NRSC REPORT

NATIONAL RADIO SYSTEMS COMMITTEE

NRSC-R12
Considerations for a 10 kHz Transmission Bandwidth in AM Broadcasting
November 20, 1986

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FOREWORD

NRSC-R12, Considerations for a 10 kHz Transmission Bandwidth in AM Broadcasting, was written following the release by the NRSC of a Draft Interim Voluntary National Standard concerning a standardized transmission pre-emphasis and 10 kHz bandwidth limitation for AM broadcasting. This report describes experimental results and makes recommendations regarding the use of 10 kHz lowpass filters in the AM broadcast chain; regarding analysis of a pulsed-USASI noise test signal; and, regarding introduction of a proposed NRSC stopband specification and a method for the determination of compliance.

The NRSC is jointly sponsored by the Consumer Electronics Association and the National Association of Broadcasters. It serves as an industry-wide standards-setting body for technical aspects of terrestrial over-the-air radio broadcasting systems in the United States.

Considerations for a 10 kHz Transmission Bandwidth in AM Broadcasting

Submitted to the NRSC by Stanley Salek
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November 20, 1986

BACKGROUND

On September 10, 1986, the National Radio Systems Committee (NRSC) released its Draft Interim Voluntary National Standard concerning a standardized transmission pre-emphasis and 10kHz bandwidth limitation recommendation for AM broadcasting.[1] In subsequent NRSC subgroup meetings, the 10kHz bandwidth topic has received much debate with regard to the desired steepness of the stopband and appropriate measurement techniques to verify compliance.

It is expected that the work of the subgroup will be completed by the end of 1986, to allow the release of the final standards document in January, 1987. Therefore, time is of the essence in achieving a consensus on this topic.

PURPOSE

The purpose of this paper is to describe experimental results and make recommendations in the following subject areas:

1. The suitability of providing steep 10kHz lowpass filters as an aftermarket product intended to be placed ahead of the final audio processor/limiting device in the transmission chain.
2. Analysis of a pulsed-USASI Noise test signal.
3. Introduction of a proposed NRSC stopband specification and a method for the determination of compliance.

It is intended that the material presented serve as a practical extension to some of the conclusions and recommendations of the report <u>Modulation, Overmodulation, and Occupied Bandwidth: Recommendations for the AM Broadcast Industry</u>, written for the AM Improvement Committee by Harrison J. Klein.

1 Available from the Electronic Industries Association or the National Association of Broadcasters, Washington D.C.

1. 10kHz LOWPASS FILTERING

The draft standard states that all audio frequencies modulating the transmitter above 10kHz should be attenuated to the maximum extent feasible. Most of the popular older and some recent audio processors currently being used do not incorporate filtering of any type. This coupled with varying degrees of pre-emphasis have caused excessive spectrum occupation.

An audio processor/limiter was constructed to evaluate different filtering placements. Although somewhat subjective, it was designed to be representative of many of the popular unfiltered processor/limiters on the market. The test conditions were as follows:

A. The output of the processor was input into a monaural laboratory test AM transmitter. This transmitter was of high quality in that THD measured less than 0.2% under all modulation levels lower than 100% and IMD (4:1 SMPTE method) was less than 0.5%. Frequency response was essentially flat to 15kHz and S+N/N ratio measured -75dB referenced 400Hz, 100% modulation. All measurements were made decoded through a modulation monitor, with the transmitter properly terminated.

B. The above setup facilitated the use of a spectrum analyzer* to observe occupied RF bandwidth. This method was chosen to demonstrate the factors of concern with a readout familiar to most observers. An analyzer resolution of 10dB/division vertically and 5kHz/division horizontally was selected to best cover the span of concern. A sweep resolution of 300Hz was selected; this allowed the analyzer to operate in an area where slew rate would not be a major problem. Also, this allowed a relatively fast sweep rate of 0.5 sec./division. The "MAX HOLD" function of the analyzer was used to obtain a 30 minute time storage of the transmitter output spectrum which proved to be adequate storage time when compared to a 12 hour storage cycle of the same program material.

C. Program material consisted of the first 30 minutes of the "Miami Vice" compact disc (MCA records MCAD-6150B). This disc contained widely varied program material including fast vocal, slow vocal and electronic music selections. The dynamics were such as to tax the abilities of most audio processing devices.

D. The audio processor itself was set to be as aggressive as it would normally be used at a station where a high degree of loudness was desired. Asymmetrical modulation was used since it produced a slightly worse spectrum than symmetrical modulation, although observed differences were not major. Legal modulation limits were never exceeded in any case. NRSC pre-emphasis also was used in all cases.

*Tektronix 7L5 used

Figure 1 shows the RF output spectrum produced by this test setup. Although the legal requirements of the 15kHz transition are still met, much spectrum space above 10kHz is used, especially in the area of the second adjacency. The rolloff noted above 20kHz on the photo was caused by the output filter present in the transmitter.

Figure 2 shows the spectrum produced using the same audio processor, except preceeded by a steep 10kHz lowpass filter. This pre-filtering produced a result somewhat lower in spectrum occupancy above 10kHz.

Figure 3 shows the spectrum produced once again using the same audio processor, but with a steep overshoot-corrected lowpass filter placed at its output. Excess audio bandwidth and processing aritifacts were virtually removed above 10kHz, producing maximum protection to the second adjacency.

In review of these three figures and in listening tests coinciding with the experiment, one conclusion came to light: Only the output-filtered configuration (Figure 3) would be suitable. The reasons for this are described below:

A. The effect of placing the filter ahead of the processor/limiter would be minimal at best. Figure 4 illustrates the benefit in the experimental case. When distortion products inherent in a non-ideal transmission system are added, this 10dB improvement area (shaded) would tend to decrease.

