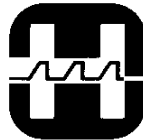


ENGINEERING
REPORT

ENHANCING AM SIGNAL
COVERAGE THROUGH
IMPROVED MODULATION
TECHNIQUES



HARRIS
COMMUNICATIONS AND
INFORMATION HANDLING

ENHANCING AM SIGNAL COVERAGE
THROUGH IMPROVED MODULATION TECHNIQUES

By C. Brian Cox

This paper will describe the various testing procedures that have brought about a new breed of AM transmitters...transmitters that have been designed to enhance the AM signal through improved modulation techniques. To prove this difference in transmitter performance, we have compared the Harris model MW-5, 5 kw AM transmitter, using the patented PDM modulator, with older high-level plate modulated transmitters. Before we get into the various tests performed, let's briefly review the signal processing which has changed greatly over the past ten years and which affects the performance of transmitters.

First, we had the old tube type limiter with a one millisecond, thumping, attack time, which held the modulation levels fairly low.

Soon, the Solid State Limiter with an attack time of one microsecond, a compression ratio of better than 30 dB, and without thumping, came into being. This limiter picked up 2 dB in a transmitter that had good positive peak capability. At this time and point, it was noticed that the transmitter would not continuously hold the negative peaks at 95% and the positive peaks at 120%. The answer, then, was to add a clipper to the output of the limiter to chop off any overshoot, thereby holding the output at 95% negative and 120% positive. However, the transmitter was modifying the input wave and causing overmodulation and distortion.

If audio is clipped by 2 dB, the loudness should also increase about 2 dB, assuming a fast limiter with a 30 dB compression ratio is used before the clipper. However, when this clipped audio is fed into the transmitter, the peaks must be reduced and only 1 dB of loudness is attained.

What in the transmitter is causing us not to get the desired results without distortion? With heavy processing, the modulator currents are now changing the loading on the high voltage power supply by two to one. Any bounce of the power supply, modulation components, or feedback is significantly affecting the transmitter output.

The first solution was to use separate power supplies, one on the modulator and one for the RF. This nearly eliminated carrier shift and increased the positive peak capability to nearly 170%. But, this still didn't solve all the problems. After carefully evaluating all of the above facts, we have designed the new PDM transmitters to handle highly processed waves. Let's now discuss the design criteria for the PDM transmitters.

First - Our design should consider phase shift. Poor audio phase linearity can modify the input wave and cause overmodulation. Because AM is basically a narrow band system when connected to an antenna, the high frequency and low frequency phase shift must be considered separately:

(a) Low frequency phase shift. The cure for low frequency phase shift is to build a DC coupled transmitter whose gain, phase and linearity are perfect to DC. The PDM (Pulse Duration Modulator) is the answer. After all, PDM is nothing but a highly efficient regulator in series with the power supply and the PA tube. It is DC coupled and has basically "0" phase shift. Consequently, low frequency response, gain and linearity problems are solved.

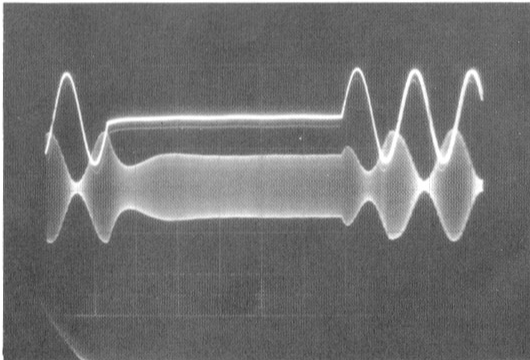
(b) High frequency phase shift. Even though a transmitter has "0" phase shift at the high end, the problem can return when the broadcaster

connects this transmitter to the antenna. The best answer is a compromise. We chose to taper the feedback and gain, to match the high frequency phase shift of the transmitter and match what could be expected in the user's antenna.

