RETURN SYSTEM SWEEP/BALANCE AND MAINTENANCE

Jonathan R. Ridley

GENERAL INSTRUMENT CORPORATION/JERROLD DIVISION

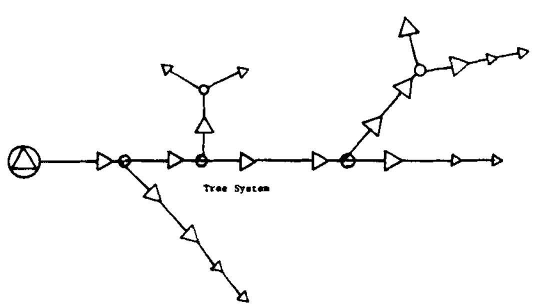
ABSTRACT

With the greater importance of bi-directional video and data transmission in today's cable systems, there now is a greater need for accurate and repeatable set-up procedures and sweep and balance techniques for both the forward and return systems.

This paper will discuss a particular method of return system testing, which will allow for rapid and repeatable system testing. The methodology will be consistent with accepted good engineering practices, so as to afford the operator the assurance of quality test results. The method is cost effective from both the test equipment cost standpoint as well as labor utilization.

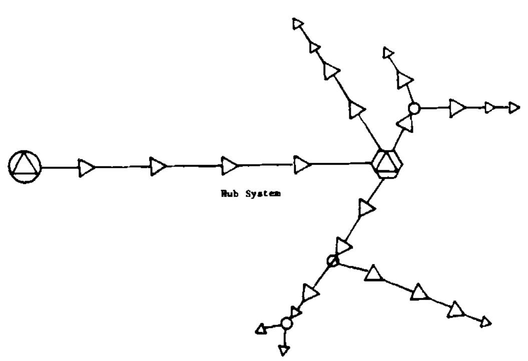
THE STRUCTURE OF THE FORWARD SYSTEM

The basic cable system design performs a dispersal function, whether the historical tree (Figure 1):



(1)

or the hub concept (Figure 2) is utilized.



(2)

In either system, the signals are dispersed to the subscribers from a source, by way of directional couplers (power/voltage dividers). In the forward system, we pay little attention to the impact of uneven directional couplers (voltage/power dividers) other than improving the economy of design.

The system is designed in the trunk or transportation portions around the unity gain concept. That is, the amplifiers are there to make up for losses incurred; external cable and passive losses, or other internal flat losses. A simplistic description of the unity gain concept is as follows:

$$\frac{\text{All losses}}{\text{Gain}} = 1 \tag{3}$$

This is also sometimes called a zero gain system.

The exception to the unity gain concept in the coaxial cable system is the function performed by the Bridging Amplifier. The Bridging Amplifier is used to elevate the signals above that of the trunk system. This is used to acquire the levels for the distribution system which will allow for design efficiency and cost effectiveness. This is the only place in the system where amplifier gains exceed system losses. In the distribution portions of the system, the unity gain concept is utilized with the line extender amplifier's gain compensating for cable and passive losses.

One of the more critical areas of concern for a unity gain system design and operation is cable equalization over the design bandwidth of the system. In both the forward and return system, correct equalization establishes passive slope correction for cable attenuation. This slope correction ensures consistency and predictability of signal levels to the amplifier. In other words, equalization is used to reestablish the proper relationship of the discrete signal levels across the entire bandwidth of the system. With predictable signal levels and known amplifier performance specifications, i.e. gain, noise figure and output capabilities, the optimum system operating levels can be calculated to acheive desired system performance.

Two distortions, noise, a power function, and composite-triple-beat (CTB), a voltage function, will be the primary offenders to picture quality and, therefore, will be the determinents in developing the operating levels in today's multi channel systems. Both of these distortions are predictable in the cable system and predictability is based on data supplied by the amplifier manufacturers.

We will now establish single amplifier and system carrier-to-noise (C/N) and carrier-to-composite-triple-beat (C/CTB) ratios at normal operating levels from manufacturers' specifications.