B. One interesting point discovered during listening tests was that the unfiltered and output-filtered processors (Figures 1 and 3) although heavily processed, did not sound objectional when detected by the modulation monitor. The input filtered version (Figure 2), however, was very objectional and distorted. The reason for this is illustrated in Figure 5. The modulation monitor, being capable of reproducing frequencies in excess of 15kHz, passed the desired audio passband from zero to 10kHz, in addition to the processor artifacts and distortion products beyond 10kHz (shaded area). This distortion was completely unmasked by program material and only about 20dB below passband audio (greater than 10% distortion).[2] A station unaware of this effect would be completely disenchanted with the results. A similar filter could be placed at the audio output of the modulation monitor, although wideband receivers would also pass this residual distortion.

2 This masking phenomena is also discussed in the Harrison Klein report, referenced earlier.

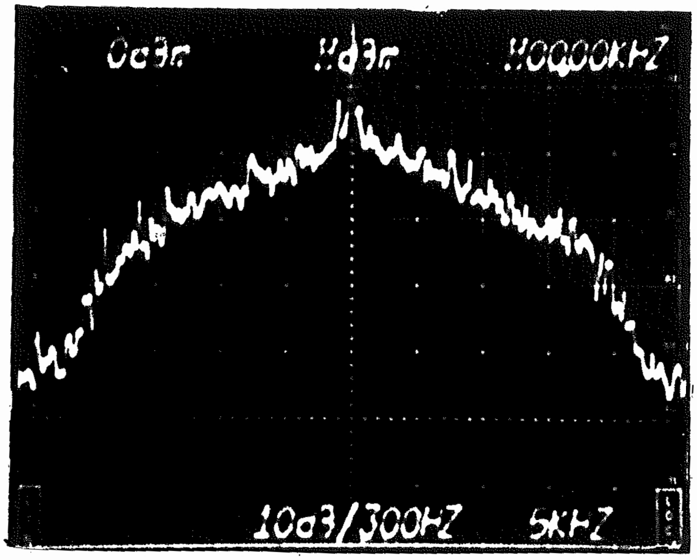


FIGURE 1

Transmitted spectrum using audio processor not employing filtering.

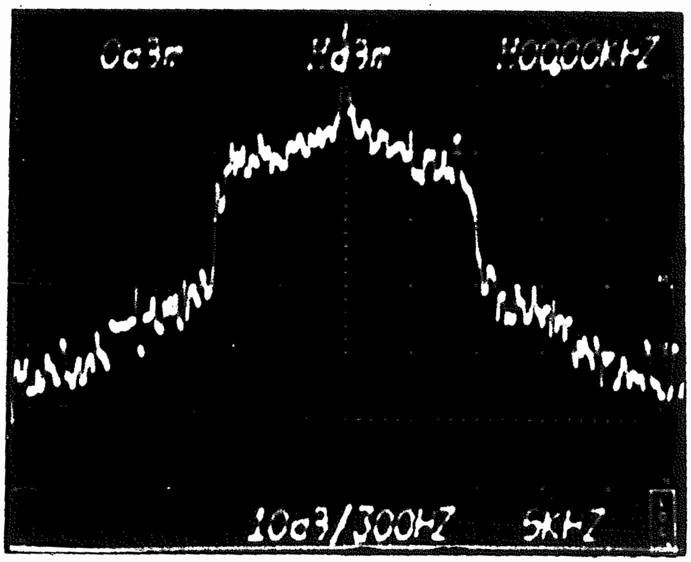


FIGURE 2

Transmitted spectrum using same audio processor of figure 1 with the addition of a steep 10kHz lowpass filter at its input.

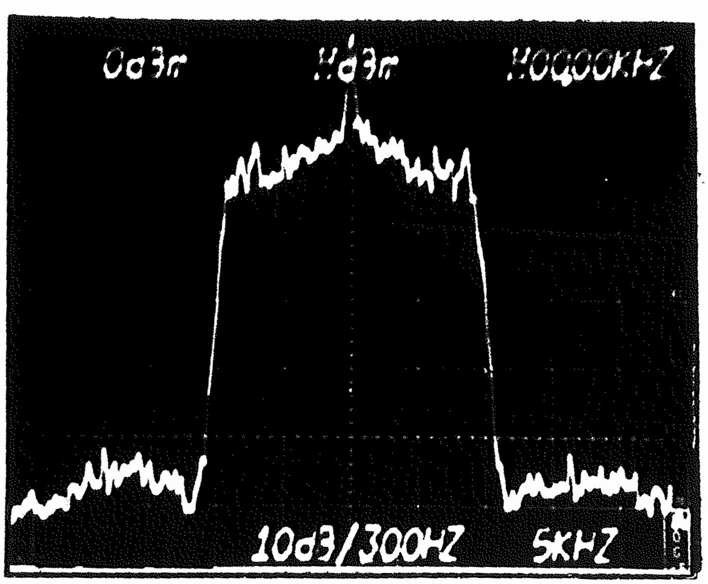


FIGURE 3

Transmitted spectrum using same audio processor of figure 1 with the addition of a steep over-shoot - corrected 10 kHz lowpass filter at its output.

