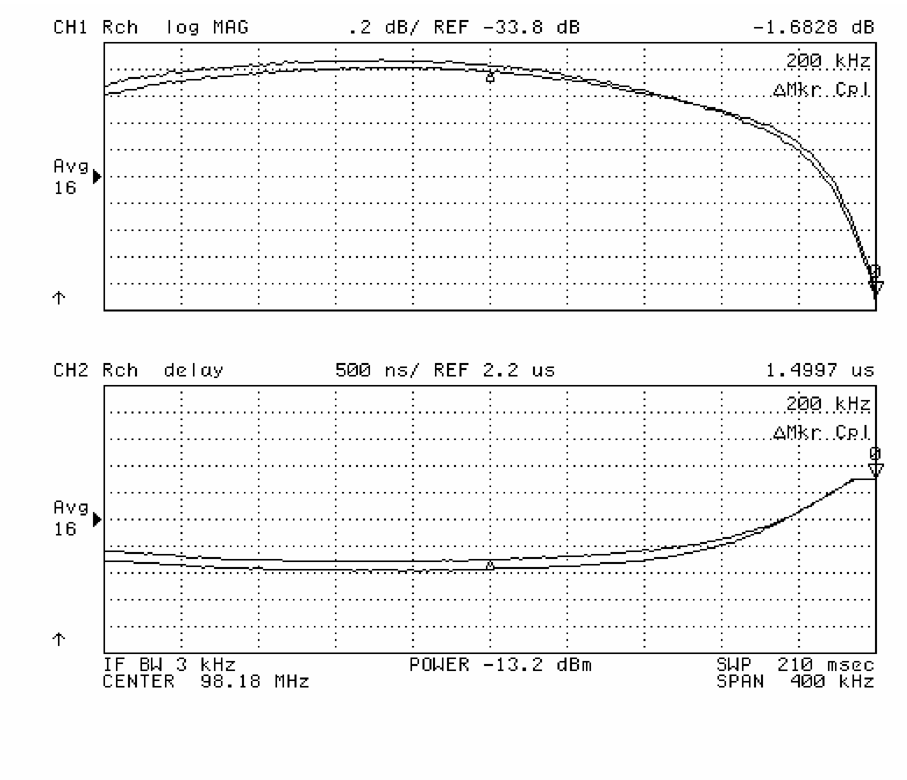

Figure 4 and 5 -Transmitter Response and Group Delay into Narrowband Path (Bandpass Filter Passive Response shown as 2nd Trace)

