CATV SYSTEM PERFORMANCE -- THE NEW YORK EXPERIENCE

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The Commission on Cable Television is comprised of several divisions. However, the Telecommunications Division is most visable to operators.

Details of a mobile monitor van, as well as conclusions and recommendations on operational testing, will be discussed.

Activities of the van and results of testing systems of all sizes throughout the state will be analyzed. Performance, as it relates to over one hundred system tests, will be detailed.

Possible technical solutions to line extensions in low density areas will be considered in the light of actual system performance measurements.

The paper will conclude with a discussion of current system design based on measured performance.

I believe it is necessary to provide a brief history of the New York State Commission and its involvement in cable as a backdrop to the discussion which follows.

The Commission was established by the State legislature through enactment of Article 28 of the Executive Law. The Commission is empowered by the legislature to exercise a broad range of supervisory authority over cable systems operating within the state. Among those are regulations pertaining to contents of franchises, review of rates charged to subscribers, assistance and guidance to municipalities considering franchising, resolution of complaints, transfers of control and rules related to construction and operation of cable systems to ensure safe and adequate service.

The experience gained in enforcement of rules regarding safe and adequate service is the topic of this paper. The rules, or technical standards, are officially known as Part 596 of the Rules and Regulations of the New York State Commission on Cable Television. Unofficially they are called many things -- some of which can not be printed.

My Division operates a mobile test van which is used to evaluate performance in systems throughout the state. Currently, there are 156 systems serving approximately 635,000 subscribers in nearly 500 communities. As you might suspect, utilizing a single test unit to test systems state-wide is a major undertaking. The old saying "You can't get there from here." is appropriate. Although Albany is located in the Up-state area, travel time to a system may well take more than 8 hours.

A prime function of the Division is assistance to cable operators in complying with both State and Federal annual testing requirements. The majority of our requests for assistance come in the 3 months preceding the Federal test deadline on March 31. In 1974, despite the severe gasoline shortage in the Northeast, we kept the van on the road for all but 6 days in February. In so doing we tested 35 systems. I must add that there was no charge for the service.

The van is well equipped for testing all facets of system performance. Table I lists the major, on board, test equipment.

Table I

Spectrum Analyzer	Frequency Counter
Tracking Generator	VHF-SLM
Sweep Oscillator	Sweep Receiver
Precision Demodulator	Pre-Amplifiers
Signal Processor	Color Receiver
Oscilloscope	Test Generators
Vector Scope	Calibrator

The van is a heavy duty, long wheel base unit which contains, in addition to the equipment listed in Table I, a variety of cables, fitting and miscellaneous pieces. Power for operation of the test equipment, lights, heaters and air conditioner is provided by a gasoline engine driven 7.5 Kw alternator.

The Telecommunications Division has tested and evaluated one hundred systems to date. Approximately 50% of the requests for testing come from cable operators. The majority of the remaining requests come from municipal officials who wish to verify proper system operation as they consider rates, or renewal of franchises. Municipal officials also request the testing of systems where there are large numbers of complaints. While I have the authority to order special testing, specific maintenance procedures and general service improvements, I do not feel the need to do so, except in cases of deviations from accepted system operating practices. Our experience to date has indicated that fewer than 5% of the cable system operators require an official notification that they are in violation of a specific rule or technical operating requirement.

The testing done for cable operators is an obvious benefit. The testing done for municipal officials also benefits the cable operator, since our testing usually indicates that the system is performing adequately. When data are collected by certified test equipment and objectively evaluated, the facts usually support the cable operator.

The technical performance standards we have imposed on some cable systems in our state have been the cause of a great deal of "red-necked" debate. We do require that systems in the six Urbanized Areas of our state and systems serving more than 10,000 subscribers from a single headend maintain a higher performance standard in regard to carrier-to-noise, cross-modulation, intermodulation and FM radio carriers than is required by Part 76 of the FCC rules. We hold firmly to the opinion that these standards are not excessive or burdensome, nor do they in any way interfere with a national cable television development policy. As I write this paper, I am not aware that a national policy on cable has been clearly defined by the Congress.