Figure 4

STEEP FILTER PLACED AT INPUT OF PROCESSOR WITHOUT OUTPUT FILTER vs. PROCESSOR WITHOUT FILTERING (SHADED AREA SHOWS TRANSMITTED SPECTRUM IMPROVEMENT)

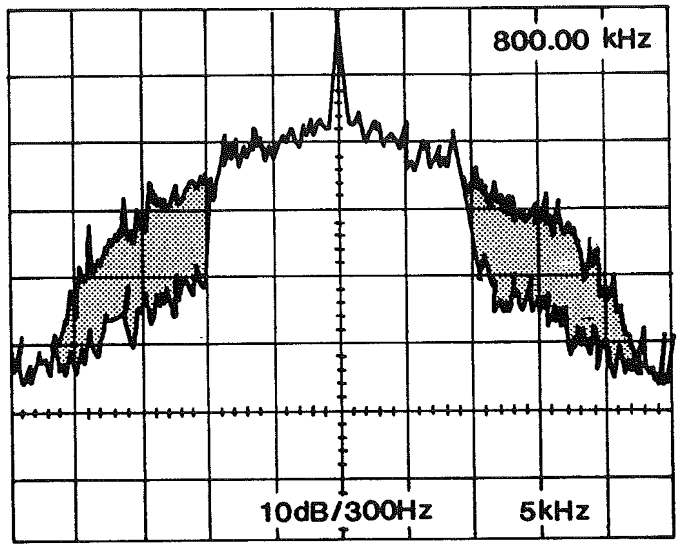
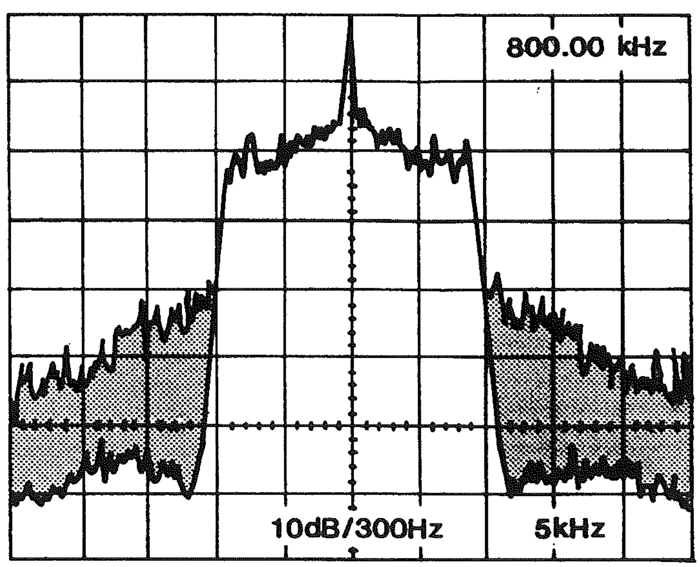


Figure 5

STEEP OVERSHOOT--CORRECTED OUTPUT FILTER vs. SAME FILTER PLACED AT INPUT OF PROCCESOR WITHOUT OUTPUT FILTER (SHADED AREA SHOWS BUILDUP OF DISTORTION PRODUCTS)



Although the output filter method used to produce Figure 3 would seem to be a good choice, a few problems exist. A steep filter design cannot be simply chosen, constructed, and placed at the input of the transmitter. Overshoot characteristics of such a filter would force the station to reduce average modulation by several decibels to avoid overmodulation. Overshoot-compensated designs, such as the filter used to produce the spectrum in Figure 3, would work well although virtually all known designs for such filters are either patented or proprietary.

Therefore, it is the opinion of the author that the NRSC not support an aftermarket input filter add-on. The reported results of stations who use such filters could be the opposite of that desired. Instead, it is recommended that the NRSC use the free market approach to a solution: to set a compliance standard for those who sell audio processing equipment or add-on overshoot-compensated filters. Such equipment would have to pass a compliance test before it could be sold as being "NRSC Compatible." This would include having a fixed NRSC pre-emphasis mode in the case of audio processors, in addition to attenuating output spectrum beyond 10kHz. A proposed audio stopband specification is included in section 3 of this paper.

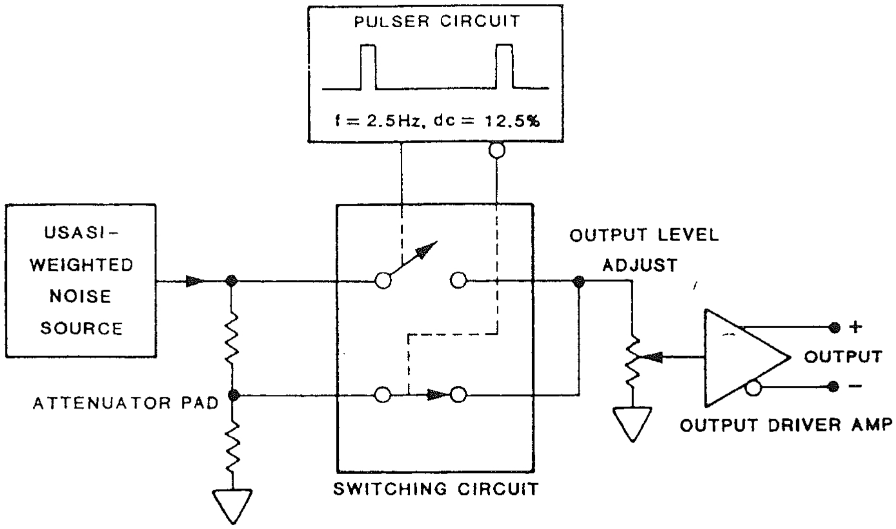
2. PULSED-USASI NOISE AS A TEST SIGNAL

USASI (United States of America Standards Institute) noise was used to simulate program material for tests performed in the Harrison Klein report (referenced earlier). It was determined to be a realistic modulating waveform for the tests performed.

Another variation of USASI noise has been proposed to more closely simulate the true dynamic conditions that occur in program material.[3] This involves the addition of a pulser circuit to add dynamic gain modulation to the source USASI noise input. A block diagram of the concept is shown in Figure 6. The pulser circuit has a period of 400mS (2.5Hz), with a duty cycle of 12.5 percent. This was chosen to simulate percussion beats prevalent in typical music. This signal is used to switch alternately between unattenuated and attunuated USASI noise, with the attenuator pad adjusted for a 20dB peak-to-average ratio.[4] This test signal appears as the amplitude/time domain representation shown in Figure 7 (stored oscilloscope image).

