CALCULATION AND BALANCE TECHNIQUE FOR
A SMALLER DEDICATED RETURN LINE

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Abstract

Many systems are using or considering using a return signal path on at least a part of their normal cable system. This paper presents some of the calculations and balance techniques which may be used in setting up a smaller, dedicated line. It does not include the complex task of balancing a large fully implemented two-way system.

Techniques presented include the use of one carrier, two carriers, and sweep methods. Discussions on thermal compensation includes pilot carrier AGC and thermal equalizers. Some comments on data transmission will also be made.

Introduction

The large scale two-way systems have received a lot of publicity and indeed have been responsible for innovative designs and technology improvements. However, the majority of two-way systems in actual operation are small dedicated runs, usually from the office to the headend or similar point-to-point networks. Large systems require extensive planning, design, and sophisticated balancing techniques. The single, most troublesome, feature of two-way systems is the combining of sub-trunks. When sub-trunk returns are combined and the span lengths are different, the problem of achieving compatible levels is very difficult and leads to complex balancing procedures. Single dedicated return runs without sub-trunk returns can be balanced relatively easily in several ways. Some system calculations must be made to determine levels, equalization, and module gains.

This paper assumes that the forward system has been designed and possibly built.

System Functions

The first step is to define the system function regarding its use. Several possible conditions are listed in Table 1.

1. Single video channel
2. Multiple video channels
3. Single data channel
4. Multiple data channels
5. Combination video and data

TABLE 1 POSSIBLE SYSTEM FUNCTIONS

These operational functions will determine the bandwidth, the required stability, and possibly the balancing technique to be used. Video channels will require a more stable operation than data channels. If the cascade is short, thermal equalizers may be sufficient. On longer cascade, an AGC system may be required. Multiple video channels will require a more accurate set up than either a single channel or data-only system.

Next, determine whether to inject the return signal directly into the trunk, directly into the distribution cable, or through a directional tap.

The simplest system results when the return signal is injected directly into the trunk through a suitable directional coupler. This, naturally, eliminates the set up of the distribution line but necessitates disturbing the trunk with possible down time.

Distribution lines are much more forgiving of disturbances but will require the additional set up of line extender reverse modules. The least

