FAILSAFE TECHNIQUES

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Techniques for maintaining distribution system continuity in the event of mechanical or electrical failure are discussed. The probability of various types of failure are considered, and various means of dealing with different types of failures are evaluated. Such means include backup devices, redundant devices, and amplifier bypass networks of several types. Amplifier bypass techniques are considered in more detail, including choice of switching devices, means of controlling the bypass function, and system performance under bypass conditions.

INTRODUCTION

This paper is concerned with provisions for keeping a CATV distribution system in operation in the event of electrical or mechanical failure. We will concern ourselves with outside plant only, between the headend and the subscriber drop, and primarily with trunk amplifiers.

With traditional entertainment services, any downtime is certainly not to be taken lightly, but with expanded premium services, and especially with the growth of data communication service, keeping the system in operation in all circumstances has become crucial.

TYPES OF FAILURE

To consider how to deal with failures, we need to list the possible range of events to be contended with. For some interruptions there is little that can be done other than repair the damage. Examples are a cable severed by fire, storm, or accident, or a direct hit by lightning.

Here are some events which result in an interruption of service, for which failsafe provisions might be made. They are arranged in a rough order of decreasing probability:

1. Loss of AC power at an amplifier station.
2. Loss of DC power at an amplifier station.
3. Electronic failure in an amplifier active device.
4. Mechanical failure in an amplifier active device.

Another event might be added to this list. It is:

5. Interruption for service reasons, e.g. removal of module for test or replacement.

This last item is not normally considered a failure, but a means of avoiding outage for this reason would be useful.

Event #1, of course, causes Events #2 and #3. In recent years, standby power supplies have come into wide usage despite their cost and complexity. Any device intended to improve system reliability must itself be extremely reliable, and a standby supply, with its sophisticated electronics, is a potential point of failure, but many consider standby supplies to be essential.

POWER FAILURE

Perhaps the most common failure in current distribution equipment is loss of station DC power. Transformers and rectifier circuits generally are very rugged in today's amplifiers. The electrical and economic requirements on regulator circuits, e.g. efficiency, put some limit on the degree of ruggedness which can be achieved.

A backup DC regulator is sometimes used, in a configuration which switches it into operation in case of failure of the primary regulator. It is desirable to have this condition reported by a status monitoring system, so that the failed regulator may be replaced.

RF FAILURES

Failure within the RF circuitry is more difficult to deal with. There are many possible points of failure. Fortunately, the active devices themselves have become much more reliable since the early days of the CATV industry, and many consider modern hybrid integrated circuits to be essentially the most reliable element in the system. The associated passive components are highly reliable, but the large number of interconnections made necessary by the requirements of modularity are associated with occasional mechanical failure. It is very difficult to guard absolutely against an occasional cold solder joint or a loose piece of wire.

A less severe kind of interruption is the one caused by deliberate removal of a module for service reasons. Of course, the module might have been removed because it had failed completely. But if the amplifier was operating in a degraded manner, the immediate, if temporary, result of removing it is a castatrophic failure. System continuity in this case would be a benefit.

How should these possible events be dealt with? In general, it is desirable to provide an alternative for any system element which is prone to failure. In the extreme, this leads us to dual cable systems, separately powered, but we want to stop short of this. We will restrict our attention to the amplifier stations, primarily trunk amplifiers.

REDUNDANT AMPLIFIERS

Redundant amplifiers, run in parallel with 3 dB splitters at the input and output, are sometimes used, as shown in Figure 1. Failure of one amplifier causes a 6 dB drop in signal level, but no protection against power failure is achieved. There are several other important factors to be considered with hot redundancy: power consumption and heat dissipation are increased; distortion is reduced, since each amplifier runs 3 dB lower in level; and noise figure is slightly worse, by about 0.5 dB, due to non-ideal splitters.

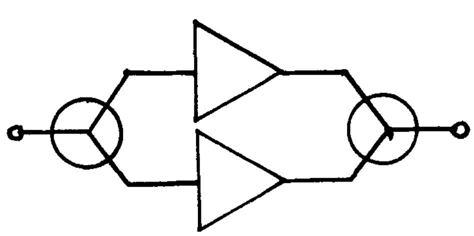

Figure 1. Redundant Amplifier

BYPASS TECHNIQUES

The technique to be discussed at some length here is in effect to remove a failed trunk amplifier from the system and replace it with a jumper cable. This must, of course, be done electrically and in some way automatically. See Figure 2. The bypass might be done separately for the forward and reverse amplifiers, but this would remove the trunk filters from the bypass network. The bridger amplifier and reverse feeder circuitry might also be bypassed, although there are pros and cons here.

