THE CASE OF THE DISAPPEARING HEAD ROOM

Warren L. Braun, P.E.
ComSonics, Incorporated
Harrisonburg, Virginia

Experienced CATV technicians are quite aware of the phenomenon of decreasing system dynamic range, although they may not know the reason why this occurs.

This phenomenon is traced to its source, the typical system bench repair of active devices. Improved reliability and system performance is available by more sophisticated device rehabilitation.

This paper details such processes.

Today's CATV system performance must be superior to that of previous years, both for new and older existing systems. This statement is valid because:

* Subscriber television set fidelity is steadily improving.
* Viewers are becoming more critical.
* Franchising agencies are becoming more critical of and knowledgable about system performance.
* Increased competition in new and renewal franchise proceedings.
* System technical performance standards imposed by--
  ** FCC
  ** Franchising Agencies
  ** State PUC's (or equivalent agencies)

With new systems, proper attention paid to design criteria and implementation can assure reasonably distortion free CATV transmission at least at the inception of system operation.

A large percentage of subscriber complaints traceable to system malfunctioning have their origin in the increased visibility of system contaminants, i.e., cross modulation, beats, noise, etc.

The majority of these system malfunctions are directly traceable to a loss of system dynamic range. Experienced CATV system chief technicians are all too familiar with the day to day reality of short term and long term effects of shrinking CATV system dynamic range. They may not know all the causative factors involved, but they are very aware of the increased frequency of trouble calls associated with degraded performance indicators, such as visible cross modulation, beats, and excessive noise.

Even with the best system maintenance and repair, certain factors have caused originally acceptable system dynamic range to become unacceptable, i.e., the system requires excessive maintenance to achieve acceptable subscriber performance. A partial list of the factors deteriorating the technical performance of the plant with no equipment malfunction is:

* Added equivalent channel loading from multi-channel stereo FM, carried at a higher system level than monaural FM to achieve noise free carriage.
* More actual channels of carriage. Many 12 channel plants started with less than 12 TV channels, are now fully loaded with no change in plant design. (Total triple beat products rise in proportion to P^3, and for 2 A-B components, total components rise proportioned to P^2, so added channels of carriage add significantly to system spurious signals).
* Television station conversion to 3.58+ MHz tightly controlled color scanning sources, changing signal status to quasi synchronous from quasi non-synchronous.
* The effects of simultaneous non-

duplication. Channels so involved are in effect synchronous, increasing the equivalent system signal burden.

In addition to the factors just presented which bring about an apparent decrease of dynamic range of the system, there is the very real decrease in dynamic range due to deterioration of the plant over a period of time. The principle causes of shrinking dynamic range are:

1) Increasing amplitude versus frequency response roughness, due to partially defective system components and cable.
2) Increased system attenuation due to partially defective cable and/ or connectors and moisture immigration.
3) Addition of system legs or branches without proper system re-engineering.
4) Improper repair of amplifiers.

The latter item is the most serious long term deterioration.

Since the amplifier repair is the most serious source of dynamic range loss, it is prudent to examine why this is so. Typical amplifier repair is accomplished as follows:

1) Removal of amplifier in question from the system.
2) Repair of the obvious deficiencies by replacement of apparently defective components.
3) Realignment and gain measurement (sometimes return loss) of the device.
4) Return of repaired device to spare stock or to system.

It is quite evident that the two most important parameters of the amplifier have not been measured, namely, the cross modulation and noise figure. While relatively expensive equipment and skilled personnel are necessary to make meaniful measurements of these important parameters, it is instructive to inspect the enormous penalty the system operator pays for not making such measurements.

In the following table, data is shown comparing typical field repaired amplifiers (Jerrold TML series) with those repaired under carefully controlled conditions including cross modulation and noise figure tests.

TABLE I

Output Level 43/40

Worst Case Average Cross Modulation[1]

Ch.	61 Units: Repair Without Cross Modulation & N. F. Test	53 Units: Repair With Cross Modulation & N. F. Test
2	-51 db	-63 db
6	-50 db	-64 db
9	-52 db	-65 db
11	-52 db	-64 db

Worst Case Noise Figure

Ch.		
2	10	8.0
11	11	10.0

While the above data is not presented in a statistical form, the tabulated date does present a correct representation of the true contribution to total system performance. From the previous, it is evident that field repair without cross modulation and noise figure analysis costs the typical system operator 14 db in dynamic range!

The system technician who is of the opinion that his "head room" has decreased since construction is entirely correct, and in most cases, the source of the decreasing head room has come from the in-house field repair or outside repairs made by others not working to fixed cross modulation and noise figure criteria.

Since this problem was brought on by the need to repair the amplifier, it would be useful to research some of the factors involved in amplifier failure.

Amplifier failures traceable to source of supply are:

* Flaws in original design.
* Vendor problems in manufacture.
* Inadequate quality control in production.
* Mishandling in shipment.

These sources of failure can be reduced radically by:

* Detailed and careful evaluation of devices before purchase for selection of an optimum vendor.
* 48 hour burn in upon receipt prior to equipment test.
* 100% QC check of all significant amplifier parameters after burn in.
* Storage of amplifiers in a proper environment until safely inside the properly waterproofed housing in the system.

