OPERATIONAL EXPERIENCE OF FEED-FORWARD HIGH LEVEL AMPLIFIERS

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The use of Feedforward amplifiers in bringing existing systems into compliance with F.C.C. Standards. The conversion of a low band system to a high band system by changing amplifiers only with feedforward amplifiers. Our experience with feedforward amplifiers has led us to the conclusion that this amplifier has some promising advantages in the CATV industry.

I would like to start this paper by going back a few years and reviewing some of the operational problems that lead to our use of feed-forward amplifiers.

All of our systems have either been rebuilt or built since 1966. Potomac Valley Television Co., Inc., operates four systems in the Maryland and West Virginia area. The largest of the systems is Cumberland, Maryland, with 21,000 subscribers; and the smallest is Paw Paw, West Virginia with 235. The other two systems are Romney, West Virginia, with 1,000 subscribers; and Moorefield, West Virginia with 800.

A few years ago when the F.C.C. 1977 standards came into being, we started to take a hard look at these systems. The Cumberland system was started in 1951 and now serves a number of smaller communities in the area. When it was rebuilt, it was changed into a 12 channel hub system with 8 major legs with an average of 40 amplifiers each. The longest leg is 50 amplifiers long.

When we rebuilt the system, it was designed with SKL Amplifiers spaced at 22dB. We used high level distribution amplifiers in some areas rather than bridgers. The distribution lines were designed for a signal at the back of the sets of 10dBMV.

We found the distribution amplifiers, when 12 channels were applied to them, did not perform well. In fact, we had our first introduction to 2nd and 3rd order products. Although the distribution amplifiers met the cross mode standards set up by the N.C.T.A.

Like everyone else in the industry, we had our doubts about the new F.C.C. standards, so we embarked on an indepth testing program as did most everyone in the industry. Some of our findings were very disheartening and some results were better than we expected. So, where ever we could, we tried to increase our standards as compared to the F.C.C. minimums.

	FCC MINIMUM	DESIRED ENGINEERING STANDARDS OF PVTV
System flatness per channel	±2dB	(-7.5MHZ + 3.6 MHZ from visual carrier) ±1dB for head end ±1dB for system
amplitude response for entire system	--	±3dB
Hum or low frequency variations	5% peak to peak	3% peak to peak
Visual carrier to noise radio(4MHZBW)	36dB	46dB
Min. visual sync-tip level	0dB	+3dBMV
Max. visual sync-tip level	--	+10dBMV

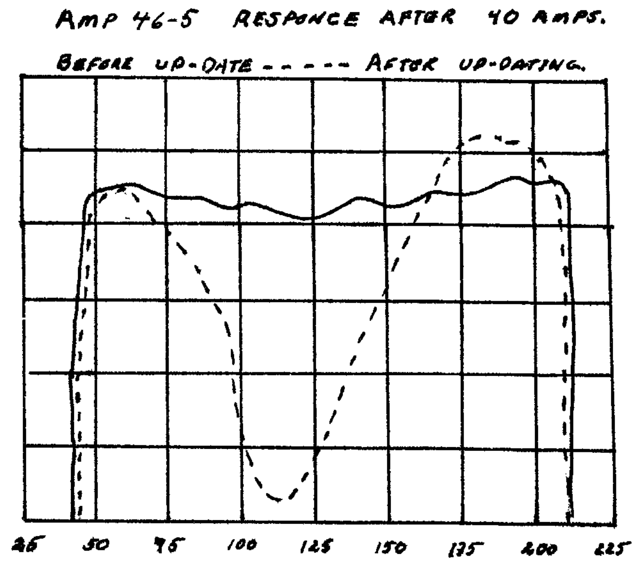
The decision was made to either make the systems conform to our standards within the next three years, or start plans for another complete rebuild. One of the first steps was to obtain some meaningful testing equipment.