The approach to be described here is to bypass as much of the RF path within the trunk station as possible. This is done with double throw switches at the input and output of the station. The AC power through the station is not switched, as this path has a relatively low probability of failure, and switches designed for 60 Hz power do not readily lend themselves to UHF RF transmission.

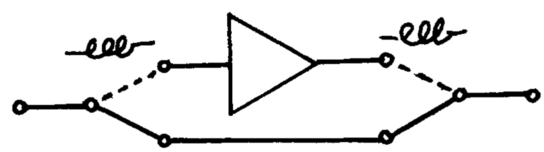

Figure 2. Amplifier Bypass

CHOICE OF SWITCHES

It goes without saying that the switches themselves must be highly reliable, if this circuitry is to enhance the overall system reliability. There is another hazard; the bypass circuitry constitutes a potential feedback path around broadband RF amplifiers. This requires that the switch isolation in the normal mode of operation be very good, since even small amounts of uncontrolled feedback can cause amplitude distortion in the transmission.

What sort of switches are to be used? Diode switches would seem to be the preferred way to switch broadband RF paths. However, this system must work in the absence of AC or DC power. This would require a battery or perhaps a large capacitor as a backup bias source. This is a major, but not insurmountable, problem, but there are other factors which weigh against diode switches.

The potential distortion which diode switches might add to the system is a potential problem, but one which is predictable and manageable. The requirements for a backup bias source favors low bias currents, which are generally imcompatible with low distortion. A more serious potential problem is the surge susceptibility of a semiconductor diode located directly at the input and output of the amplifier station.

A major factor in the improved electrical ruggedness of today's amplifiers is the fact that the active devices are well buffered from the input and output. Pushpull circuits with transformer coupling and two way filters contribute to this buffering. The station input and output, which is where the bypass switches should be located, are very hazardous locations for bandswitching diodes.

This brings us to electromechanical devices, which have the proper power-down state, are not likely to contribute distortion, and are relatively immune to surges. Of course, as system frequencies move into the UHF band, the relay must be carefully chosen. Preferred devices are those designed specifically for RF operation for frequencies in this range.

BYPASS CONFIGURATION

A pair of double throw relays, as shown in Figure 2, form a basic failsafe bypass configuration. In the simplest mode of operation, the relay coil is operated by the station's DC power, so that when the DC power is down for any reason, the station is bypassed. A more sophisticated means of control of the switches will be described later.

In Figure 3, several of the elements of a real trunk amplifier station are added, specifically two way filters and reverse amplifier, and the AC power network.

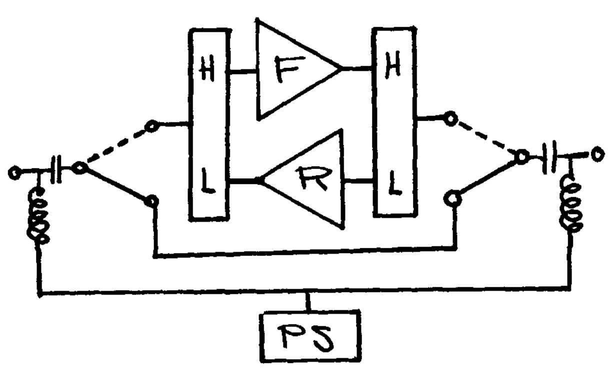

Figure 3. Trunk Station

In Figure 4, a bridger amplifier has been brought into the picture and for simplification, two way filters are not shown. In this situation, the bridger amplifier can also be bypassed, with an additional switch. Of course, the bridger amplifier could be separately bypassed with a pair of switches, but the complexity grows rapidly. In the simpler version, a splitter is incorporated into the bypass network, to maintain continuity to the feeders. Note that this increases the loss in the trunk path when the bypass is active.