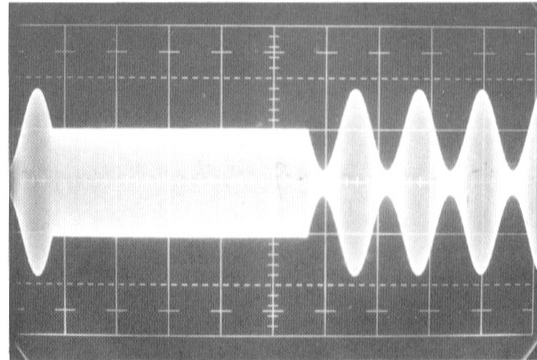
Second - Design criteria - bounce. Between the power supply, the modulation system, and feedback, the usual transmitter can have up to 20% bounce. This will not show up as carrier shift because the bounce is both positive and negative. One cure is to throw out the modulation transformer and modulation reactor. But, be careful. The modulation reactor is also a filter inductor. We may take it out of the modulation circuit but just put it back as a filter inductor in the high voltage supply. Then our problem is back - unless we go to a 12 phase power supply. The conventional star or 6 phase supply is normally used; however, it is difficult to get adequate filtering without using a choke or hum-bucking which is also unacceptable. Hum in a 12-phase power supply is over 40 dB down under balanced line conditions with no filter. By adding a filter capacitor, a very tight power supply with adequate filtering can be attained. The final touch is to add DC feedback around the entire transmitter and nearly eliminate carrier shift and bounce in a PDM transmitter. We use this system in both the MW-50 and MW-5 transmitters.

We have now designed a new transmitter to cure the problems discussed earlier in this paper. You say - prove it! Okay, let's go to it. Let's take an old transmitter which has been known to be loud and clean and compare it with the MW-5 PDM transmitter.

First - We ran a proof on both transmitters and the response, distortion, and carrier shift were about the same. The MW-5 has slightly lower distortion, a little better response, and "0" carrier shift--but the differences are so small, it could be the test equipment. This proves one of two things. Either the new transmitter is no better or the old tests are not adequate. We're sure the new transmitter is better so let's run some less standard tests before we perform the real test - that of the program material itself. The first group of tests will be using tone bursts of different frequencies. First, a 20 Hz tone burst using four on and four off pulses is used in an attempt to excite the transmitter similar to a music beat. Maybe this will shake out some problems not seen in a standard proof.



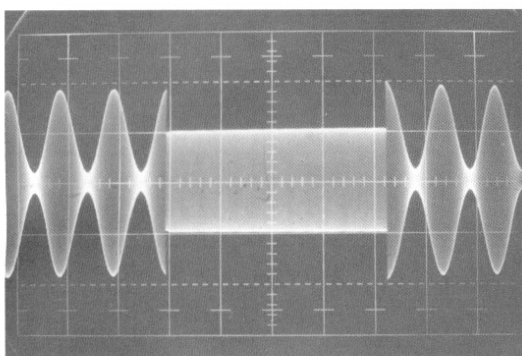
WAVEFORM NO. 1



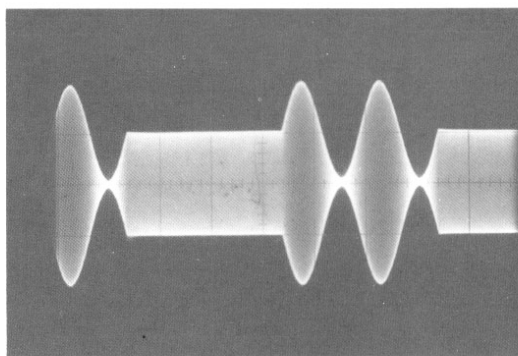
WAVEFORM NO. 2

Waveform No. 1 shows the old transmitter. The bright line shows the input and, of course, the other scope input is the modulated carrier itself. It can be seen that the transmitter has a hard time getting started and after it does, when the audio stops, the transmitter does not. This is bounce! If full modulation were applied immediately after the tone burst, the transmitter would have overmodulated in the negative direction and then as the carrier bounced positive, it would have overmodulated in the positive direction.

