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Technology

A Brief History On Distortion In Amplifiers And Why It Is Essential To Control It

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Distortion in Amplifiers is something we live with and are constantly aware of when selecting equipment for a new build or rebuild, however we sometimes loose focus in why its is essential to control it in repaired or older equipment when upgrading a system.

When I first got into the cable television industry in 1964, the major limiting factor in CATV systems was cross mod, or as we called it back then "wipe". In 1964, the industry was making a transition from 6 channel low band tube systems to 12 channel transistorized equipment.

At that time there was no standard method of testing for cross modulation and in fact the tests that were being done were very subjective and in no way based on any standard. When I started at Ameco, the method used was to place the amplifier under test on a bench and run 11 modulated channels and 1 un-modulated channel through it, at the proper levels and tilt. The channels were standard off-air channels with channels converted from off-air to fill in the unavailable channels. The person running the test would then raise the level 1 db at a time, while watching a television tuned to the un-modulated channel, until the first "wipe" bars appeared and then lowered the level by one db. This was the amplifiers maximum output capability or the level at which the industry would come to accept as the -57 db point in later years.

This test was subject to an almost infinite amount of variables such as the contrast setting of the TV, the brightness setting, the age of the TV, the age of the eyes observing the TV, the amount of sleep the observer had got the night before and on and on. Needless to say it was not a very good system and we had to do better.

In about 1966 the first actual cross-modulation (XMOD) distortion test sets begin to appear although each manufacturer had their own modulation method. The basic premise of all the systems was the same, 11 channels modulated with one un-modulated, after demodulating the un-modulated channel a tunable AC voltmeter was used to read the 15,750 component that was resident on the un-modulated channel, as compared to 100% modulation. The resultant number was the XMOD expressed as a negative number. Some features of these systems became the NCTA standard, a 15,750 modulation source with a 50% duty cycle and all channels being modulated with the same source. Some of the variations were a 15-microsecond modulation pulse, duplicating the actual sync pulse and non-synchronized modulation. These variations in procedure could affect the final number by as much as 10 db, so when a manufacturer gave you a XMOD spec, you then had to ask if it was a sync-sync number and what was the duty cycle.

In the late 60's the NCTA came out with a standard and it became much easier to know what the actual XMOD performance of an amplifier would be.

Although the actual crossmod performance of the amplifiers still was not very good, at least we could rely on the testing. XMOD was somewhat relegated to the back room because we had a new thing to worry about, the second harmonic of the low band signals or what the industry finally got around to referring to as second order distortion.

In about 1966 the industry was rocked when the city of Tucson Arizona granted a franchise to Jack Kent Cook in which he promised to deliver 20 channels of television. Lawsuits flew because at that time there were no systems delivering more than 12 channels and because no

one had solved the multi octave problem.

The basic problem was simple, the second harmonic of the low bands fell in the mid band area, the very frequency that eager cable engineers were eying covetously for their channel expansion. In fact the FCC had recognized this problem in the late 40s and early 50's as they set up the VHF channel allocations, conveniently leaving room between channel 6 and channel 7 for the low band second harmonics to fall without causing problems.

The problem was eventually bypassed by going to a single octave solution and deleting the low band signals all together and then carrying 20 channels between 120 Mhz and 240 Mhz. By 1968 the first of the discrete component push-pull amplifiers were rolling off the production lines of the major manufacturers with second order distortion products that fell in the mid band somewhat under control.

About this time, those of us working in systems with long cascades started noticing that sometimes when we had a leg that the levels were high on, we would see in the picture what would appear to be little worms, in fact we called it wormy pictures. This would appear a long time before we would see the actual cross mod or wipe. It was referred to in many cable engineers as "transistor cross mod", mainly because no one had ever seen it in the tube systems that we had previously operated. It took a few more years before this "transistor cross mod" was identified as triple beats and techniques were developed to measure and minimize it.

In 1972, TRW came out with the first Hybrid amplifier, the CA 601, a 30-db-gain block for a line extender. This single event, in my mind was one of the most significant and pivotal events in the history of CATV amplifiers and did more to minimize distortion and standardize amplifier design than any other advance before or since.

A few years ago it wasn't unusual to see amplifier cascades of 32 or 64. I have even seen a 100-amplifier cascade, but now with modern HFC networks the cascades of amplifiers are much shorter. Because of the shorter cascades we are able to run much higher levels out of our amplifiers and still remain within the optimal distortion specifications. We are able to do this because of the increased distortion specifications of today's amplifiers, the shorter cascades and because the industry has adopted a uniform method for testing 100% of the equipment before it goes into service.

This only holds true if every piece of equipment we place in service meets or exceeds its original specifications.

There is a mistaken assumption out in the real world of system operation and amplifier repair, that unless an amplifier has had its hybrid replaced you do not need to check distortion!

This is not true!

We have discovered that an amazing number of amplifiers fail to meet the distortion specifications set by the original manufacturer, no matter what was done to them in our shop. In fact we recently had 7 out of 21, 750 MHz Line Extenders, manufactured by a major manufacturer, fail our final distortion test and all we had done to them was replace the filter capacitors in the power supply.