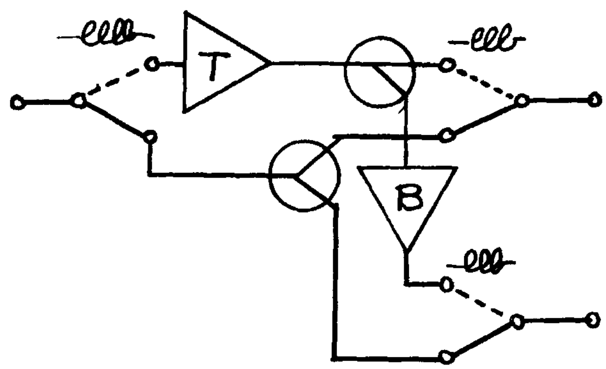

Figure 4. Trunk/Bridger Bypass

If a bridger amplifier is to be bypassed, then the line extenders in the corresponding feeder lines might be bypassed as well. A choice is at hand, whether to degrade the trunk performance in the interest of keeping continuity to the feeders. Signal level considerations, to be discussed later, suggest that the trunk ought to be maintained at the expense of an individual bridger service area.

STATUS MONITOR

If the switches are controlled by the station DC supply, then the bypass is automatic, in the power down case. To deal with other types of failure within the amplifier, a status monitor system is essential. The system must be capable of causing the bypass switches to be activated under remote control. It must be configured so that a failure which would require the failsafe system to activate does not disable the status monitor system which controls the switches! Figure 5 indicates the proper configuration. The signal pickoff for the status monitor receiver must be put upstream from the switches and station. This allows communication and control to be maintained in the event of failure of the forward amplifier.

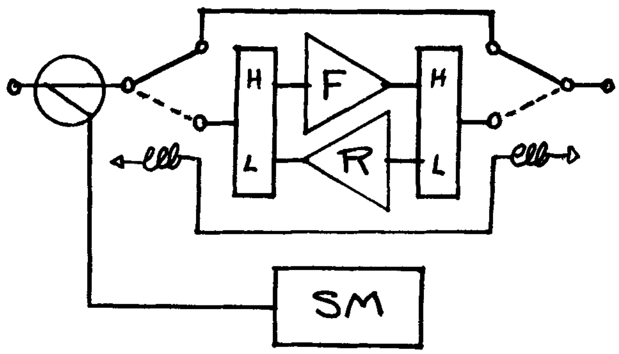

Figure 5. Status Monitor Connection

SYSTEM PERFORMANCE IN BYPASS

What happens to system performance if one trunk amplifier in a long cascade is bypassed? The gain of that station, of course, drops to a bit less that 0dB. If we consider a trunk spacing of 21 dB at 450 MHz, the bypass will drop signals by about 21 dB, but that is only at the 450 MHz. At 50 MHz, the spacing is only about 7 dB. The succeeding AGC/ASC amplifiers will pull the signal levels back up to normal levels, providing some reserve gain is available in the amplifiers, which is normally the case. The carrier to noise ratio will, of course, suffer because of the low input levels, but nowhere near the 7 to 21 dB which might be suggested by the localized loss in level.

Frequency, MHz	50	200	450
Cable Loss, dB	7	14	21
Normal Amplifier Gain, dB	7	14	21
Amplifier Noise Figure, dB	9	9	9
Normal Input,dBmV	10	10	10
Reserve Amplifier Gain, dB	4	3	2
Number of Amps to Recover Normal Signal Level	3	6	12
C/N at Point of Level Recovery, dB	51.1	43.1	34.7
Normal C/N at This Point, dB	55.2	52.2	49.2

Table 1. System Performance in Bypass

Table I indicates the results of carrier to noise calculations for a case in which the first amplifier in a cascade is bypassed. The table indicates 3 frequencies, with the normal spacing and reserve gain for each. The number of succeeding AGC/ASC amplifiers needed to restore normal levels is shown, along with the resulting carrier to noise at the point of restoration, as well as the normal C/N at that point. Note that in the low band the degradation from a station bypass is very much localized. In a failsafe system, the most essential services, e.g. data communications, should be located at the lower frequencies.

FEEDER LINES

Bypass circuitry could be provided for line extenders. But level recovery is not feasible, since line extenders are not normally cascaded more than 2 or 3, and AGC line extenders are relatively uncommon in any event. If as mentioned above we consider AC failure to be a major reason for failsafe circuitry, line extenders will go into bypass at the same time as the trunk station which feeds them AC, as well as, RF goes into bypass. This requires putting additional loss into the trunk bypass path, as shown in Figure 4. It would appear that it is preferrable to sacrifice the feeders for a given bridger service area in the interest of maintaining the trunk as clean as possible.

CONCLUSION

System continuity in event of failure may be maintained by a variety of techniques. It is important to determine the probability of the types of failure to be dealt with, and establish what action is to be taken for different types of failure.