Waveform No. 2 shows the MW-5 under the same condition. A perfect reproduction. No modulation problems and no bounce.

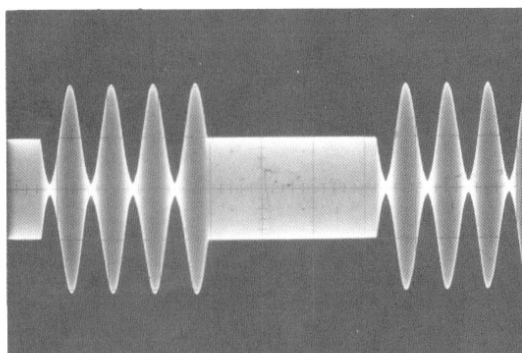


WAVEFORM NO. 3

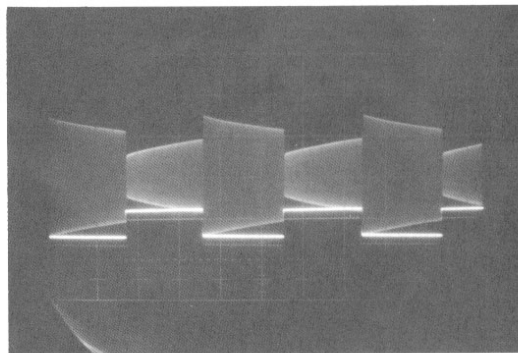


WAVEFORM NO. 4

Waveform No. 3 again shows the MW-5, but this time the tone was stopped at a high level of modulation to see if any other resonance or overshoot could be seen. None is noted. Waveform No. 4 shows the MW-5 with a 50 Hz tone burst with two on and two off cycles. Again a perfect reproduction.



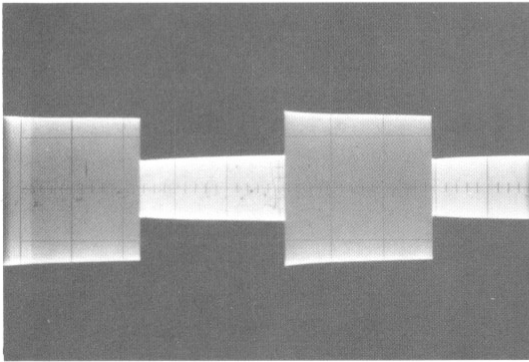
WAVEFORM NO. 5



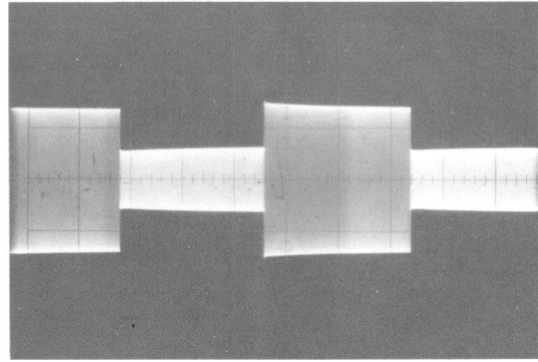
WAVEFORM NO. 6

And last, Waveform No. 5 shows the MW-5 with a 1000 Hz tone burst with a perfect reproduction.

So far, we have proved that the music beat may be exciting the bounce of a transmitter not designed for heavy modulation. What happens when the clipper is added? How might the two transmitters perform now? Let's compare them using square waves. First, let's look at the old transmitter, using a 100 Hz square wave (Waveform No. 6). The output is very tilted, which could lose all the power the broadcaster expected to gain by using clipping.