Manufacturers' Specifications for Trunk System

Operating Gain = 25 dB
Recommended output level = +32 dBmV
Noise Figure = 7 dB (4)
Composite-triple-beat at operating level = 84 dB
System cascade = 20 Amplifiers

Carrier-to-Noise

Carrier-to-Noise in dB is a function of the amplifier's noise figure and gain expressed as a ratio of the carrier level to the noise level in dBmV across a specified bandwidth. To relate amplifier noise figure to the carrier noise ratio, the following formulas are needed:

C/N = CO - NO
NO = -59.2 dBmV + NF + G
C/N = CO -(-59.2 + NF + G)
C/N System = CO -(-59.2 + NF + G) -10 Log N (5)

Where:

C/N = Carrier-to-Noise in dB
NO = Noise output in dBmV
CO = Carrier output level (6)
IL = Input Level
NF = Noise Figure
G = Gain
N = Number of similar amplifiers in cascade

System noise figure is as follows:

NF system = -59.2 dBmV + (C/N -CO) + G (7)

An example of Figure 5 would be:

C/N = COL -(-59.2 + NF + G) -10 Log N (8)

Where:

NF = 7 dB
COL = 32 dBmV
N = 20
G = 25 dB
C/N = 32 -(-59.2 +7 +25) -10 Log 20
C/N = 46.2 dB

An example of Figure 7

NF System = -59.2 dBmV +(C/N -CO) + G (9)

C/N = 46.2 dB
C/O = +32 dBmV
G = unity or 0

NF System = -59.2 +(46.2 -32) + 0
= -59.2 + 14.2
= dB
NF System = -45 dB

Carrier-to-Composite Triple Beat

Carrier-to-composite triple beat is a function of the operating level of the amplifier and its linearity expressed as a ratio of the output signal level to the output level of all third order distortion products expressed in dB.

Predictability of CTB in cascade is as follows:

C/CTB cascade = C/CTB single amplifier at operating levels -20 Log N (10)

Where:

C/CTB single amplifier = the predicted CTB at operating levels
N = the number of similar amplifiers in cascade

An example of Figure 10:

C/CTB cascade = C/CTB single amplifier at operating levels -20 Log N
= 84 dB -20 Log 20
= 84 dB -26
C/CTB cascade = 58 dB

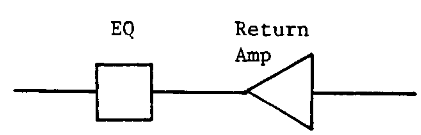
THE STRUCTURE OF THE RETURN SYSTEM

The return system, unlike the forward, is a collector of all information being directed to a focal point; most often the headend. Because of the collection requirements, the use of eneven power/voltage dividers is not recommended. However, economic system design often does not permit this. Similar to the forward system, the return system utilizes the unity gain concept. However, unlike the forward system, which uses pre-equalization almost exclusively, there are two schools of thought on return system equalization. They are:

1. Post-equalization
2. Pre-equalization

Both methods are equally valid. However, there has been much ado concerning the impact of post versus pre-equalization on the system noise figure. Refer to Figures 11 and 12 for an evaluation of Post-equalization.

Post-equalization Block Diagram:



(11)

Where:

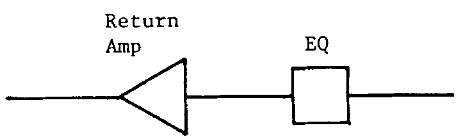
Equalizer loss = 3.6 dB
Cable loss = 6 dB
Input at Amp = 17 dBmV
Gain = 17 dB
Output level = 34 dBmV
Number of return amps = 208

Solve: NO, C/N SA, C/N return system NF return system.

NO = -59.2 + NF + G
= -59.2 + 7 + 17
= -35.2 dBmV
C/N SA = CO - NO
= 34 -(-35.2)
= 69.2 dB
C/N system = 69.2 -10 Log N
C/N = 46 dB

NF system = -59.2 + (C/N system - C/O) + G
= -59.2 + (46 -34) + 0
NF system = -47.2 dB

Pre-equalization Block Diagram:



(12)

Equalization loss = 3.6 dB
Cable loss = 6 dB
Input level = 17 dBmV
Gain = 17 dB
Output level = 34 dBmV
Number return Amps = 208
NF = 7 dB
C/N single amplifier (SA) = 69.2 dB
C/N return system = 46 dB