3 Personal communication with Christopher Payne, (202)862-1549

4 This peak-to-average ratio has been subjectively determined to be the same as the mean of typical program audio.



PULSED-USASI NOISE GENERATOR

Figure 6

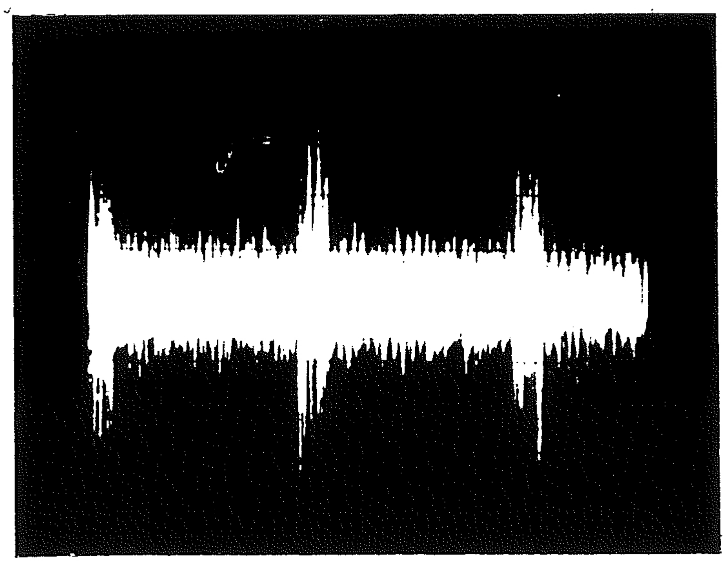


FIGURE 7
Pulsed - USASI Noise Test Signal

This test signal was used in the same way program audio was used to evaluate filter placements (described earlier), under equivalent test conditions. Figures 8, 9, and 10 show the resultant stored spectrum displays over a 15 minute storage cycle, after which no noticable change was detected.

A few observations were made during the use of this test signal in lieu of program audio. First, the modulated envelope as viewed on an oscilloscope appeared much as it does with real program audio. Positive and negative peaks, as well as the frequency content distribution were much more realistic than static noise sources. Second, although the test employed NRSC pre-emphasis as before, passband audio was rolled off in the high frequency area. This was due to the rolloff of the USASI noise curve, which did not posess the amount of peak energy in the higher frequencies as program audio did. Even with the addition of pre-emphasis, higher frequencies remained further below the limiting threshold, although a significant amount of high frequency limiting was noted.

Although the passband exhibited this response drop, it can be seen that the amplitude of the stopband components remained similar to that when program audio was used. In fact, in the case of the processor without filtering (Figures 1 and 8), it can be observed that the rolloff characteristics of the 20kHz filter in the test transmitter are not as noticable in Figure 8 as they are in Figure 1. This is caused by the fact that the test signal was not band-limited and therefore contained more energy above 15kHz than program audio would.

From these tests, it would seem that the pulsed-USASI Noise test signal would be quite useful in measuring stopband compliance. It appears to uncover the stopband components of interest without taxing the high frequency modulating capabilities of the transmitter (when used to characterize the full transmission system). Additional field testing would also be helpful to gain further experience with this test signal.

3. A PROPOSED NRSC AUDIO STOPBAND SPECIFICATION

Some discussion has taken place as to the appropriate location in the transmission path where compliance to a 10kHz stopband specification should be measured. Although RF measurement at carrier frequency with a spectrum analyzer would seem to completely characterize the spectrum occupancy, a number of variables exist. Harmonic and intermodulation distortion in the transmitter, incedental phase modulation, effects of stereo systems, and antenna system deficiencies can all affect the occupied bandwidth. Complete characterization of effects caused by each of these factors, although suitable for further study, would consume more time than is currently available.

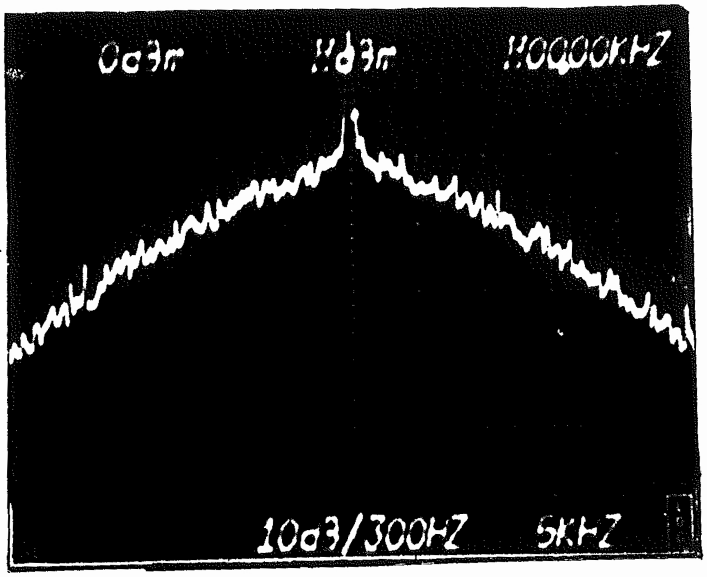


FIGURE 8

Same test as in figure 1 except pulsed - USASI noise used in lieu of program audio.