We purchased what we felt was a good choice of test equipment at that time. A Tektronix T.D.R. and a 7L12 spectrum analyzer with a 7K11 preamp. At the same time, we changed our sweep system to an Avontek CR1000. In addition, we installed the sweep receiver in a new Telsta step-van. By changing the amplifier maintainence crew from a two man to a one man operation, it helped to defray some of the cost of the new test equipment.

An internal trouble reporting system was started in addition to the normal customer trouble calls. If any condition was found that did not meet our standards, a report to the engineering office is filled out by our personnel. These reports are followed through until that problem is resolved. The following is a summary of the results of these reports:

In checking out the response and noise of the head ends and the microwave systems, we found them to be in reasonably good condition. Although the response was very difficult to maintain to within +-2dB over a single channel. The trunk line amplifiers had some problems. The response at the ends of the system had as much as 16dB peak to valley in the mid band through 40 amplifiers. Our reports showed the total system needed routine maintainence. We started a program of returning each line amplifier to the shop for repair and updating. The photo mod A.G.C control units were removed and replaced with PIN diodes. The transistors were replaced with Amperex A230 devices.

None of our systems are in the top one hundred markets, but we felt that every effort should be made to well surpass the F.C.C. standards. Our early testing proved to us that our trunk line amps were capable of operating with midband channels, if we could control the response. The bridgers were marginal, so every effort was needed to maintain signals to a minimum of level change. This was accomplished by very close alignment and by increasing the number of duel pilot slope control amplifiers. The over all signature of the system was controlled by mop-up equalizers. These units were placed at every 20th location, or ahead of major branching points. The results of this work can be seen in the graph.

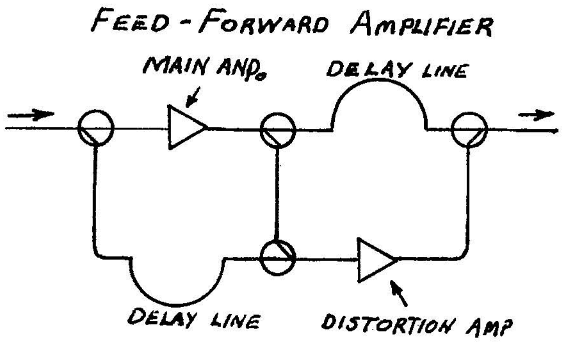


When we were in the midst of this up-dating, Bill O'Neil, of Amplifier Design and Service, Waltham, Massachusetts, asked if we could do some field testing of an amplifier that he was in the process of designing.

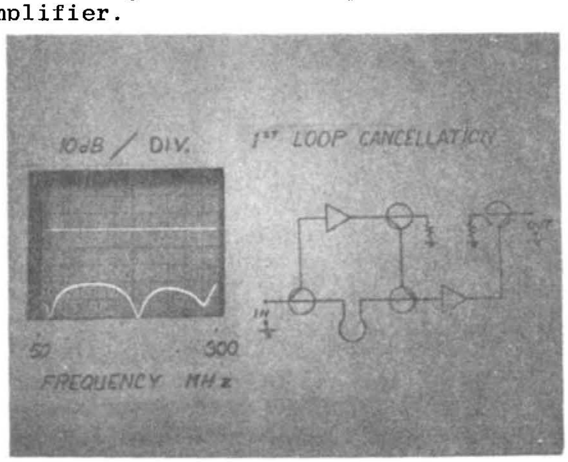
We agreed, and Bill brought his black box amplifier to Cumberland and it was tested at our hub head-end in Cumberland. The amplifier had a gain of over 50dB and a noise figure of less than 10dB. When we checked it's out-put ability, we found it to be capable of over 60dBMV with 12 channels flat. With all distortions cross mod, 2nd and 3rd order well below 57dB. The amplifier was installed in the head end and drove the feeder lines in the down town area. It also was monitored on the 12 monitors in the head-end daily. The amplifier was returned to Boston for further testing. At the time, patent clearances were being processed so the details of the unit were not revealed to us.