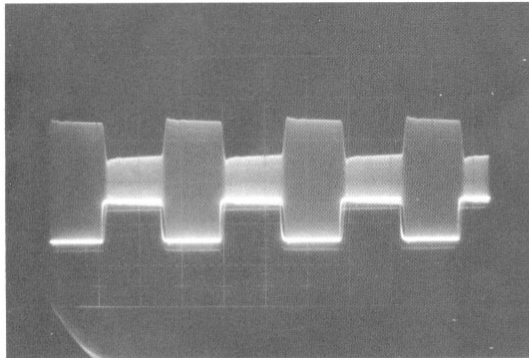


WAVEFORM NO. 7

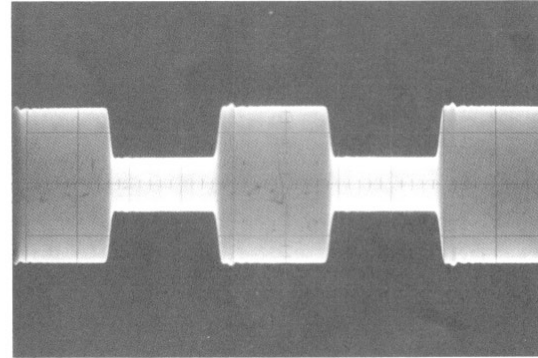


WAVEFORM NO. 8

If our new design is any better, it should perform better than this at a lower frequency. Let's move the frequency down to 30 Hz or about two octaves below the test for the old transmitter and see how the new performs. Waveform No. 7 shows very little tilt or overshoot two octaves below that test performed on the old transmitter. At 50 Hz (Waveform No. 8) it is even better.

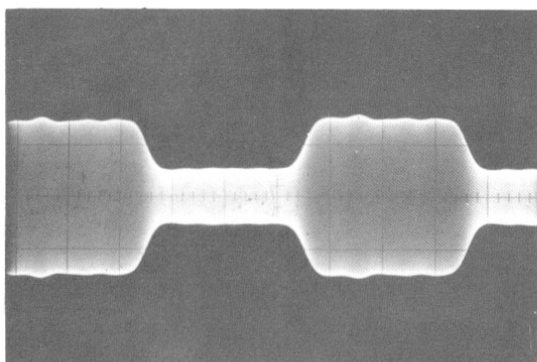


WAVEFORM NO. 9

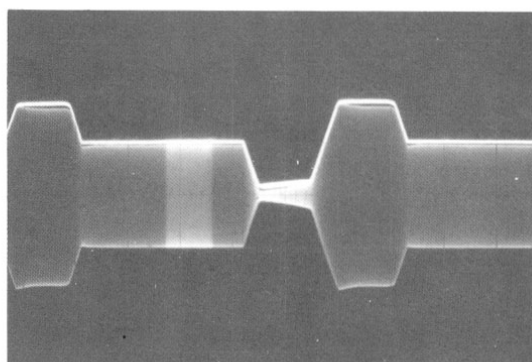


WAVEFORM NO. 10

Let's go back to the old transmitter using a 1000 Hz square wave. Waveform No. 9 shows a good reproduction. This would be very acceptable during clipping. Waveform No. 10 shows the MW-5 using the same test. The wave is even sharper and flatter than the old transmitter. Most important, very little ringing or overshoot can be seen. In trying to stretch the high end response, overshoot can show up, destroying all that was gained in the low end.



WAVEFORM NO. 11



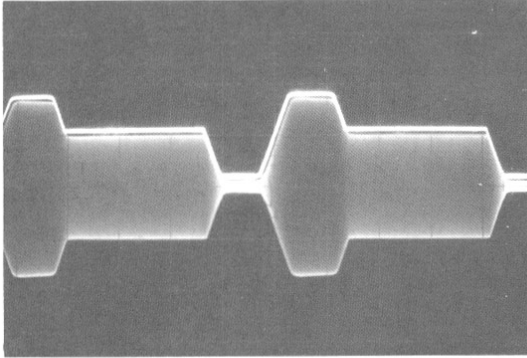
WAVEFORM NO. 12

Waveform No. 11 shows a 3000 Hz square wave through the MW-5. Very little ringing or overshoot, but the effects of a limited bandwidth system can be seen.