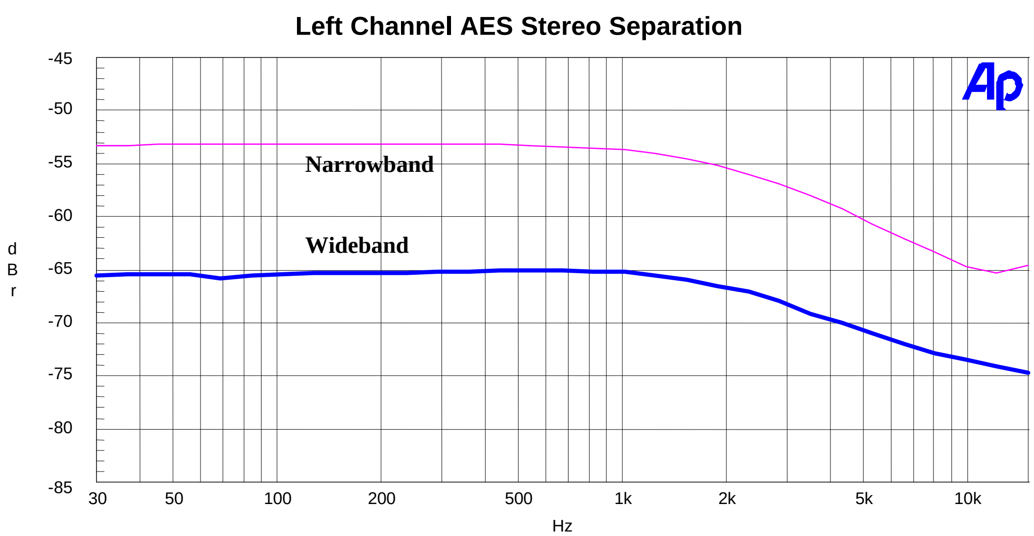

Figure 6 – Stereo Separation for Wideband and Narrowband Paths

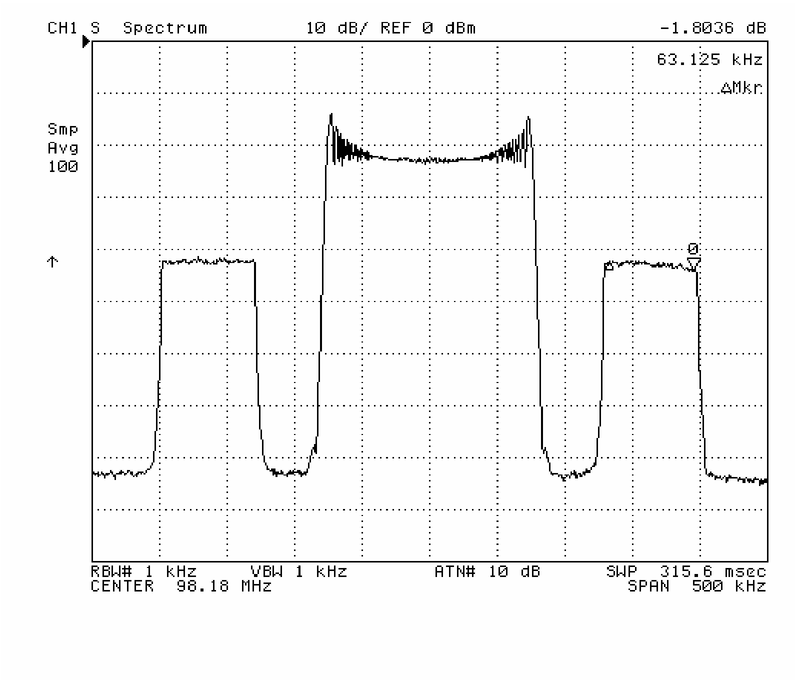

Figure 7 – FM Hybrid Spectrum for Narrowband Path

The degradation in signal quality was severe; synchronous AM noise degraded by 17dB, stereo separation degraded by 12dB and obvious tilt to the HD carriers of approximately 1.8dB.

SOLUTION TO LIMITED CHANNEL BANDWIDTH

The solution considered was straightforward: insertion of a digital FIR filter at the baseband of the exciter stage with the inverse amplitude and group delay response to the system thus canceling the signal degradation.

The filter would pre-equalize the baseband signal. Using a linear transmitter would allow these phase and amplitude corrections to be carried through to the output. Having the amplitude response and group delay characteristics for the channel, an appropriate filter was designed and implemented. Measurements were made once more through the narrowband path.

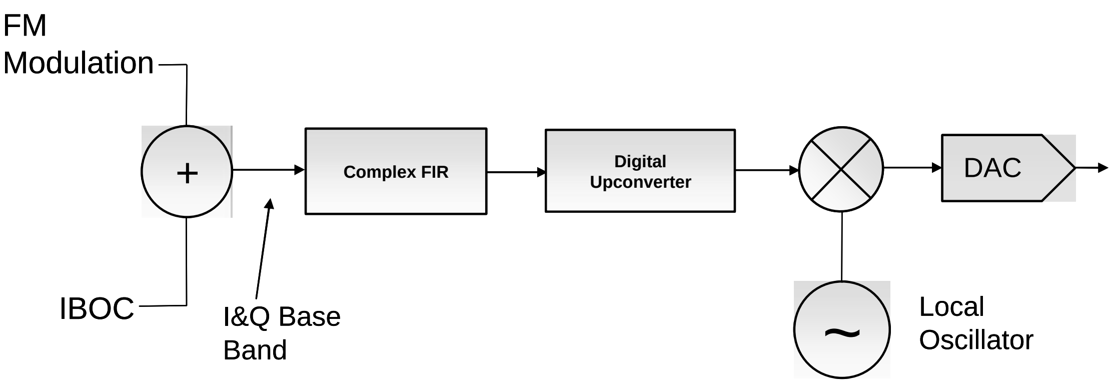

Figure 8 – Exciter Block Diagram with Filter Location

PRE-EQUALIZER RESULTS

With the pre-equalization in place, AM synchronous noise was measured to be 55dB. The remaining results are shown below.