NO = -59.2 + NF + G
= -59.2 + 7 + 17
= -35.2
C/N SA = CO - NO
= 34 -(-35.2)
C/N SA = 69.2 dB
C/N system = 69.2 -10 Log N
C/N = 46 dB

System noise figure is as follows:

NF system = -59.2 + (C/N -C/O) + G
= -59.2 + (46 -34) + G
NF system = -47.2 dB

It has become obvious that the system noise figure does not change. The only change that can take place is variations in C/N as related to output level. The placement of the equalizer has no impact on the system's noise figure.

Distortions in the return system add exactly as they do in the forward system. Due to bandwidth and resulting limited channel capacity, composite triple beat is not a limiting distortion in the return system. Instead, we find that discrete third order beats, second order beats, and inter-modulation distortions are the limiting distortions.

The manufacturers' specification for discrete third order (B^3) and inter-modulation distortion (IMD) are obtained from data sheets. The formula for third order distortion predictability is:

Cascade B^3 distortion = single amplifier B^3 -20 Log N (13)

Where:

N = the number of similar amplifiers in cascade

For second order beat (B^2) predictability in the cascade, we use the following formula:

Cascade B^2 distortion = single amplifier B^2 -10 Log N (14)

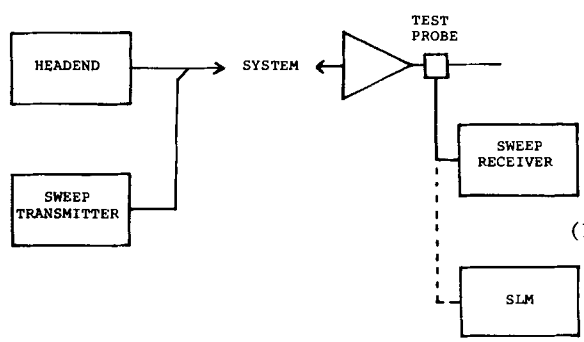
Where:

N is the number of similar amplifiers in cascade

FORWARD SYSTEM SET-UP AND SWEEP/BALANCE

The alignment of modern cable systems must be accomplished through the use of sweep/balance techniques, if the system "flatness" performance that the equipment is capable of achieving is to be realized. System flatness, typically expressed as peak-to-valley, is the measurement of deviations from ideal or design in dB. Sweep/balancing techniques enable the system's engineer or technician to see the effect each alignment control has on the amplifier's response across its entire operating bandwidth. This technique, on an individual basis, allows the operator to fine tune each amplifier in cascade for maximum system flatness.

The set-up and sweep/balance is a straightforward procedure.



(15)

The technician should exercise care in the injection of the sweep signal into the system. Validation of headend levels and sweep response should be logged and photographed, if possible. This documentation of the headend system peak-to-valley is needed to allow the engineer or technician to reference cascade peak-to-valley against the headend to ascertain the real peak-to-valley of the system.

Finally, variable alignment controls within the amplifier must not be used to eliminate excessive peak-to-valley excursions at the amplifier caused by deficiencies in the cable, system's passives or poor splicing. Whenever excessive peak-to-valley excursions are observed at the output test point of an amplifier, it is recommended that the input to the station be checked after equalization, prior to adjusting the variable alignment controls within the amplifier.

Another important aspect of the system set-up, sweep/balance, and preventative maintenance is record keeping. A log should be kept of input and output R.F. levels, AC voltage, and peak-to-valley on each and every amplifier. This is to allow the service technicians to troubleshoot the system rapidly.