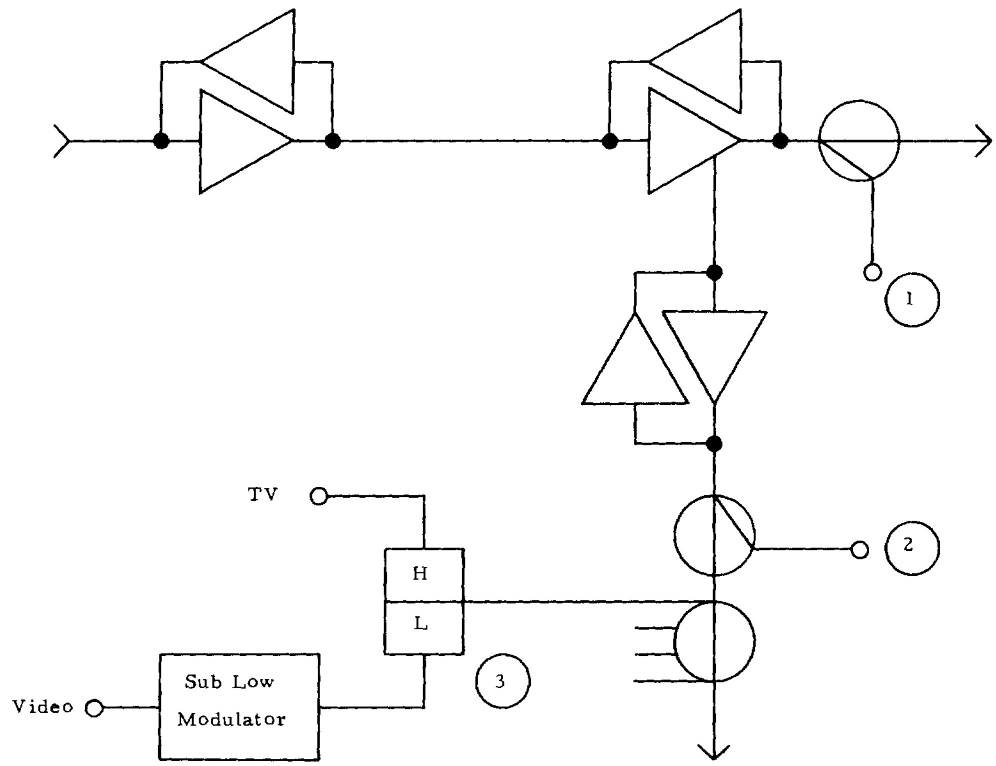

FIGURE 1 REVERSE SIGNAL INSERTION LOCATIONS

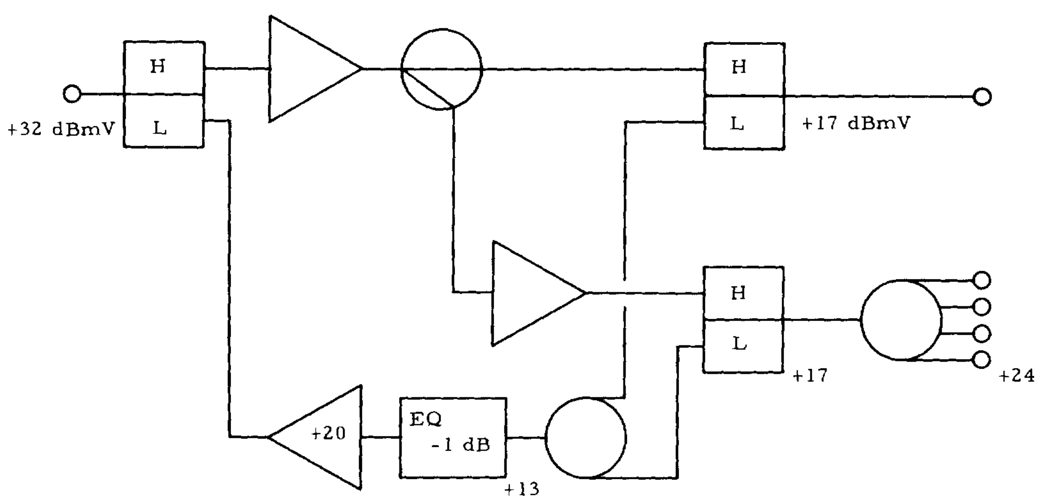

FIGURE 2 TYPICAL STATION LEVELS

system interruption occurs when the return signal is injected directly into a tap. Figure 1 shows three locations for inserting signals into the system.

Direct Trunk Insertion

Signals may be inserted into the trunk at either the first trunk reverse station or at any point in a reverse cascade. Usually if only one channel or one source location is used, the first reverse amplifier will be placed just ahead of that location. There would be no need for one placed further downstream. The first reverse module should be set for nearly maximum gain. It is common practice to leave one or two dB reserve gain for any unforseen level variations. Next, the required input level to the station must be calculated. Determine the actual operating gain and the desired output level. Desired output levels may usually be obtained from the manufacturer's data sheet. The output level minus the gain yields the input level to the amplifier module. Add to this level any combining losses, which may be built into stations, and the equalizer insertion loss, if not included in the amplifier gain. These losses mean that the input level to the station must be higher by that amount. Figure 2 shows an example of how these losses determine the input level.

The trunk directional coupler value must be determined next. To do this, the connecting cable losses and the signal source levels must be known. Calculate the cable losses at the actual reverse channel carrier frequencies, i.e., 13 MHz, 19 MHz, etc. If the signal source is a modulator, plan to operate it several dB below maximum output level to allow for level variations during actual set up and equipment aging. The directional coupler value can then be determined as the additional loss needed to meet the required input level after subtracting the cable loss from the modulator level. Typically, the coupler will be a DC-16 or DC-20. If the cable loss is relatively low, the modulator may be set near minimum output level or may even require pads to be placed at its output as shown in Figure 3.