A recent average taken from our laboratory notebooks indicate the following reasons for new amplifiers of various manufacturers failing to meet published specifications:

1 NCTA Synchronous 12 channel loading.

TABLE II

PERCENTAGE SHOWN OF TOTAL POPULATION NOT MEETING PUBLISHED SPECIFICATIONS

Trunk Amplifiers

* Test points - 39% (out of tolerance)
* Cross Modulation - 15% (3% seriously defective)

Distribution Amplifiers - All Types

* Test Points - 27% (out of tolerance)
* Cross Modulation - 20% (4% seriously defective)

It would be totally erroneous to assume from these data that the manufacturers are doing a sloppy job. The fact is that these tests were conducted after storage, shipment, and a 48 hour burn in. It behooves the wise system operator to set up a product acceptance testing system, either in house, or contracted, for any new system construction, or new equipment purchase.

Obviously, tight system performance criteria tend to ferret out marginal equipment performance, and this technique does assure greater longevity of initial system performance than "boiler plate" performance criteria.

Unfortunately, the majority of the cross modulation failures in the previous data were marginal (approximate average 3 db), and therefore, when comingled in the system, would have a relatively small overall effect initially. What is serious was discovered when detailed analysis was made of the amplifiers failing to meet the cross modulation standards. In almost all cases, the poor performance was traceable to partially defective active devices, or components which had drifted out of tolerance after manufacture. In other words, each of these amplifiers would contribute to the "disappearing head room" after installation.

After the equipment has been installed, additional environmental factors lead to loss of head room.

Although not truly representative of all systems, the following data has been developed from a composite of systems located in the Southeastern U. S., which systems have been subjected to close scrutiny. Keep in mind that these devices under this analysis had "failed" by the usual system definition.

*	Transient Intrusion	33%
*	Improper Field Installation (11%) Improper Diagnosis (device operative) (17%)	28%
*	Water damage	6%
*	Component Failure (Other than obviously transient related)	16%
*	Alignment Drift (Including technician maladjustment)	8%
*	Residual Manufacturing Defects	4%
*	Misc.	5%
		100%

It is quite evident that transient intrusion is a large factor in the system reliability problem.

It is important to note that the second category of problems does not appear until a technician attempts to locate a problem! From the previous it is quite evident that beyond the prior checkout of equipment upon receipt, a very large percentage of the system outages can be prevented simply by improving transient intrusion immunity of the system. It is also quite obvious that proper technician training and supervision can avoid much unnecessary system equipment "maintenance". It is also interesting to note that most water damage is due to poor system workmanship, or a lack of proper moisture-proofing technology.

Transients find their way into the CATV plant via the cable powering points and through direct injection, due either to instantaneous sheath potential drop, or via collapsing magnetic flux, or both. In most cases, the transients via the cable power point tend to be of the asymmetrical half supply cycle--roughly 3X applied voltage variety. The latter variety of pulses are extremely high speed pulses of very high amplitude. The former type of over-voltage can be controlled by careful attention to amplifier power supply design (or revision), and appropriate protective circuitry at power insertion points.

The latter type of transient intrusion is most destructive in its subtlety. By example, if the original source of transient intrusion was lightning, the cable sheath can experience "pin hole" puncturing. Quite often the effect of such sheath puncture is not seen until months later when the cable dielectric becomes water soaked.

Jacketed-flooded cable is a great assist in reducing damage from this source.

If the source of the transient is from adjacent AC power company primary breaker operation, the sheath current can become large enough to destroy or seriously damage passive devices for several thousand feet in each cable direction from the area of transient origin. Reducing co-mingling of plant grounding is of enormous assistance in reducing the system vulnerability to transients of this source.

Irrespective of the origin of the high speed transient, the rise time and energy content of these transients are such that R. F. transistors and power supply devices alike are damaged by their presence. Most insidious of all is the "secondary breakdown" effect, where the R. F. device dies slowly, after being exposed to this type of transient, with failure usually precipitated by the next high temperature stress period. Various attempts have been made in the past to improve the transient resistance of amplifier circuitry, but unfortunately, only careful analysis after failure is of any real value in determining circuit revisions necessary to improve transient resistance.

In any case, this is the point where conventional bench repair fails most miserably. After an active device has been exposed to a high speed transient, several of the active devices, diodes, I.C.'s, discrete devices alike, even regulators, will have been overstressed. Unless the amplifier is carefully checked for performance after repair there is a substantial opportunity for the device to be returned to service with partially defective devices still in the circuitry. The only sensible solution to this problem is to completely check every amplifier for compliance with performance criteria (or have it done). It should be obvious that critical criteria are cross modulation and noise figure, as these parameters are the most device performance sensitive. For systems with beyond 12 channel capacity, a second order performance test is imperative as well. Recent experience with implementation of such system practices has shown over a ten fold improvement in amplifier reliability. I must hasten to add that this experience involves systems in the Southeastern U. S., with high lightning exposure. A secondary benefit of the system reliability has been the substantial improvement in system dynamic range, and consequently higher overall day to day quality.

Conclusion

From the previous it can be seen that CATV system dynamic range can be assured by:

* Adequate initial quality control of
  ** System design
  ** System devices
  ** System proof
* Initial system implementation of
  ** Optimum system grounding
  ** Optimum power protective devices
  ** Proper training of maintenance personnel
  ** Proper calibration of system measurement equipment.
* Careful and sophisticated repair and rehabilitation with all device parameter qualification after a 48 hour burn in.
* Failure analysis coupled with device reengineering to improve transient immunity where needed.
* Periodic surveillance of total system distortion with particular emphasis on second and third order product evaluation.
* Plant reengineering to solve dynamic range problems not uncovered in original design.

From the previous, it should be obvious that the past practice of simple repair and alignment of active devices is the principle cause of "the disappearing head room". Capital and personnel commitments commensurate with these requirements are a must for any knowledgable CATV operator. If these requirements are too stringent for in house implementation, he may wish to retain an independent laboratory to provide such service.

Case of the disappearing headroom solved!