The vast majority of our state systems are outside Urbanized Areas, thus are subject to only the technical requirements of the FCC. We do require some additional tests of all systems: old, new, urban and non-urban. The requirements most discussed are those of establishment of monitor test points and a subscriber complaint procedure. Later, I will address these points.

The requirements which are different from the FCC Part 76 technical standards are listed in Table II. I would ask the reader to keep these values in mind. He should question whether he would design a system that did not meet these goals, as an absolute minimum. In the discussion which follows the table, the reader will see the results of numerous carrier-to-noise tests conducted by our Commission.

Table II

Carrier-to-Noise Ratio	40dB*
Cross Modulation Ratio	-46dB*
Intermodulation Ratios	Variable**
FM Radio Carriers	10dB below Ch. 6 Visual Carrier*

*Urban Area and 10,000 + Systems
**Modified Jeffers Curve

We do require that all systems in the state make a telephone number available to which subscribers may direct their comments, questions and complaints. You may call this petty, but there also may be cable operators in your state with an unlisted telephone.

In the many comments that have been filed with our Commission regarding technical standards, the one which drew the most fire (and continues to do so) was that of a 40dB carrier-to-noise ratio requirement. It follows quite naturally that in system testing we would direct our attention to that parameter. The results obtained in our tests were, at first, very confusing.

We have concluded that carrier-to-noise measurements made at subscriber drop levels do not truly represent system performance. At the inception of our testing program we thought that our spectrum analyzer was defective. We were measuring noise figures which did not compute. The analyzer was returned to the manufacturer for repair and recalibration. We were surprised to find that the analyzer did not need repair <u>or</u> calibration. Further work in the field indicated that the noise measurements varied significantly as signal levels were varied.

Our spectrum analyzer has a noise floor of -110dBm. However, when used as directed by the manufacturer, the <u>best</u> carrier-to-noise ratio that can be measured is 38dB at a tap level of 0dBmV. It becomes obvious that, if we are to measure carrier-to-noise ratios accurately, we must always look to signal levels which will allow us a measurement range in excess of the expected noise level. Therefore we have made standard the practice of measuring carrier-to-noise ratios at signal levels not less than +20dBmV.

Our field strength meter presents a similar problem when looking at 0dBmV tap levels. The noise floor begins to influence measurements at +3dBuV. We are fortunate in owning a meter which always reads positive numbers. The zero on our field strength meter is 0dBuV, or -60dBmV. The narrow IF of the meter requires an 18dB noise power bandwidth correction factor. Therefore, when used at a tap level of 0dBmV, the best carrier-to-noise measurement which can reliably be read is 39dB. When utilizing the signal level meters commonly in service, with -40dBmV as a minimum measurement capability and as IF power bandwidth correction of 3 to 4 dB, there is no way a system can be certified to meet a 36dB carrier-to-noise with a 0dBmV subscriber drop level input! I submit that every cable system operator who used the signal level meter to measure his system carrier-to-noise at zero level drops has recorded readings which may have a significant error.

Our carrier-to-noise investigation has resulted in a significant discovery regarding system performance as it relates to system cascadability. The importance of this discovery can not be underestimated. In these days of economic woes which assail the cable industry, the ability to extend trunk systems, rather than construct new headends, or establish microwave links, may well make service available to areas which otherwise could not be built.

We do not have a laboratory, nor do we have the equipment or manpower to establish such a laboratory. Our data is empirical and is based on our work in many systems utilizing many types of equipment in widely varying conditions of cascade length, temperature and system age. Our data are not weighed to a greater degree than is the industry in utilization of specific equipment types. Our conclusions are not colored by manufacturers names, since the performance of trunk line equipment did not differ significantly regardless of make or model.

I submit that current methods of designing systems utilizing the well established formulae for cascadability, carrier-to-noise and cross-modulation, mandates systems and service areas that are much smaller than are necessary. The current practice in system design precludes long cascades. It is common to hear that cascades in excess of 30 amplifiers can not be built. Our state has at least two areas where cable operators, apparently on the advice of manufacturers, will not build beyond 30 amplifiers despite the need and the more than adequate density beyond that point. I am certain that manufacturers who test systems for performance as a part of their turnkey obligation are no longer surprised when the test data shows that the system design is most conservative.