However, we did still have a problem with our high level distribution amplifiers that had a gain and out-puts that were similar to the amplifier that was now called an H60M. This new feed forward amplifier could be mounted in our existing locations. So we started plans to change out the two hundred high level distribution amplifiers with H60M's. This took 18 months to complete.

The feed forward amplifier works on the concept that the input signal is compared to the output of the main amplifier section 180° out of phase. This compared signal will contain the distortion of the main amplifier. The distortion is then amplified and used to cancel these distortion products at the output combiner. The results are an amplifier that has about a 20dB advantage over the single devices in the amplifier.

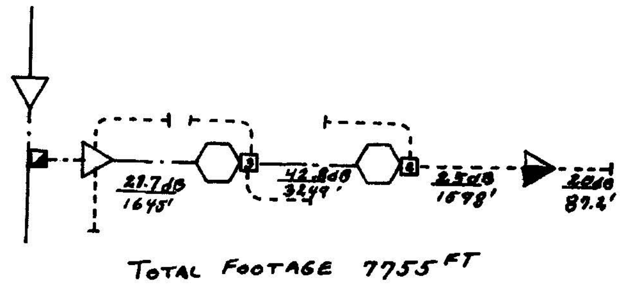


We have now installed over 200 of the feed forward units in high level locations so far. They are being ran out 50dB on channels 2 through 6 and 57dB on channels 7 through 13. Like any new design, we have had some problems; but in every case the trouble has been traced down to a mechanical fault. To date, the oldest units have been in operation about 2 years. We have had about 10 units in for service and in each case the trouble was traced down. Six of the failures were due to broken wires in the delay lines in the early production units. This breakage was due to too much strain on the wire in assembly. Two of the troubles were traced to poor solder joints. Two intermittent problems were traced to bad connection inside of the amplifier chips. We have no evidence that the delay loops have shifted in phase, or the cancellation has changed with temperature of aging. If, for any reason, the cancelling amp or loop should fail, the signal level will remain about the same. So when the amplifiers are checked, picture quality must be monitored. At the present time, the cancellation loops can best be checked on a tracking sweep or checking the overload point of the amplifier.



The photo shows an H60M after a cascade of 49 rebuilt amplifiers and the 50th is an H60M with 12 TV channels and over 40 FM channels.

We were so pleased with the performance of the high level feed forward units, we set up a new test. This time we installed 2 - H60M's in cascade with a three way split on the output of the first one and a two way split on the second H60M's output. The object was to serve a rural area with a minimum number of amplifiers.



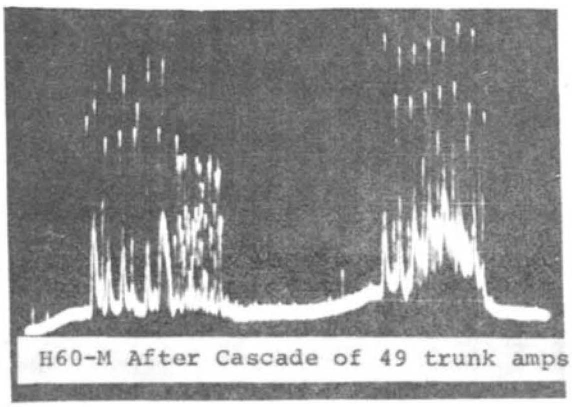
The results of this cascade showed the H60M amplifier could be cascaded at high levels and supply good service to the customer at the same time.

The philosophy of the company is to go out and look for trouble. Do not wait for service calls. For this reason, the Cumberland system is maintained daily by in-service sweeping. Any trouble found is cleared that day, if possible. There are servicemen on duty or on call from 8:00 AM until 12:00 Midnight, seven days a week. Any customer that has had a call back on service is used as an F.C.C. check point. This gives a random selection to the checks. We receive less than 12 trouble calls a day from all the systems. Of the 12 calls, about half of these are matching transformers.