Direct Distribution Insertion

The calculations of this method are very similar to that of the trunk insertion. The first reverse line extender module should be set just below maximum gain and the input level determined as before. Compute the cable and flat loss going into the trunk station by adding the cable loss at the carrier frequency and all distribution passives, taps, and combiner losses. Check the station block diagrams carefully for these losses. The combined cable and flat losses from the last (reverse direction) line extender to the trunk reverse module must be less than the trunk reverse amplifier gain. If it is not, the line extender reverse output level will have to be raised accordingly. Carry these levels back to the signal source to be sure that enough signal level is available. If additional level is required, use either a smaller direc-

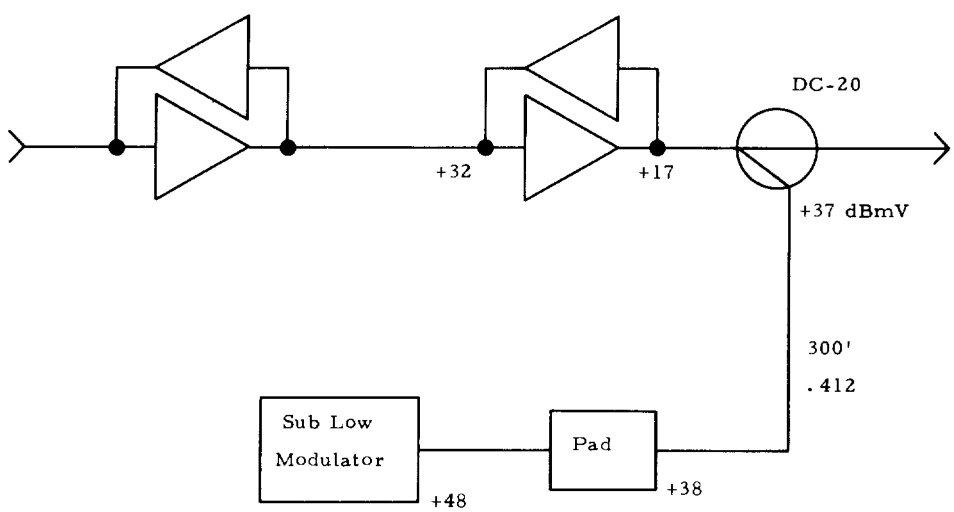

FIGURE 3 TYPICAL LEVELS FOR TRUNK INSERTION

tional coupler or additional amplification at the source. Figure 4 illustrates this method.

Directional Tap Insertion

The system calculations of this method are identical to that of the direct distribution insertion except that tap loss is considered instead of a directional coupler loss. All passives including taps must be able to pass the 5-30 MHz band. Many of the older taps and passives simply were not designed to operate at 5 MHz. Most systems which have been rebuilt or built recently will already have 5-300 MHz passives. If this is a special run where only a portion of the trunk was rebuilt for a specific reverse run, check the passives to assure they are also 5-300 MHz equipment. Replace any unit in the reverse system that does not pass 5 MHz with one that does. All modern passives that are designed to pass 5 MHz will have the same attenuation in both the forward and reverse direction. Figure 5 illustrates the tap insertion method.

System Balancing

The reverse system may be balanced in several ways:

1. Sweep
2. Meter Balance
    a) Two carrier reference
    b) One carrier-modulated

Sweep balancing is the cleanest and most accurate method. If several channels are planned or if a large part of the 5-30 MHz band is going to be used, the sweep method is certainly recommended. Connect the sweep generator at the source and set a reference as in normal forward sweep. Set sweep width for 5-30 MHz. Balancing is accomplished in the same way as in the forward direction, working from the source to the headend. The unity gain per span concept applies with this method as in the forward direction. If the reverse line extender output level must be different than the trunk output level because of more flat loss or cable loss, the sweep reference level will have to be shifted accordingly. A little thought and care will be necessary here. See Figure 6.