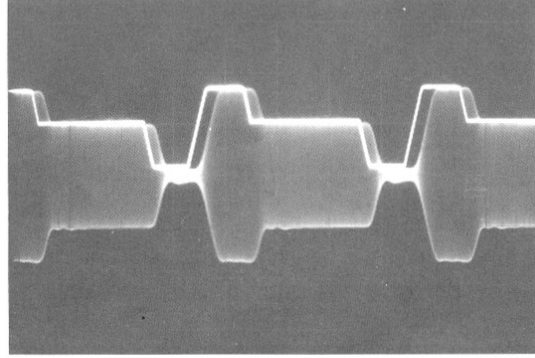
Let's further test the new transmitter and see how it does at high modulation levels. Square wave testing, when done, is normally at 50% modulation. The broadcaster uses the transmitter at 100% modulation so let's go to a pulsed and clipped sine wave and see if any problems show up.

We will use a dual trace scope so we can monitor the input and output at the same time. A good scope capable of measuring DC and having a chopper must be used for meaningful information. An AC coupled scope at 30 Hz is useless.

First, a 30 Hz clipped sine wave using one pulse on and one pulse off. Waveform No. 12 shows the input (the white or bright line on the top side of the envelope) is tilted at the negative peak due to a problem in the negative side of the clipper. We left the problem to see if the transmitter would follow the tilt on the negative and squared wave on the positive. As you can see, the transmitter hardly modified in input.

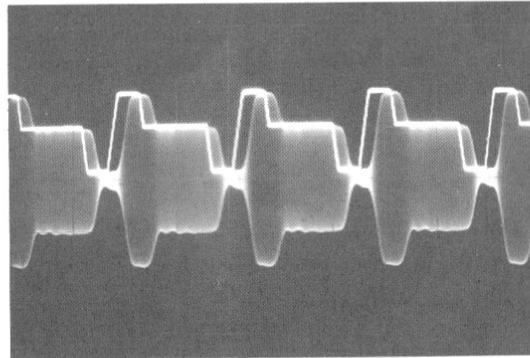


WAVEFORM NO. 13



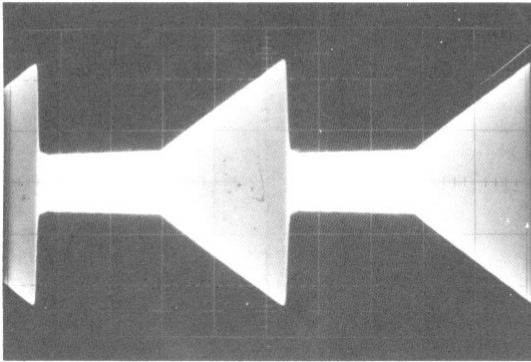
WAVEFORM NO. 14

Waveform No. 13 shows a 500 Hz clipped and pulsed sine wave going through the MW-5. Looks perfect. Waveform No. 14 shows a 3000 Hz clipped and pulsed sine wave. Although the wave was slightly modified, due to the limited bandwidth of AM, it did not overmodulate or cause any problem. And last, Waveform No. 15 shows a 5000 Hz test as before. A little more of the limited AM bandwidth problem is showing but still no overmodulation or problem.

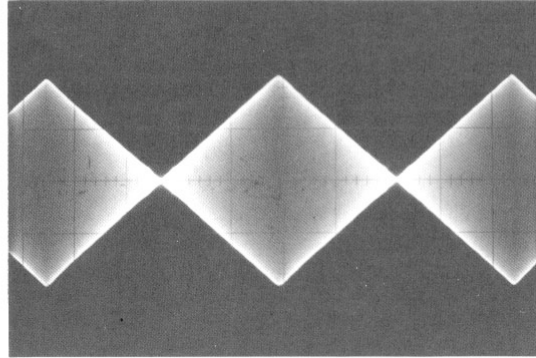


WAVEFORM NO. 15

Our last special test is to prove the transmitter is capable of high positive peaks and little or no distortion. The best proof, at least as far as we're concerned, is a ramp test. The ramp is asymmetrical and will not cause overmodulation on the negative peak while looking at the positive peak performance.