These units were not even repair units. They were removed from service by a major MSO and transferred to another system. The MSO had the equipment routed through our facility to clean, screen and test and we found that a significant number of them needed additional work.

Removing a working unit from service and transferring it to another system will not guarantee that the unit and the system will perform properly. All equipment removed from service should be completely tested, including distortion, before being reinstalled in another system. If you are rebuilding a system with equipment recycled from another system and fail to follow this critical step you may be seriously compromising the operation of your newly rebuilt system.

As you can see in Figure 1, all of these amplifiers in at last one category were more than 3 db out of spec, and in some categories the amplifier was out of spec by more than 10 db.

Figure 2 shows the actual distortion characteristics of one of these amplifiers before and after replacing the output hybrid.

Dependent upon the number of amplifiers in cascade in your system and the accuracy of your test equipment, any of these amplifiers could cause you problems and the worst ones are almost sure to. If you happened to get two or three of these in the same line you could go a little crazy trying to figure out what was wrong.

Normally the repair of this problem is the replacement of the output hybrid and in well over 90% of the cases this corrects the problem. However there are times that we have to replace the input hybrid also. In some amplifiers we have found that we cannot meet the distortion specs no matter how many hybrids we change, **even though the amplifier swept fine**. Subsequent investigation found that as the solder on the circuit board oxidizes, the junction between the oxidized solder and ground becomes a diode and causes distortions. We had to remove the board, heat up all of the solder that contacts the chassis and then reinstall the board, making sure all of the

Figure 1

Mfg Specs		Amp 1	Amp 2	Amp 3	Amp 4	Amp 5	Amp 6	Amp 7
CSO	61.9	55.2	54.8	58.1	57.2	56.6	58.2	52.5
CTB	66.5	68	57.4	61.9	61.5	61.4	60.4	55.8
XMOD	65.3	68	68.2	67.8	68.3	74.2	74.2	74.2

Figure 2

Parameter	Mfg Specs	Before Hybrid Change	After Hybrid Change
CTB	61.9	52.5	62.1
CSO	66.5	55.8	68.5
XMOD	65.3	74	74

screws are properly tightened before the unit will pass the distortion tests.

The purpose of this article is to alert you to the fact that a repaired amplifier, without a proper distortion test is potentially a problem waiting to happen. Many repair facilities do not have the capabilities to properly test for distortion and many charge extra for it. Please, for the integrity of your plant, make sure that whoever does your repair work, even if you have to pay more, can fulfill the following:

1. Checks to see that every piece of repaired equipment is close to the original manufactures distortion specifications.

2. That they maintain a library of manufacturers original specifications

3. That they record and return to you the results of the distortion test

4. That they have the proper equipment and personnel to do the tests

The best way to do a distortion test is with a Matrix signal generator capable of generating at least 77 channels, and a HP or Agilent 8590 Spectrum Analyzer with the either CATV software package or experienced personal to properly set up the test. The signal generator should also be able to generate at least 4 channels of return spectrum so that the return amplifiers can be checked also.

We have seen a significant amount of failures in return amplifiers especially Composite Second Order distortion (CSO). Trying to run a modern 2-way digital system with Internet returns, through amplifiers that have bad CSO will absolutely drive you crazy.

It is possible to build a decent distortion test set out of discreet components, however if your repair facility has done that, make sure that they have personnel that can keep it operating and in calibration. The Matrix system is almost automatic and provides repeatable and accurate readings with relatively unsophisticated operation. Running a homemade system requires a great deal of sophistication, knowledge and experience.

The older distortion systems made by Dix Hill are absolutely fine and although a little harder to operate than the Matrix, will provide repeatable and accurate readings.

The integrity of your plant is your responsibility. Keep the distortions generated to known and predictable levels. If you do not know the distortion of the repaired or recycled amplifier module you are placing in service, you cannot guarantee the integrity of your plant, the quality of your pictures and the reliability of your data stream. ❑

About The Author

Steven K. Richey is the President and CEO of 4Cable TV. Prior to founding 4Cable TV he was Vice President New Product Development at dB-tronics, where he was responsible for all of the final engineering and any new board designs needed to upgrade thousand of amplifiers that are now in operation. Steve has over 42 years of varied CATV experience, including being in charge of repairs at a major manufacturer (Ameco) and the former Chief Engineer at CADCO.

While at CADCO he coined the term "Emergency Alert System" and developed the first EAS and the first comb generator-based Emergency Alert System in 1972. Later he developed the first satellite block down converter now used in all satellite systems. He was the owner/operator of 8 CATV systems in Texas and Oklahoma and went on to build a 150 system private cable operation. He also has published over 20 articles in CATJ, Private Cable Magazine *and* Popular Electronics. *In the early 1990's as a International Long Distance operator he was involved some of the first VoIP experiments. He can be reached at steve.richey@4cable.tv*

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