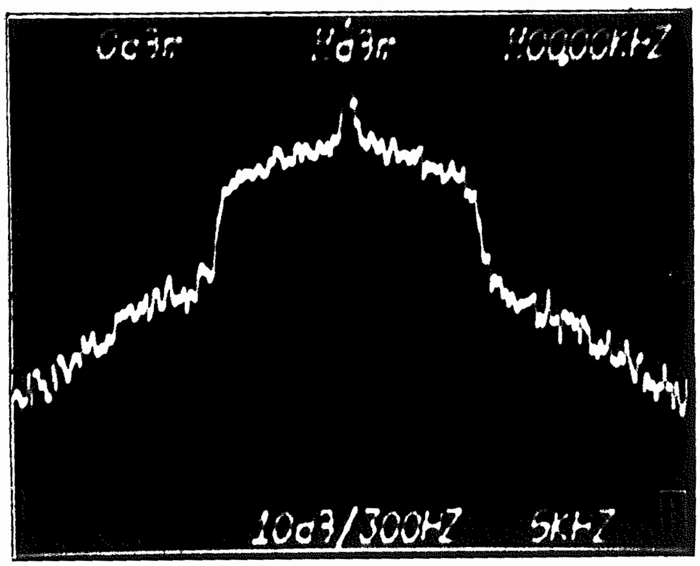


FIGURE 9

Same test as figure 2 except pulsed - USASI noise used in lieu of program audio.

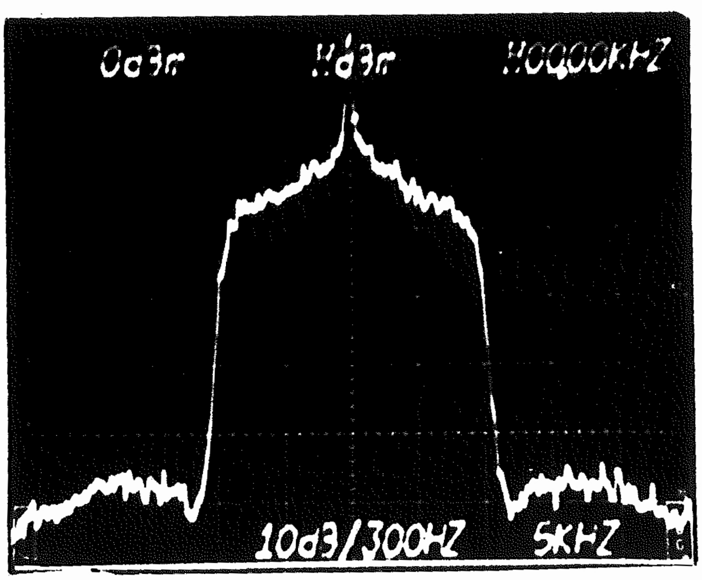


FIGURE 10

Same test as in figure 3 except pulsed - USASI noise used in lieu of program audio.

The previously mentioned report by Harrison Klein, however, concluded adamantly that the primary cause of splatter is excessive high frequency content of the modulating audio. With this taken into account, it would seem that the appropriate place to measure occupied bandwidth would be at the envelope audio input terminals of the AM transmitter. Reducing bandwidth to the audio input of the transmitter would also tend to aggravate the causes of the above mentioned variable factors much less. Additionally, such a specification could be measured in all cases, including AM stereo stations, since the audio at this point must be compatible with monaural audio.

Figure 11 graphically illustrates the proposed NRSC Stopband Specification. Audio modulating the transmitter would be attenuated by at least 30dB by 10.5kHz from a reference 1dB above a 200Hz sine wave that modulates the transmitter to 90% (negative). At 11kHz and beyond, the audio would be attenuated by at least 40dB from the stated reference. With the exception of initially setting the reference, compliance would be dynamically measured. The NRSC pre-emphasis curve would be employed in the processing device during measurement.

The justification for this specification is as follows:

A. The sharp transition would occur prior to 10.5kHz providing at least 30dB of attenuation at 10.5kHz. This takes into account the transmitter-generated distortion products, which would tend to fall just below this level in most cases.

B. The step in the specification between 10.5 and 11kHz allows for the design of processor filters that are somewhat less than "brick wall" in design. Benefits would include greater ease in delay equalizer and overshoot compensation network design, providing for higher quality passband audio.

C. Attenuation levels would continue at 40dB below the reference from 11kHz to 15kHz and beyond. This would insure that processor artifacts in the second adjacent channel region would not modulate the transmitter by more than 1%.

D. The reference was chosen at 1dB above a 200Hz sine wave that modulates the transmitter to 90% for several reasons. First, 1dB above 90% modulation represents the point at which the transmitter would modulate 99%. Stating this in such a way allows the reference to be measured without forcing the transmitter to modulate where it may not be capable. Second, the selection of 200Hz as the modulating frequency for the reference represents a point below the pre-emphasis curve and near the amplitude peak of USASI noise level weighting. This allows the use of a pulsed-USASI noise test signal (described earlier) as an input source to measure for compliance.