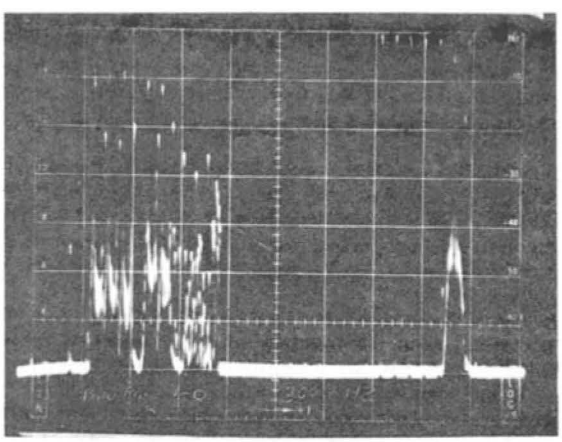
Now we had a problem in Paw Paw, West Virginia. That system was built with equipment that was removed from the old Cumberland low band system. We needed more channel handling capability because of a new educational station that was now available in the area.

If we would use conventional amplifiers, we would have to change the amplifiers spacing, the feeder lines and reset most of the taps. The old amplifiers were running out at 32dB on channel 2 and 38dB on channel 6 into the feeder lines. We projected it would take 47dB on channel 13 and 40dB on channel 2 into each feeder line to meet the requirements of the high channels. The feed forward amplifier was designed with an automatic slope and gain control circuit. The power supply was changed to line powered and the unit was mounted in a strand mounted housing.

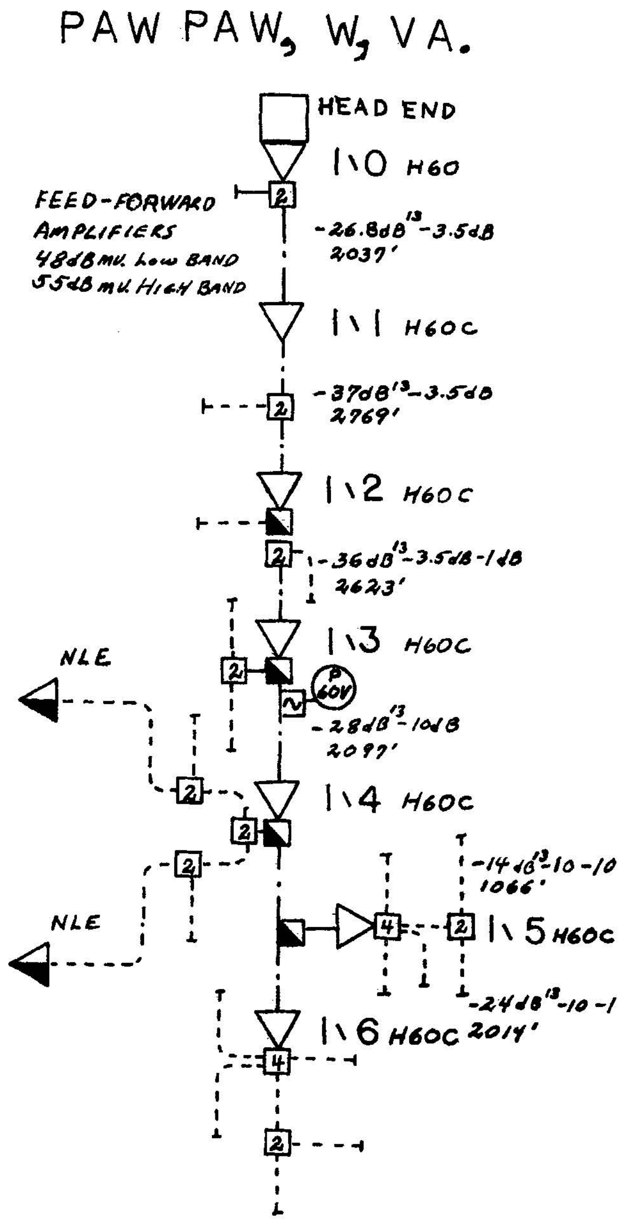
In order to serve our needs and test for a worse case condition, each amplifier was ran out at 56dB on the high band and 50dB on the low band. The signals were fed to the feeder lines by splits and the trunk was fed by a 10dB directional coupler. To maintain 40dB, spacing pads were used on the inputs when needed. The layout of the Paw Paw, West Virginia system as shown:



1ST AMP AT HEAD END

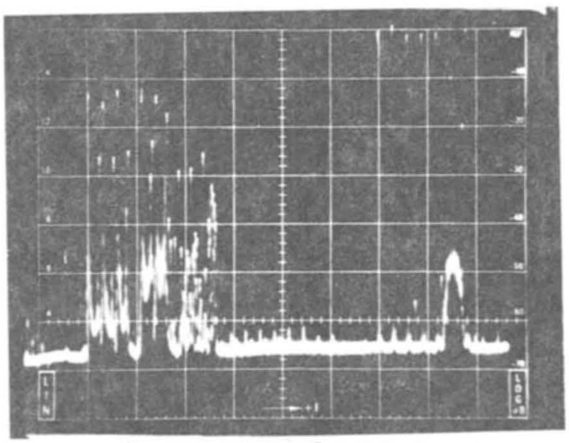


1ST AMP AT HEAD END
4TH AMP



You will note each unit has automatic slope and automatic gain controls. There is no bridgers; so in order to meet the level requirements, the feeder makers are designed with the trunk line having the most loss.

The system was changed from a low band system to a high band system in one day. Not one tap had to be changed and no cable had to be rerun. When the end of each tap line was tested for a minimum of 20dBMV, two tap-line equalizers were installed to maintian a 6dB window.



6TH AMP PAW PAW

The Paw Paw system will be able to handle over 20 channels without any amplifier changes. The problem is due to the terrain. There are only 7 channels available and three of them are NBC.

The results of the Paw Paw experiment showed these results of the cascade of 6 amplifiers. The tests were made with 12 channels with the low band operating at 50dBMV and the high band was 57dBMV.

Signal to noise ratio low band	-45dB
Signal to noise ratio high band	-54dB
Cross mode 12 channels	54dB
2nd order products from low band	50dB

One of the findings in the Paw Paw cascade was the cross mode. Second and third order distortions did not add up as would be expected in standard amplifier cascades.

Our conclusions of feed forward amplifiers are these. We first used the amplifier to solve a problem in high level distribution. We found it to be capable of signal levels at least 10dB better than the amplifier it replaced with less distortion.

The most important finding, after experimenting and testing for over two and one half years, is their excellent cascade ability. In Paw Paw, West Virginia, we were able to maintain an input of 17dB of better. The gain was set at 40dB each. The amplifiers were equalized for flat system response with a 7dB block slope. The high channels were held at 57dB. The system has had one failure. That was traced to a water leak in a strand mounted cabinet.

We are starting to evaluate the feed forward amplifier as a trunk line replacement unit. Not only for it's ability to handle more channels, but to meet the demand for a much higher signal to noise ratio on our existing systems. Modern color television receivers are being designed with signal to noise observable to -50dB and better. We are starting to consider this in our designs. Tests conducted with newer television receivers have shown us we should be designing for a minimum of -53dB signal to noise in our systems now.

The heart of the new amplifier will be a feed forward output stage which will be run at about 45 to 50dB flat. The bridger will have unity gain on the high end with about 5 to 7dB slope. The input stage will have an average noise figure of about 8dB. To design an amplifier with extremely lower noise figure would be impractical. With this amplifier, we intend to keep the inputs about 20dBMV. With this design, the unit will drop into our standard locations spaced at 22dB plus at channel 13. The amplifier will be capable of being equalized for 12, 20, or 30 channels as we decide.

We should be able to cascade over 100 of these amplifiers and retain a signal to noise of better than 50dB. Distortions should be below 50dB for 30 channel operation.

REFERENCES: A Wide-Band Feedforward Amplifier, Robert B. Meyer, member IEEE, Ralph Eschenbach, and Walter M. Edgerly Jr. IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. SC9, No. 6, December, 1974.
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