I have avoided use of specific manufacturers names in this paper and, with the one exception which follows, I will continue to do so. We do not make recommendations regarding test equipment or CATV system components. However, everyone seems to be familiar with Starline I equipment. If I said that, at best, Starline I could not be cascaded beyond 50 amplifiers in a loaded 12 channel system, I'm sure that no one would argue, except perhaps to say that 50 amplifiers is too many. Using accepted calculations for cascadability the Starline I will meet 36dB C/N and -57dB cross-mod 50 amplifiers out. We have measured 37dB C/N and -51 cross-mod at a bridger output 71 trunk amplifiers deep in a New York system. Those performance figures have been measured in January, May and October. Currently accepted engineering calculations will tell us that we have somehow defied or repealed the laws of physics. That, as we know, is beyond the realm of possibility - even for the New York State Commission!

I believe that the above must lead us to conclude one of two things: the data were improperly derived, or the formulae were somewhat misleading. I reject the first, since long experience, certified equipment and many hundreds of individual measurements must lead us to conclude that when systems consistantly outperform the calculated criteria, the calculations rather than the measurements are to be questioned.

We could show that an improvement of about 1.5dB in noise figure in all 71 of the amplifiers above would result in the carrier-to-noise performance we measured. It is very unlikely that that is the case.

We could show that operation of the amplifiers at an output level resulting in a combined trunk-feeder cross-modulation performance of -46dB (the State and Federal requirement) would result in the performance measured. This would entail a minor readjustment in amplifiers in the trunk to increase the output by 2.5dB. The resultant cross-modulation in a well behaved amplifier would be -52dB and cascadability would be increased to more than 70 amplifiers. To our knowledge this was not done. The cable operator indicated that the equipment was adjusted to manufacturers recommendations. Our limited tests within the trunk system bore this out. Short spacing at about

18.5dB would accomplish a similar effect. However, that was not done.

A factor we do not often hear discussed in CATV may be the one we should address. It is assumed that all amplifiers are operated flat and that all amplifiers have a perfect frequency-amplitude response in the band of interest. It is further assumed that these ideal amplifiers are both amplifiers of incoming white noise and generators of white noise.

While we always consider white noise in our calculations, the actual amplifier does not exhibit the specific characteristics which allow white noise to pass through unchanged. It may well be that the amplifiers in cascade are actually generators of pink noise due to the bandpass shape and the overall response of the amplifier at the various frequencies within its bandpass.

We do not, as stated earlier, have a laborabory in which to investigate the performance of cascaded amplifiers. We do have many test reports which indicate that systems do not perform as expected. Table III indicates a range of cascade lengths and carrier-to-noise performance.

Table III

System	Mi.	Age	Test Location	C/N
a	220	9 yrs.	HE	49-51
	Tr 1		29A	40-42
	Tr 1		71A+B	37
b	156	9 yrs.	HE	46-47
	Tr 1		24A+3LE	42-43
	Tr 2		30A+3LE	42
	Tr 3		19A	44-45
c	285	9 yrs.	HE	44-48
	Tr 1		7A+1LE	39-46
	Tr 2		7A	39-41
	Tr 3	5 yrs.	35A+B	43-45
d	85	2 yrs.	HE	48-53
	Tr 1		8A	48-53
	Tr 2		16A	43-51
e	220	3 yrs.	HE	49-53
	Tr 1		21A	47-51
	Tr 2		24A+B	48-50
	Tr 3		22A	48-50
f	45	16 yrs.	HE	42-48
	Tr 1		8A+1LE	37-42
	Tr 2		14A+1LE	35-37

HE - Headend
A - Trunk Amplifier
B - Bridger
LE - Line Extender

Analysis of the measured performance of system in regard to carrier-to-noise reveals a very startling fact. System noise performance is not degraded in a logarithmic progression. Given a specific carrier-to-noise ratio at the headend we have not found, for example, a 10dB degradation at the tenth amplifier. Systems that are engineered, however, rather than strung from pole to pole, do not follow the usually accepted cascade factor. It does not appear to be very important whether the amplifiers are push-pull or single ended so long as the system has had the benefit of engineering talent in its design. Table III includes new Urbanized Area systems as well as older single ended systems. It is not exhaustive in that I have selected system test data representing large and small plants in widely varying localities within the state.