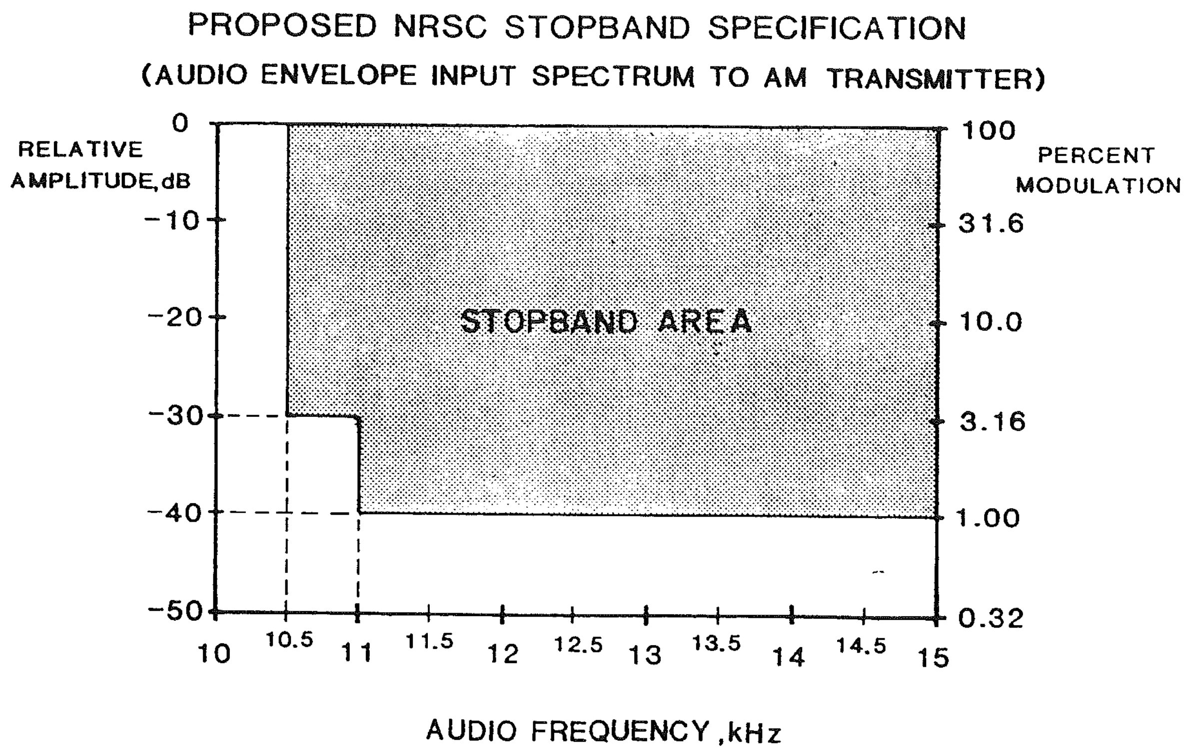


Figure 11

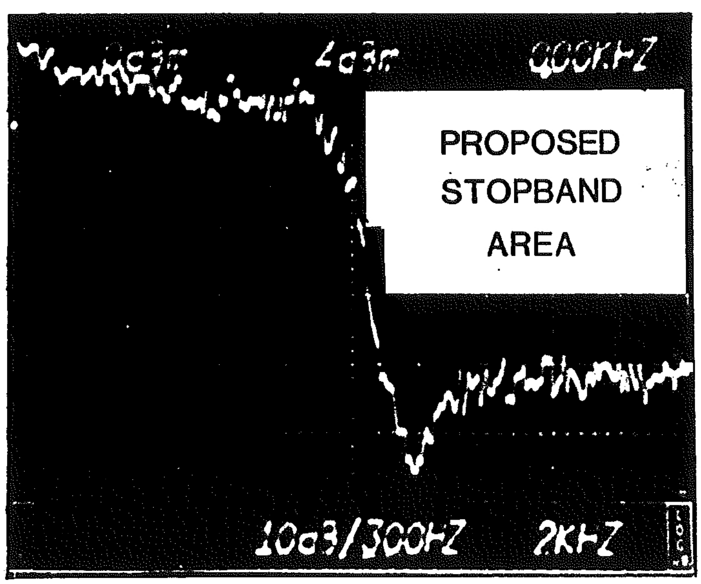


FIGURE 12
Stopband spcification compliance measurement, using program audio.

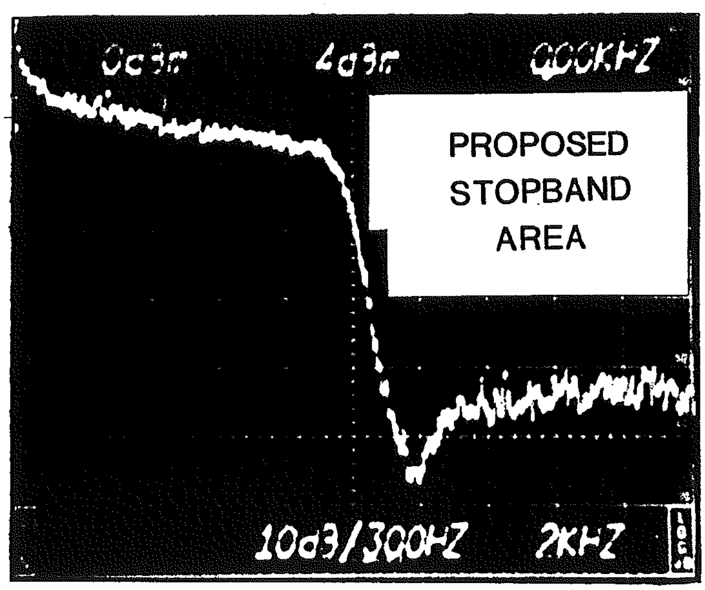


FIGURE 13
Stopband specification compliance measurement, using pulsed - USASI noise source.

E. Dynamic measurement of this specification is very important. It assures that filtering techniques employed are sufficiently overshoot-corrected without producing excessive stopband artifacts.

F. No passband specification is indicated. Many processing devices include multi-band equalization devices and other dynamic, frequency-weighted circuitry. The market for such a device would dictate its suitability and therefore a passband specification would be of no real value to the intent of the NRSC, except for the inclusion of the NRSC pre-emphasis characteristic.

Figure 12 shows a measurement of the above specification on the aduio processor used to generate the photos of Figures 3 and 10. A 30 minute spectrum analyzer storage time was used with the same program audio from prior tests. The 2kHz/division horizontal span permitted convenient location of the stopband specification transition points. Once again, a 300Hz resolution bandwidth was selected, allowing for rapid measurement without significant analyzer slew rate limitations. Figure 13 repeats the measurement, except with pulsed-USASI noise as the input signal.