WAVEFORM NO. 16

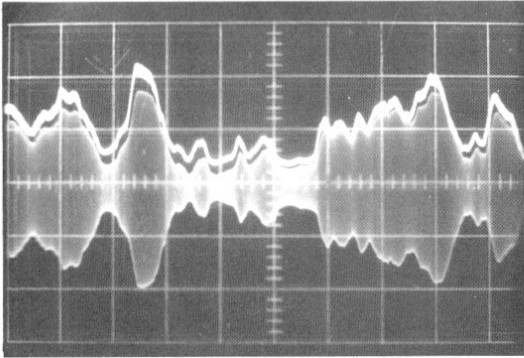


WAVEFORM NO. 17

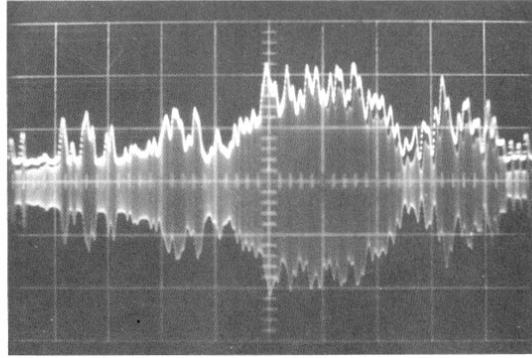
Waveform No. 16 shows the MW-5 modulating to about 135% (dotted line on scope is +100% modulation) on the positive peak and about 50% on the negative peak. This ramp has many frequencies in it. The repetition rate is 500 Hz but the rise time of the ramp has frequencies less than 500 Hz, the fast down time is much greater than 500 Hz and the lower flat part is nearly DC. A good overall test. Finally, a saw tooth test, Waveform No. 17, to check the linearity down to 100% negative and up to 100% positive. Again near perfect reproduction.

If the explanations given and the tests shown prove anything, the new MW-5 should be able to operate on program audio much better than the old one. Let's face it, transmitters are not programmed with square waves, pulsed sine waves, or saw tooth waves, they are programmed with a complex wave which cannot be simulated. So, let's use the complex wave.

Again, let's set the scope up so it can look at the audio input to the transmitter and the carrier output at the same time. Again, a dual trace DC coupled scope is used. The transmitter is treated like a black box. One trace on the scope is connected to the input audio wire going to the transmitter and the other is connected to the RF going out of the transmitter.

