CATV APPLICATION OF FEEDFORWARD TECHNIQUES

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ABSTRACT

Several papers and many articles have been written explaining what feedforward is, but little has been presented on just where such technology should be applied. It is not feasible in just any location, due to inherent operational limits and cost considerations. This paper presents the aspects which must be considered when applying feedforward to CATV systems. Analysis of operation in trunk, super-trunk, bridgers, and distribution positions are given. Conclusions are hypothetical since very little hardware currently exists.

INTRODUCTION

Feedforward amplifiers utilize a circuit technique whereby the output signal is compared to the input signal and the distortion components of the amplifier are cancelled. A significant improvement in amplifier linearity is achieved at the cost of increased circuit complexity. This paper leaves the discussion and analysis of feedforward to the references on the last page. The purpose here is to examine the performance versus cost consideration in system design.

SYSTEM ANALYSIS

Assuming that feedforward is a viable concept and can be developed into a technically consistent product, where are the system locations that can best utilize this improvement? Obviously, any distortion improvements are welcome in a system, but one must look at the economic considerations to determine if the improvement is worth the cost.

An assumption was made of the typical performance levels of a feedforward trunk, bridger, and line extenders based on preliminary development of actual circuits. These levels are shown in Figures A and B. These new performance specifications were inserted into computer programs of current system design. The assumption of compatible gain, spacing, powering, and AGC were also made. The system configuration included 20 trunk stations with a one output bridger at the last station and followed by two line extenders.

Figure C shows the results of the new system design with various combinations of feedforward modules. All the numbers shown were calculated at the end of the second line extender. Note that little improvement was made with FF in the trunk only, indicating that major contributions to distortion are made in the distribution lines. Obviously, if the assumptions in Figure B are true, the trunk alone would improve by the same amount as the basic FF modules.

Significant improvements were made in performance by putting feedforward in the bridger and line extenders while using standard trunk modules. A 3 dB improvement in cross modulation and composite 3rd order was achieved by using a FF bridger only and 5 dB improvement with a FF line extender only. Combined FF bridger and line extenders yielded 10 dB improvement over standard modules.

The next test involved assuming specific distortion levels as outlined in Table D and computing the available operating levels for the bridger and line extenders while maintaining trunk levels of +32 dBmV. Figure E shows the computed operating levels based on the system performance levels listed in Figure D. The last two feedforward configurations shown in Figure E yielded operating levels of +57 dBmV and +58 dBmV respectively.

Module Parameters \ Type of Amplifier		Trunk		Bridger		Line Extender	
		Std.	FF	Std.	FF	Std.	FF
Cross Modulation	dB	-93	-113	-61	-81	-63	-83
Carrier/Noise	dB	-59	- 59	-63	-63	-71	-71
Second Order IM	dB	-81	- 91	-65	-75	-67	-77
Comp C/TB	dB	-94	-114	-66	-86	-69	-89

1. 30 Channel Output Levels (2-D/E-13/J-R)
   Trunk - (28/30/32) dB
   Bridger - (43/45/47) dB
   Line Extenders - (43/45/47) dB

FIGURE A. STANDARD AND FEEDFORWARD MODULE SPECIFICATIONS

1. 10 dB improvement in 2nd order distortion over standard modules.
2. 20 dB improvement in X/mod and composite 3rd order distortion over standard modules.
3. The noise figure will be the same as a standard module.
4. Feedforward (FF) module cost parameters:

   A. FF Trunk Module — 29.5% increase over standard module
   B. FF Bridger Module — 27.9% increase over standard module
   C. FF Line Extender Module — 62.8% increase over standard module

TABLE B. "FEEDFORWARD MODULE ASSUMPTIONS"

CONDITION \ PARAMETER	Cross Mod	C/N	2nd Order	Comp. C/TB
Standard	-51.2	-45.9	-60.6	-55.9
FF Trunk Only	-52.8	-45.9	-61.4	-58.1
FF Bridger Only	-54.2	-45.9	-62.3	-58.7
FF Line Extender Only	-56.6	-45.9	-62.9	-60.3
FF Trunk and Bridger	-56.2	-45.9	-63.5	-61.9
FF Bridger and Line Ext.	-63.4	-45.9	-66.4	-65.7
FF All Modules	-71.2	-45.9	-70.6	-75.9

FIGURE C. SYSTEM DISTORTION LEVELS IN dB

These are unreal levels, since for 30-plus channels, +51 dBmV is a maximum due to limitations in the FF circuit. That is, the error amplifier starts contributing severe distortions above +51 dBmV which cannot be cancelled.

These two configurations were rerun with the output levels held at +51 dBmV. Figure F shows the additional system performance advantage under this condition.

System cost analysis was done by computing system cost savings by using higher distribution levels and comparing with a standard system. The increased cost of the complex feedforward module was estimated and subtracted from the system cost saving. These values are listed in Figure G. The bridger seems to be the only contributor to real cost savings, and is probably the easiest to implement. While the other combinations appear to be quite expensive, they do contribute to significant performance improvements. It is these improvements versus cost factor which must be weighed against system objectives.