One argument that could be made is that many AM broadcast stations do not have ready access to a spectrum analyzer, with which to verify compliance of the stopband specification. Although a suitable spectrum analyzer can usually be borrowed from a local television station or through a nearby SBE chapter, a much simpler device is conceivable that could be constructed to measure for compliance. The most likely location where compliance could be measured, however, would be at the audio processor manufacturer, since the audio processor is likely to be the final audio device before the transmitter.

The audio processor manufacturer should measure for compliance with the stopband specification under all calibrated operating conditions. When this is complete and the device passes, the manfacturer could be allowed to advertise it as being "NRSC Compatible," or "Meets or exceeds all NRSC guidelines."

MAJOR POINTS AND CONCLUSIONS

The following major points were drawn in this paper:

1. The value of placing a steep 10kHz filter before the final audio processor/limiting device which does not employ audio filtering is variable at best. Preceived distortion could be detected due to unmasked processing artifacts present at the audio monitor output on the station modulation monitor or wideband receivers. The best solution involves the use of an overshoot-corrected processor output filter.

2. A pulsed-USASI noise test signal was introduced which appeared to represent the dynamics of typical program audio well. This test signal seemed well-suited for use in bandwidth compliance testing.
3. A proposed NRSC stopband specification for audio input to the transmitter was presented. This specification defines the qualities of the audio processor output frequency spectrum required for adequate second adjacent channel protection, along with a dynamic measurement method to determine compliance. Such tests could be performed as part of the audio processor design process, partially relieving stations from this responsibility.

With attention to the concepts presented in this paper, it is the author's opinion that high-fidelity AM broadcasting is possible without the requirement that stations make major concessions in desired loudness. Although the need for further research is still indicated, the implementation of a standardized NRSC pre-emphasis curve and transmitted audio stopband characteristic can provide a considerable boost to the preceived quality of AM broadcasting.

The author can be reached at (602)438-0888.

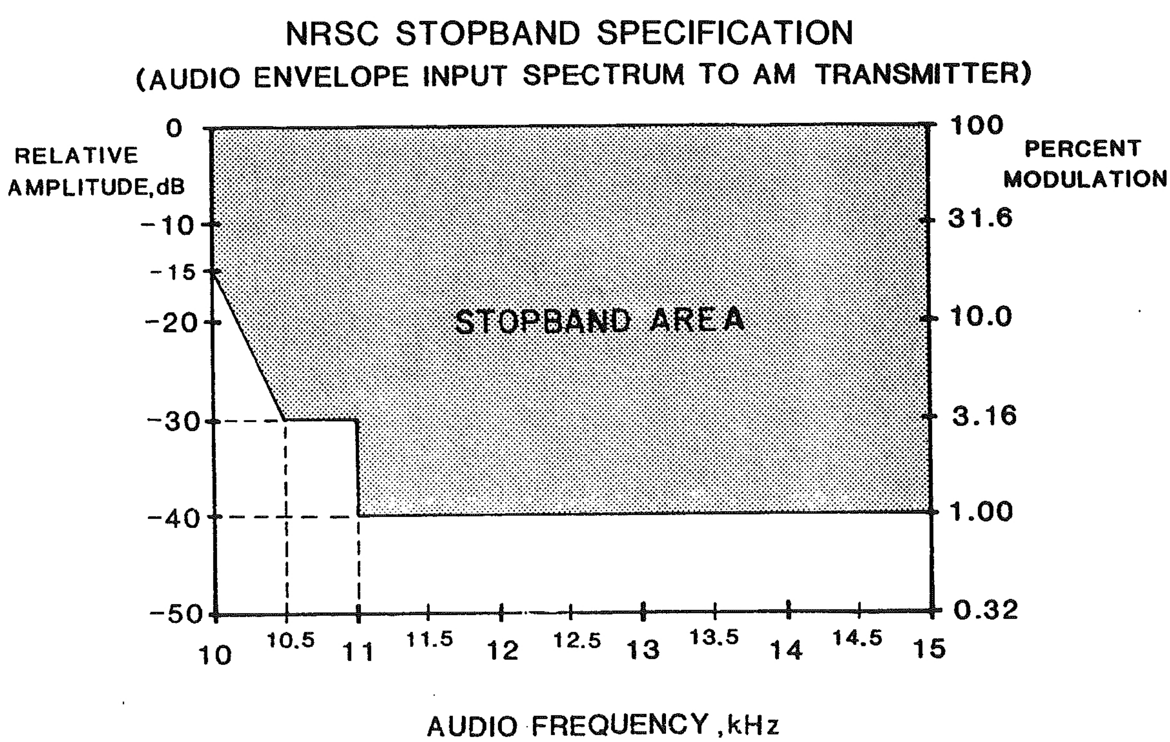
November 21, 1986

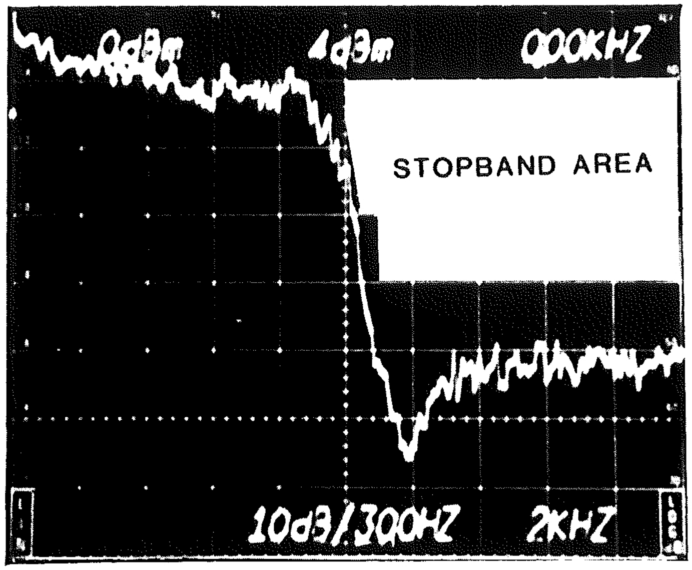
ADDENDUM TO

"Considerations for a 10kHz Transmission Bandwidth in AM Broadcasting"