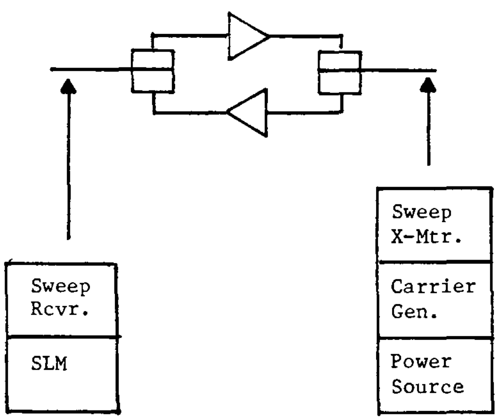
RETURN SYSTEM SET-UP, SWEEP AND BALANCE

There are two methods of setting up the return system using the sweep/balance technique:

1. From the extremities to the headend.
2. From the headend to the extremities.

Figure 16 is a Block Diagram of the test equipment required for Procedure 1:

Block Diagram



(16)

This requires the location of a sweep generator and carrier generator at the extremities of the system, where the technician would begin system alignment. The advantages of this method are:

1. The amplifiers are treated the same as the forward amplifiers.
2. The output of the amplifiers would be flat.

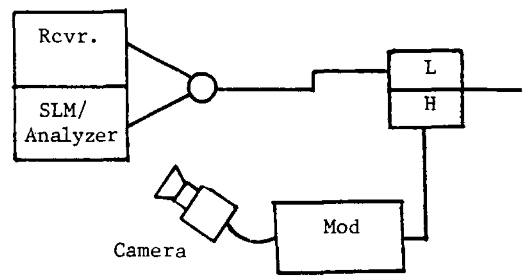
The disadvantages of this method are:

1. It is hard to repeat the set-up throughout the system.
2. Time consuming when sweep/balancing uneven power splits.
3. The expensive piece of test equipment left at the end of the system requires security and/or manpower surveilance.
4. There will be a significant increase in the required number of field calculations.

Now, let us review the second procedure for sweep/balance. This method starts at the headend working towards the extremities of the system. Figure 17 is a Block Diagram of the test equipment required for Procedure 2.

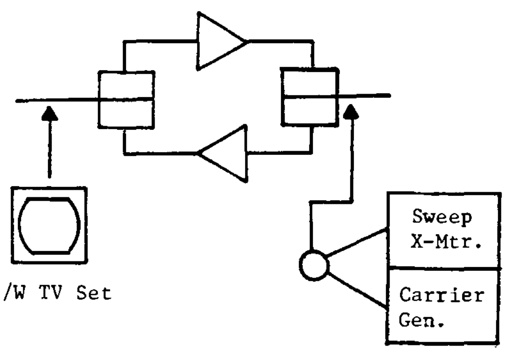
Block Diagram

Headend



(17)

System



Procedure No. 2 is a more direct approach, requiring a sweep receiver, SLM or analyzer, a black and white TV camera and a modulator at the headend, and a sweep transmitter, carrier generator, and a black and white TV set at the amplifier being swept/balanced. The technician has to set up only the correct input level at the sweep injection point to the return amplifier input and then monitor the headend levels and peak-to-valley with the black and white television set. This can be accomplished at the distribution test point or a tap in the forward system. The TV set can be battery operated and taken up to the amplifier, thus utilizing only one technician to perform the sweep/balance. Uneven power splits become unimportant with this balance technique because the system is balanced against the headend for flatness and levels rather than for the specific flatness of an amplifier.

By careful alignment of return system starting at the headend, the system can be set up for repeatable test results. If the sweep injection levels are known, any point in the system can be validated at any time by one person utilizing standard test equipment available at all newer systems. The advantages of the sweep/balance Procedure No. 2 are:

1. Repeatability of measurement.
2. Requires less manpower to perform.
3. Requires less capital equipment.
4. Allows system troubleshooting and repairs from the headend to the terminator.
5. Allows for simultaneous qualification of the return system to the terminator with forward system.
6. Reduces time in testing uneven power splits.
7. Utilizes commonly used test equipment.
8. Requires no guesswork or calculations as to levels or terminator cable or splicing integrity.

SUMMARY

It is obvious, to obtain repeatable and accurate tests of return systems during the operational life of a cable system, that the tests have to be easily accomplished, utilizing a minimum of manpower and capital equipment. The method established as Procedure No. 2 reduces the number of technicians required for return system testing as well as the risk of having unattended high-cost test equipment and vehicles at the system extremities. This procedure establishes defined input levels against defined headend input levels, thus reducing the number of field calculations to one, that is the level of 31.5 MHz at the headend from the first amp. It eliminates the mystique and mystery from return systems testing.