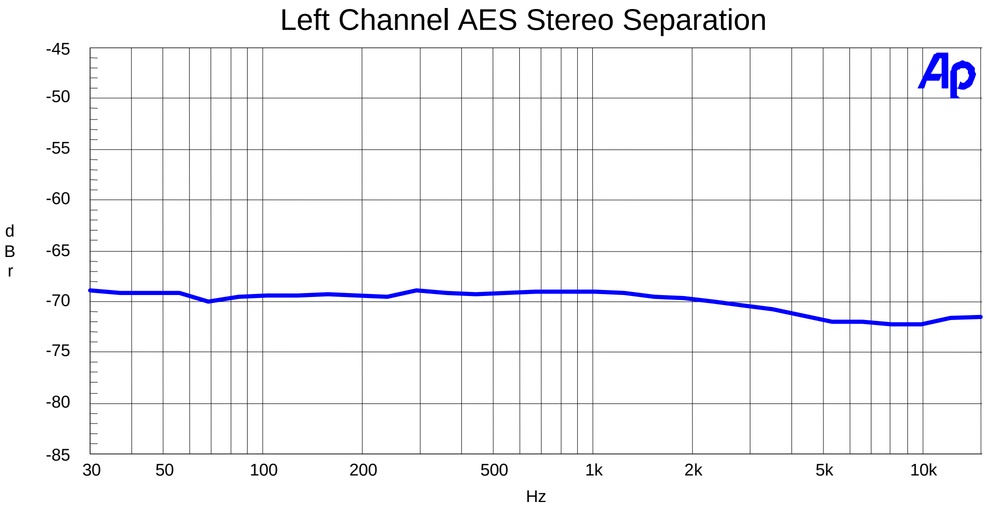

Figure 9 – Equalized Stereo Separation for Narrowband Path

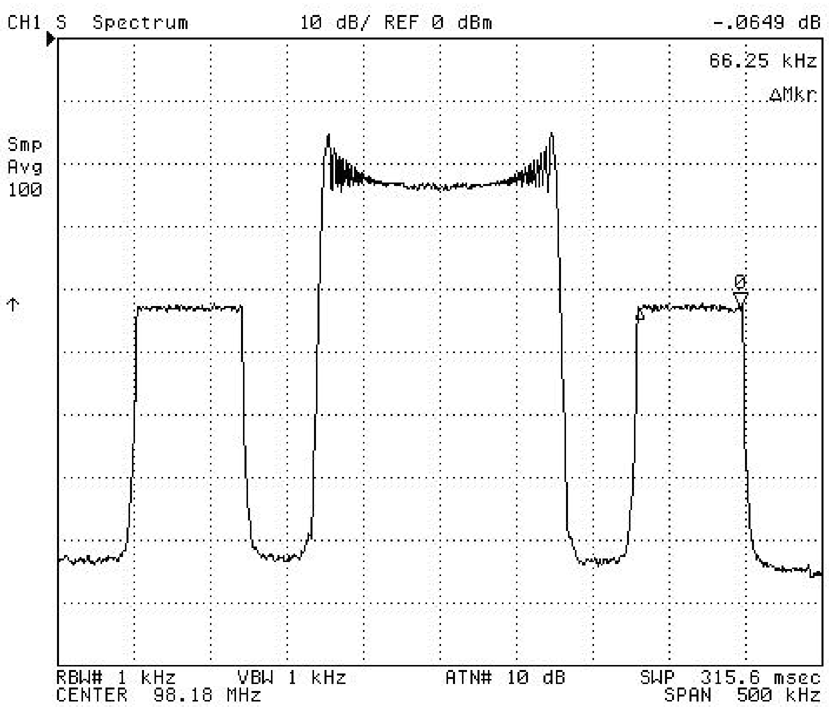

Figure 10 – Equalized FM Hybrid Spectrum for Narrowband Path

CURRENT LIMITATION OF EQUALIZATION

The current hardware resources available for the FIR filter limited the correction capabilities to approximately 2dB and 1uS over the 400kHz bandwidth. From the narrowband path plots, group delay variance is shown to be 1.5uS. The filter does correct the variance to within iBiquity requirements.

In order for the transmitter to properly respond to the pre-equalization, a linear transmitter is required. However, should the input VSWR created by the filter become severe, transmitter protection circuitry could cause power fold back resulting in additional response issues which pre-equalization cannot correct.

CONCLUSION

Amplitude response and group delay variation due to filters in the transmission path cause degradation of the FM broadcast signal. Knowing the characteristics of this filter, it is possible to pre-equalize the exciter signal to negate these effects and improve signal quality in an FM HD Radio™ system.