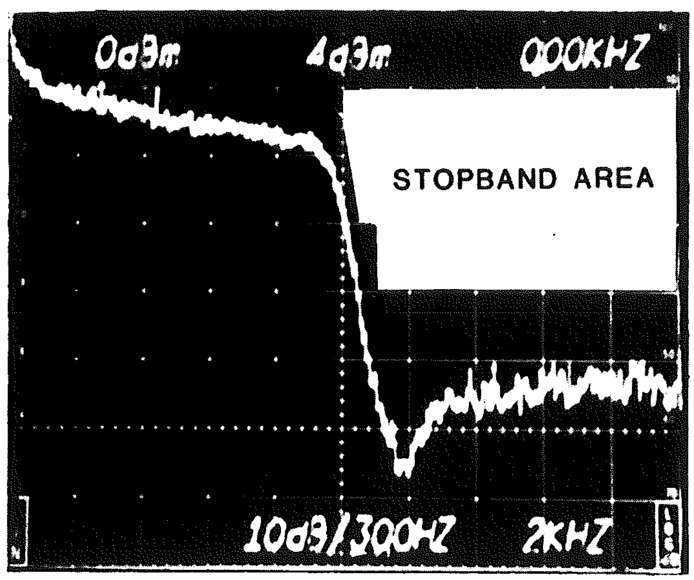
by S. Salek

During the November 20, 1986 NRSC subgroup meeting, the adjusted stopband specification shown below was chosen:





STOPBAND SPECIFICATION COMPLIANCE
MEASUREMENT,USING PROGRAM AUDIO



STOPBAND SPECIFICATION COMPLIANCE
MEASUREMENT,USING PULSED-USASI
NOISE SOURCE

January 13, 1987

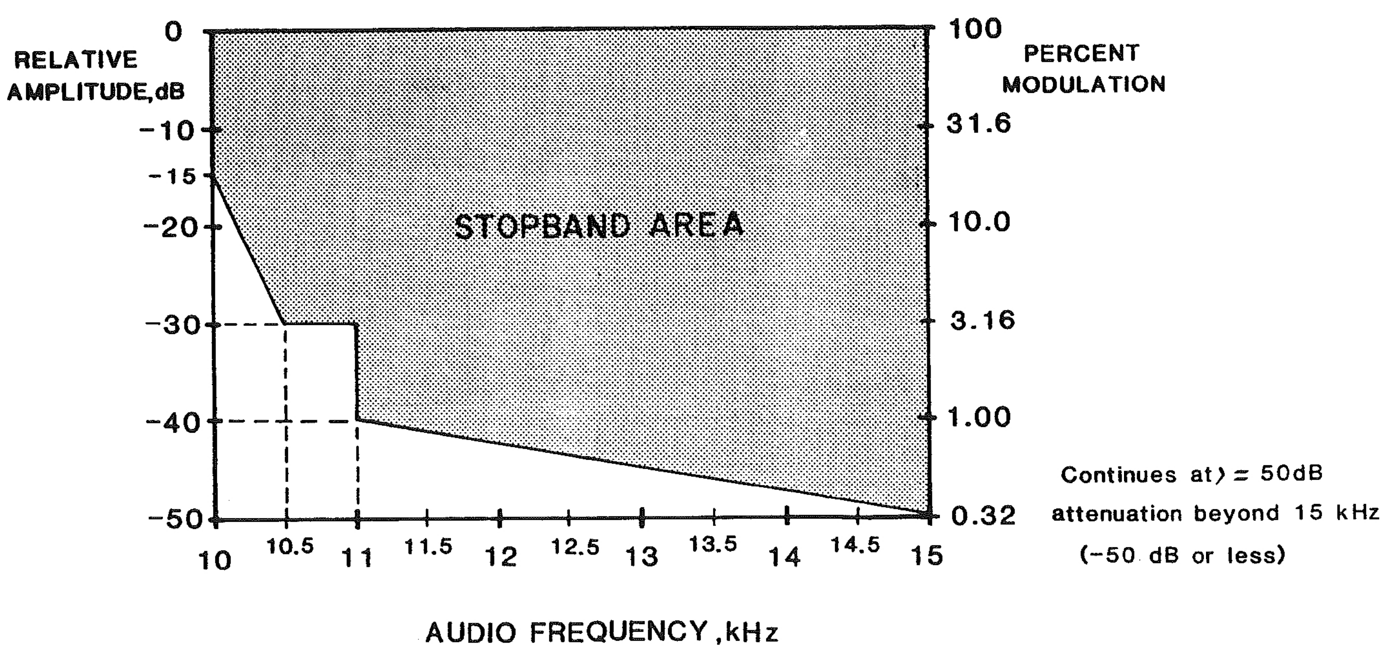
UPDATE TO

"Considerations for a 10kHz Transmission Bandwidth in AM Broadcasting"

by S. Salek

During further discussion at the full NRSC meeting held on January 10, 1987 in Las Vegas, NV, the stopband specification was further modified as shown below:

NRSC STOPBAND SPECIFICATION
(AUDIO ENVELOPE INPUT SPECTRUM TO AM TRANSMITTER)



NRSC Document Improvement Proposal

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