There are no standard levels in a cable system, thereby making most difficult the task of comparing performance between systems. It would be desirable to establish specific operating parameters which could be applied to each amplifier in a system. An amplifier being operated at a +32dBmV output with a +12dBmV input will have significantly better noise performance than that of an amplifier with the same output, but with +7 or 8dBmV input. While those two conditions might well represent "normal operation" for those amplifiers in a system, they do not allow the ready comparison of data between systems, or amplifiers. I would urge the NCTA, SCTE and IEEE to address this problem of standard levels, so that we all are referencing identical conditions when making performance measurements.

We have concluded that cross-modulation is not as severe a problem as has been previously thought. We do not make synchronous cross-modulation tests of systems. Our goal is to perform system tests in a way which does not interfere with subscribers viewing pleasure. We do not intend, except in rare instances, to perform tests which are service disruptive. Since the goal of all system testing is to ascertain system performance in actual normal operation, we have made every attempt to allow reasonable test procedures which do not disrupt service.

Every system test requires both objective measurements and subjective observations. We observe our monitor for cross-modulation and measure the pilot carriers. In every instance where we have seen and measured cross-modulation, we also have seen and measured objectionable intermodulation products. However, we have measured cross-modulation on pilot carriers and have seen none in pictures. We have been led to conclude that where a system condition exists which creates severe intermodulation products, we will observe cross-modulation. Corss-modulation measured in the low 50 and high 40dB ranges does not appear to present a noticeable picture impairment to even trained observers.

I have a reservation in regard to the definition of cross-modulation as a ratio of peak carrier power to modulation sideband. As you know, this definition is that of the NCTA in Engineering Standard NCTA 002-0267. Since it is sideband power (particularly the first) which causes the undesired modulation, a more appropriate method of definition would appear to be the ratio of desired modulation to undesired modulation. Since the first sideband, as observed on a spectrum analyzer, is 16 to 18dB below carrier peak power the numbers produced would be shocking to those of us accustomed to the threshold of visibility of cross-modulation as -51dB. Utilizing the ratios of sideband powers, we would have cross-modulation visibility thresholds at -33 to -35dB. I would strongly urge that the ratios of sideband powers, rather than peak carrier VS sideband power, be used to determine the cross-modulation ratios.

Earlier, in the text I referred to the modified Jeffers curve* for intermodulation products. The modification smooths the curve and adjusts the values as suggested by Jeffers. As published in our rules, it is a very close approximation of the intermodulation curve published in BP-23.** In our intermodulation curve, the values range from a -30 to a -57dB in relation to the visual carrier. It is my opinion that the values shown by the curve are valid and are attainable with reasonable system design.

The majority of problems encountered are those of spurious signals generated at the headend. Most of these come from strip amplifier headends. Our long experience with strip amplifier headends indicates that many cable system operators utilize the amplifiers at full gain, thus allowing placement of the first trunk amplifier between 3000 and 4000 feet from the headend. This, of course, saves one trunk amplifier at the expense of the viewer. The cable system operator is generally not aware that manufacturers do not recommend full output from strip amplifiers when used in adjacent channel systems.

The maximum output from strip amplifiers, when used in an adjacent channel headend, should not exceed +66dBmV when the individual amplifiers are rated for a +72dBmV output. The AGC action is still adequate at a gain which results in a +66dBmV output and spurious signals are reduced by 12dB. The addition of channel pass filters is strongly recommended to further reduce spurious signals.

Heterodyne signal processors offer greater control of signal levels, but can create additional problems from several sources. One very noticeable defect is 45MHz IF leakage to the trunk. Another is the color subcarrier image at 3.58MHz, placing a color beat in the lower adjacent channel. Common in older processors was the local oscillator leakage at the input terminals. Without a preamplifier to act as a buffer, these local oscillator signals could radiate from the antennae, mix at pre-amplifier inputs thus creating significant intermodulation products in other channels on the system. We have measured leakage signals as high as +25dBmV from processor inputs.