SYSTEM PARAMETER	MINIMUM SYSTEM SPECIFICATION
1. 30 channel crossmodulation	-51 dB
2. 30 channel carrier-to-noise	-44 dB
3. 30 channel 2nd order	-60 dB
4. 30 channel composite 3rd order	-55 dB

TABLE D. "TYPICAL CATV SYSTEM SPECIFICATIONS FOR A (20 TRUNK/1 BRIDGER/2 LINE EXTENDER) CASCADE"

Configurations	Trunk	1 Port Bridger	Line Extender	Distribution Level Change
Standard	28/30/32	43/45/47	43/45/47	0
FF Trunk Only	28/30/32	44/46/48	44/46/48	+1
FF Bridger Only	28/30/32	45/47/49	45/47/49	+2
FF Line Extender Only	28/30/32	47/49/51	47/49/51	+4
FF Trunk & Bridger	28/30/32	46/48/50	46/48/50	+3
FF Bridger & Line Ext.	28/30/32	53/55/57	53/55/57	+10
FF All Modules	28/30/32	54/56/58	54/56/58	+11

FIGURE E. SYSTEM OUTPUT LEVELS IN dBmV

DISTORTION PARAMETER	ORIGINAL SYSTEM PERFORMANCE OBJECTIVES	FEED FORWARD IN BRIDGERS & LINE EXTENDERS	FEEDFORWARD IN ALL MODULES
30 channel cross modulation	-51 dB	-59.8 dB	-64.1 dB
30 channel carrier to noise	-44 dB	-45.9 dB	-45.9 dB
30 channel 2nd order	-60 dB	-64.7 dB	-68.9 dB
30 channel composite 3rd order	-55 dB	-63.1 dB	-69.3 dB

1. Specifications based on 20 trunk/ 1 bridger/ 2 line extenders.
2. System output levels

   Trunk = (28/30/32) dBmV

   Bridger = (47/49/51) dBmV

   Line extender = (47/49/51) dBmV

FIGURE F. ADDITIONAL SYSTEM PERFORMANCE ADVANTAGES FOR FEEDFORWARD CONFIGURATIONS LIMITED TO +51 dBmV

CONFIGURATIONS \ COST FACTORS PER MILE	SYSTEM COST SAVINGS W/FF	SYSTEM COST FOR FF MODULES	NET COST TO SYSTEMS
Standard	0	0	0
FF Trunk Only	-$17	+$52	+$35
FF Bridger Only	-$45	+$34	-$11
FF Line Extender Only	-$88	+$184	+$96
FF Trunk & Bridger	-$65	+$86	+$21
FF Bridger & Line Ext.	-$100	+$218	+$118
FF All Modules	-$100	+$270	+$170

FIGURE G. SYSTEM COST ANALYSIS PER MILE

SUPER TRUNK LEVELS	20/30/32	33/35/37	38/40/42	dBmV
XM	-87	-77	-67	dB
C/N	-46	-51	-56	dB
2nd O	-78	-73	-68	dB
C/TB	-88	-78	-68	dB

FIGURE H. FEEDFORWARD SUPER TRUNK ANALYSIS BASED ON 20 AMPLIFIER CASCADE

Feedforward amplifier techniques seem to be ideally suited for long super trunk applications. If feedforward were used in a super trunk system, the results in Figure H might be expected for a 20 amplifier cascade. The object of this is to improve the carrier to noise ratio enough so that the super trunk is transparent to all distortion parameters. The cost increase for a feedforward super trunk station is estimated to be 30%.

CONCLUSION

This paper has summarized the economic and performance factors associated with feedforward type amplifiers. The economics of the FF system configurations presented in this paper may seem on the surface to imply that a FF amplifier is too costly to incorporate into CATV distribution systems. This is basically true if you only consider the initial amplifier costs associated with such a system. The increase in system performance with a FF type system is worth considerable attention when you consider other system factors such as:

1. Increased customer satisfaction associated with better pictures quality.
2. Increased system performance tolerances over temperature.
3. Lower system maintenance associated with a lower number of active devices per mile.

The increased cost of the FF amplifiers must be carefully weighed against the system advantages listed above. It is very difficult to assign a dollar value to these system advantages. Since the primary function of a cable system is to provide a service to its customers, we must assume that by increasing the quality and reliability of the service, that the final result will be increased revenues.

The degree to which these amplifiers will be used in the near future will be a function of the system operators requirements. The FF super trunk applications seems to be the first logical approach for FF amplifier modules. The next step may be to develop a FF bridger module which is compatible with existing bridger modules. In this manner, the operator can drop in a FF bridger in his existing system and improve the performance of his system at a very nominal cost.

In summary, the FF amplifier has definite system advantages over conventional type amplifiers.

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