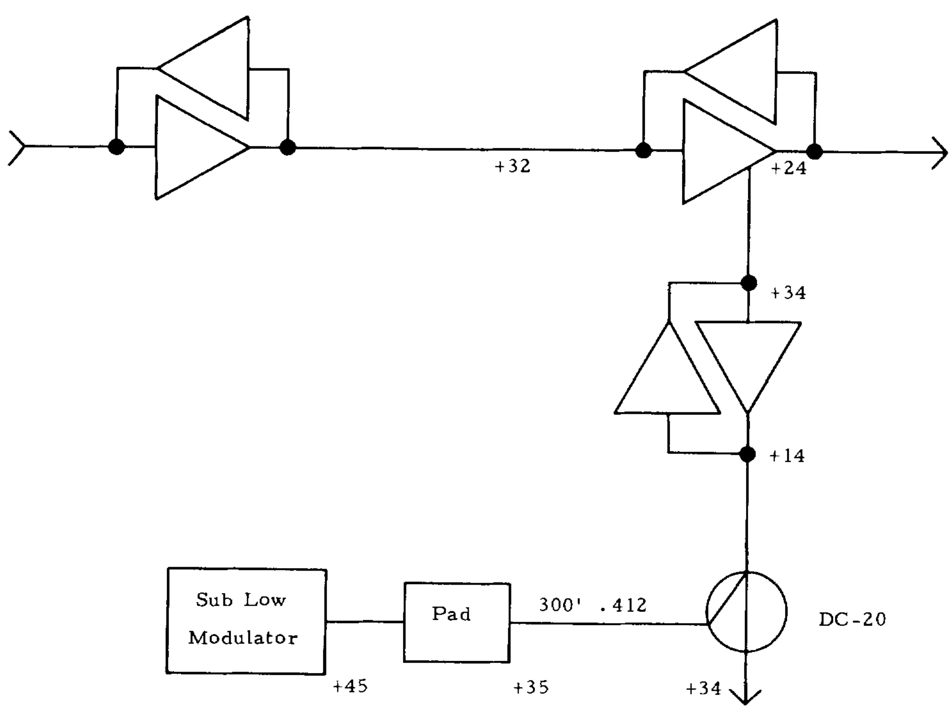

FIGURE 4 TYPICAL LEVEL FOR DISTRIBUTION INSERTION

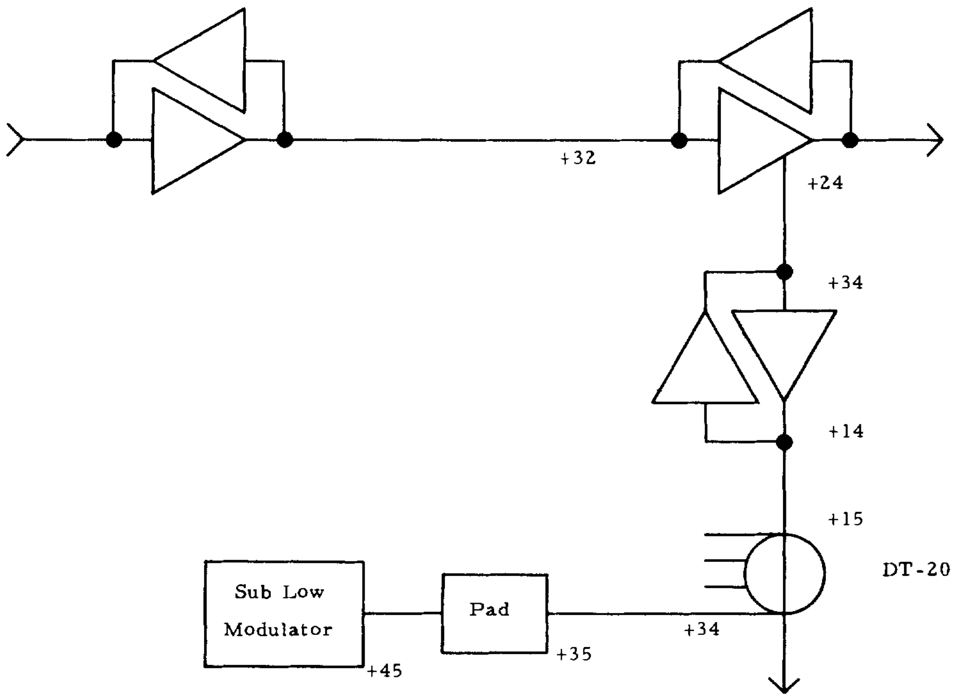

FIGURE 5 TYPICAL LEVELS FOR TAP INSERTION

Meter balancing is much easier but is less accurate. However, if two carriers are inserted so that one carrier frequency is near 30 MHz and the other is near 5 MHz, a reasonably close slope and gain condition can be achieved. A calibrated signal level meter should be used. Again, connect the signals at the source and balance upstream toward the headend. If the desired carrier is available, simply add a stable CW carrier as far away in frequency from it as possible and balance to these two. Balancing on one modulated carrier is possible, if the relationship between the video and sound carrier levels are closely maintained. This is not a desirable method due to the lack of adjustment resolution.

The actual mechanics of balancing will vary with the type of equipment used. The value of equalizers, the pivot point of the slope control if one exists, the type and location of test points, and recommended operating levels are different with each manufacturer.

Adding a Second Source

To add another source to a mid point location on a reverse system, determine the type of insertion method required, i. e., direct trunk or distribution insertion. Next, determine the input level necessary to make the new carrier compatible with the existing trunk reverse carrier. For trunk-inserted carriers, this could be taken at the input test point. For distribution sources, compatible levels would be taken at the trunk-distribution combiner as illustrated in Figure 2. Given the input levels, the remaining calculations are done as before.

Distortion Calculation

Cross-modulation calculations in cascade are made the same way as in the forward system but only for two or more channels. There can be no cross-modulation with only one channel. Any cross-modulation that does occur must be added directly to the contribution that channel will receive in the forward direction for a total cross-mod level. For example, if two reverse channels are used, compute the cross-mod for the reverse cascade based on two channels and add this to the cross-mod that each channel would normally receive in the forward direction.