Our rules require that cable operators establish monitor test points in systems and that the monitor points be measured once a month to determine carrier levels. Additionally, a subjective evaluation of picture quality is required. Many hold the view that the information is neither valid nor useful. I believe that monthly tests are important to the system operator to determine the operating characteristics of the system. When compared to the results of the annual tests it is relatively simple to determine system performance. Experience will show the operator when to begin a distribution and trunk maintenance program rather than continue to dispatch technicians on subscriber complaints.

An example of how this may work for the operator is in measurement of the visual-aural carrier ratios. When properly set at the headend, the ratio is 15dB. The system should not change this ratio. However, we measure many systems where the ratio does change. The cause of the change in ratio is a change in system flatness due to reflections from bad cable,connectors or taps, or poor amplifier response. When an operator sees, during the monthly monitor tests, that the visual-aural ratios are not uniform from headend to subscriber tap, he should begin a system sweep to determine the cause.

* Jeffers, Michael, NCTA Convention Record, 1970

** Canada, Department of Communications, Broadcast Procedures 23

A particularly vexing problem which cable operators must attempt to solve is that of line extensions into less dense population areas. Many municipal officials insist on extensions when, in fact, the economics of the situation do not warrant the plant construction. We have begun to assist in the resolution of the different views which may result from an operator's insistance that he cannot afford to build, while local officials insist that he can.

We are operating a programmable calculator programmed to consider construction and operating costs, potential subscribers, acceptable installation and monthly charges and a reasonable profit (as determined by the operator). Many variables and combinations of variables can be considered in the program. Given monthly and installation charges and desired profit, for example, we can help the operator determine the maximum he may spend in construction to achieve his goals. While we have not had the program in operation a sufficient length of time to ascertain its degree of success, we are guardedly optomistic in predicting that it will be successful.

The requirement for lower cost construction, sometimes indicated by our line extension program, has dictated that we evaluate construction practices which heretofore have been considered only for very short extensions. Specifically, we must now consider utilization of one-way-only trunk amplifiers, twelve channel capacity (where the rules do not preclude these) and line extenders cascaded beyond two or three.

Line extenders have been developed to a degree approaching trunk amplifier performance. Extensive use of IC chips and the addition of AGC make these units viable in long extensions. Where there are limited numbers of subscribers along the trunk route, it is practical to tap the trunk. However, it is not recommended that trunk taps be other than directional coupler types. We have seen pressure taps in trunks, but do not recommend their use.

I know of fourteen systems in the state, dating from 1967, which are tapped trunk twelve channel systems. Of these, thirteen use single-ended trunk amplifiers and are short (up to 9 miles) systems. The remaining system has a subscriber density below 25 per mile, has all line extenders, is a 40 mile plant and meets all pertinent parts of Part 76 and Part 596. We are not aware of subscriber complaints,which seems a good indicator of acceptable performance.

In conclusion I would stress some key paragraphs. Carrier-to-noise ratios, exceeding 36dB in systems are not a deterrent to long cascades even with single ended equipment. It is not more costly to design a system for high performance than to string it from pole-to-pole. When strand mapping is done in a way which allows good system continuity, it is likely that a system can be built less expensively to perform better than Part 76 envisions. With the advent of high performance IC chip amplifiers, a system can be built with a feeder-to-trunk ratio as high as 6 to 1, dramatically reducing per mile cost while maintaining excellent signal quality.

Amplifier design has changed radically in the last year. The net effect is that trunk and feeder systems have vastly improved performance. Notwithstanding, the changes in design, actual systems utilizing older single ended amplifier design perform significantly better than can be calculated from existing formulae.

Line extender design has improved with the advent of IC chips, improved AGC, slope and thermal control. Line extenders from some manufacturers have performance nearly equaling (sometimes equaling) trunk station specifications. I have no hesitancy in recommending that cable system operators should very seriously consider cascades of twenty or more line extenders in low density areas to bring cable to potential subscribers at reasonable costs.

Measurement of carrier-to-noise, cross-modulation and intermodulation should not be done at subscriber drop levels. This procedure will result in significant errors in measurements. Measurement techniques must be reevaluated and the objective measurement correlated with subjective observation of picture quality. Discrete amplifiers respond differently from IC units and measurements do not track with visual observations.

Without the aid and cooperation of the New York Network technical staff, several munufacturers, and most importantly the cable system operators in the state, this paper would not have been possible. To all of them and to my staff-thank you.