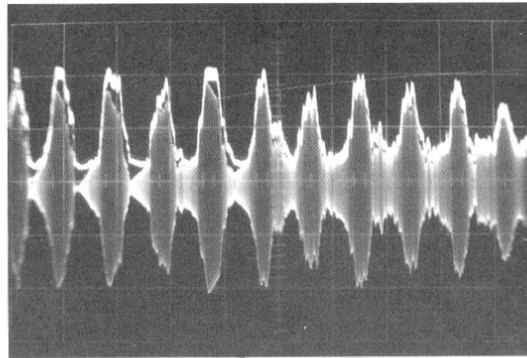


WAVEFORM NO. 18

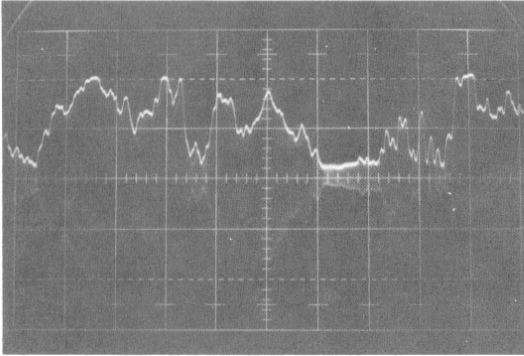


WAVEFORM NO. 19

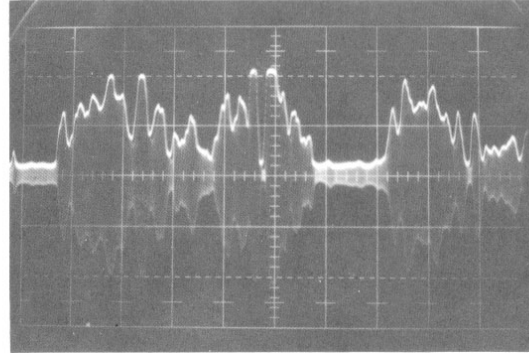
First, the old transmitter. Waveform No. 18 shows the output not following the input (bright line) by a large amount. The transmitter is bouncing, but otherwise following the audio. Waveform No. 19 of the old transmitter shows much the same. The modulation level is held down because of the bounce. The positive peaks are undermodulated and the negative peaks are overmodulating with respect to the input. Waveform No. 20 shows the old transmitter after a clipper is added. The input is held to about 80% modulation but the output of the transmitter has overmodulated due to bounce, tilt and overshoot. Holding the input level to average peaks of only 80% is causing overmodulation. Two dB is being lost.



WAVEFORM NO. 20

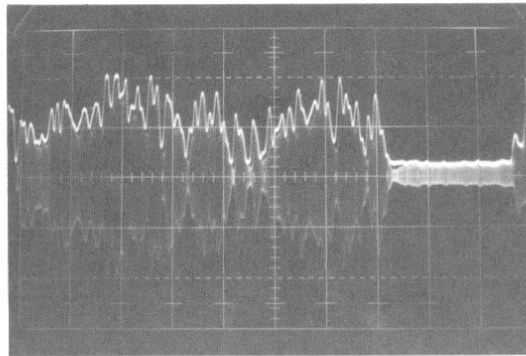


WAVEFORM NO. 21



WAVEFORM NO. 22

Now, let's look at our new transmitter, the MW-5, and see how it does under the same conditions. Waveform No. 21 shows a little clipping being used and the input and output following almost exactly. Waveform No. 22 shows the MW-5 with more clipping on the input audio, but the transmitter still holding nearly perfect. Finally, we turned up the clipper until we didn't care to listen to it and caught this picture...Waveform No. 23. Here's some really violent clipping and the transmitter nearly made it. It overshoot only slightly on this long clip. Notice, no bounce even after this really hard hit.



WAVEFORM NO. 23

In summary, what are the features of a properly designed transmitter that will handle square waves, pulsed waves, saw tooth waves, and complex waves:

1. Low distortion
2. Excellent frequency response
3. High positive peak capability
4. Low or no carrier shift
5. Excellent transient response
6. Increased reliability
7. A cleaner and louder signal

Transmitters and audio processing have advanced rapidly in recent years. Equipment that has the characteristics we have discussed, will give significantly improved listener coverage, and a dominating sound for your area.

TEST EQUIPMENT USED FOR PERFORMANCE MEASUREMENTS

1. Harris Solid State AGC - 994-6629.
2. Harris Solid State AM Limiter - 994-6543.
3. Harris Modulation Monitor - AM-80.
4. Harris Cartridge Tape Playback - Criterion 80.
5. Harris Clipper.
6. Distortion Analyzer - Hewlett Packard 334A.
7. Dual Trace Oscilloscope - Fairchild Model 766-H/F.
8. Pulse Generator - General Radio Model 1396-B.
9. Function Generator (Square Wave, Ramp, Sawtooth, Sine Wave)
- Wavetek Model-111.



HARRIS CORPORATION Broadcast Equipment Division
123 Hampshire Street, Quincy, Illinois 62301