To illustrate the accumulated cross-

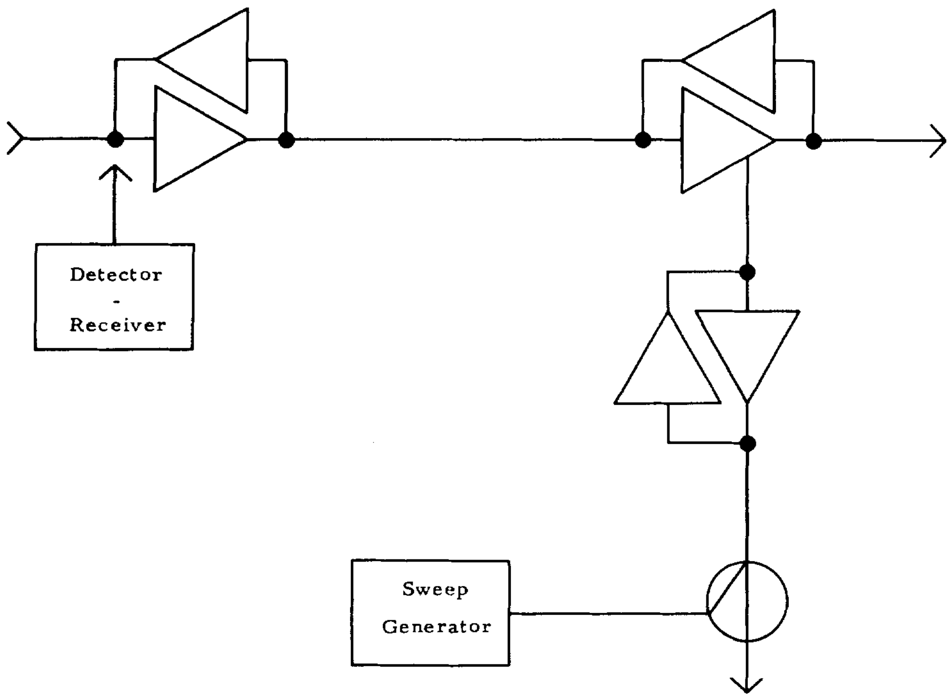

FIGURE 6 SWEEP EQUIPMENT SETUP

modulation of the reverse channels, assume that channel T9 goes through 10 reverse amplifiers, is converted to channel 6, and is sent down 20 forward amplifiers with 19 other forward channels. Assume further that channel T8 goes through 5 reverse amplifiers, is converted to channel 9, and is sent down the same forward cascade. No cross-mod would be generated in T9 from the tenth to the fifth station. Then, channels T8 and T9 would cause cross-modulation in each other through the five remaining reverse amplifiers. Compute the cross-mod of 2 channels through 5 amplifiers. A typical number might be:

-107 dB for each amplifier
+ 14 dB for five amplifiers
- 93 dB for reverse system

The forward system of 20 channels and 20 amplifiers would contribute typically:

-93 dB for each amplifier
+26 dB for twenty amplifiers
-67 dB for forward system on channels 6 and 9

The contribution of the reverse system to channels 6 (T9) and 9 (T8) is less than 1 dB, so the total system cross-mod on these two channels would be about -66 dB on the trunk.

Noise accumulation occurs in every amplifier location both forward and reverse. The total carrier-to-noise ratio is based on all amplifiers in the signal path. Since different types of amplifiers have different noise figures and different input levels, the base C/N of each station must be computed. These individual C/N are then added, through logrithms, to get a combined system C/N ratio.

To illustrate this concept, assume that channel T9 flows through 10 reverse stations and 20 forward stations. Assume C/N base numbers of -63 dB for the reverse and -59 dB for the forward stations.

-63 dB for one reverse station
+10 dB for ten reverse stations
-53 dB for T9 in reverse

-59 dB for one forward station
+13 dB for twenty forward stations
-46 dB for T9 forward

-53 dB reverse
-46 dB forward
-45 dB total

Carrier-to-noise ratio for T8 would be:

-63 dB for each reverse station
+ 7 dB for five reverse stations
-56 dB for reverse
-46 dB for forward
-45.6 dB total

Data Channels

Digital data channels such as computer links, telecommunications, or control links are handled somewhat differently from video channels. Typically, the bandwidth is from one to four megahertz and is a function of the data rate. Modulation type is usually a form of frequency shift keying (FSK) for control and computer links and pulse code modulation (PCM) for voice telecommunications. These data signals may then be applied to a high quality CATV type modulator for insertion into the cable system. Either AM or FM modulators will accept this type of modulation, but check with the manufacturer for proper operation. Some AM modulators have AGC circuits which operate from TV sync pulses and may be easily fooled by the lack of sync pulses in the data stream. FM modulators tend to have wider bandwidths than AM modulators, so carrier frequencies must be selected carefully to avoid interference.

Carrier-to-noise ratios are less critical on data carriers than on TV carriers. Data carriers are usually carried 10 dB below adjacent TV carriers to reduce any possibility of distortion to the TV carriers. If the reverse system is to carry data channels only and no video carriers, the data channel may be operated at normal system operating levels.

Conclusion

The two areas of consideration that must be carefully thought through is the calculation of signal levels at every stage in the cascade path and the unity gain balance points. Single channel systems are less critical of the actual operating level, but the trunk and distribution levels must be made compatible. Pay close attention to levels near the modulator to be sure that the modulator can supply sufficient level. Balancing techniques may have to allow for a difference in distribution and trunk return levels. This will be more difficult with sweep than with meter balancing. Good prior planning and forethought will prove invaluable.