CATV SYSTEM RETURN PATH INTERFERENCE

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The usefulness of a viable return signal path associated with an existing forward system signal distribution system is of greater value now than ever before. With this objective in mind it seems worthwhile to review some of the established methods which have been designed to make this objective a technical reality as well as to offer a recently developed technique which will prove to be a valuable addition to any two way system maintenance program.

This new technique was developed to combat COMMON PATH DISTORTION which is a relatively recent addition to the list of distortions which occur in bidirectional cable systems. When the conditions exist in a system that cause this distortion, interference is generated by the forward system signals which impacts the return system frequency spectrum. This potentially interfering energy is ofen misidentified as ingress when the return system is viewed on a spectrum analyzer. The mechanism which causes this distortion and a method to isolate this system problem will be described in detail.

INTRODUCTION

One of the most burdensome problems associated with a bidirectional cable system is the disruption caused by ambient radio frequency energy which enters the system and interferes with the desired return path signals. It is this permeation of undesirable energy, referred to as "Ingress", that has been the subject of exhaustive studies which have been undertaken to define the exact mechanisms that allow this condition to occur and to establish guidelines that can be followed, by those affected, to minimize this problem.

The results of the completed studies indicate that a single qualifiable and quantifiable parameter controls the acceptability of the components, that are used to construct a bidirectional cable system, if they are to provide the necessary shielding required to maintain the return frequency spectrum available for use by the system operator. This parameter, which is called Transfer Impedance, is defined as the opposition to the flow of radio frequency current. Typically, the more resistance or impedance a system component, relied on for shielding, offers to the flow of radio frequency current, the poorer its performance will be as a shield against external energy fields.

Solid aluminum outer conductor cable provides excellent shielding over the frequency spectrum of interest to the cable television industry. It has a uniform and acceptable transfer impedance provided the outer conductor is not violated by a crack or a hole. Therefore, if quality cable and good construction techniques are used, then the majority of the system in terms of physical length will provide adequate shielding. However, the requirement to splice into the cable necessitates cutting the cable and the introduction of connectors and an equipment housing. This is typically when potential ingress problems start. If the connection to the cable by the connectors, the connectors to the housing and the housing itself do not provide a low transfer impedance, then ingress will result.

RADIO FREQUENCY CURRENT DENSITY

The increased surface area of connectors and equipment housings brings a second condition into play which is referred to as current density. Due to the fact that the connectors and housings provide a greater surface area, relative to that of cable, on which the radio frequency current can flow, a slightly higher transfer impedance can be tolerated without degrading the shielding provided by the cable.

EQUIPMENT SUPPLIED TO THE INDUSTRY

In order to minimize the transfer impedance of their equipment, manufacturers have made significant modifications to their products. Integral sleeve connectors, for example, were introduced to eliminate the problem of cable sheath cold flow and vibratory manipulation sustained by the cable sheath inside of the connector. Also, close attention has been given to the housing interfaces. Wire mesh gaskets and other conductive materials are supplied with the primary purpose of minimizing ingress into the equipment housings. Some vendors have gone a step further by constructing the modules that the housing contains so that they will provide adequate shielding without the housing. This is accomplished by using wire mesh gaskets between the module frames and covers.

In spite of the efforts made, ingress still presents a problem. Inordinate ambient field intensities prove to be a challenge. Also, the ravages of vibration and thermal cycling necessitate a constant maintenance effort. Fortunately, there are some methods that have been developed to locate the sources of inadequate shielding.

METHODS TO LOCATE AND MINIMIZE INGRESS

One technique utilizes the forward signal path to transport a test signal to all extremities of the system. A receiver is then used external to the system to monitor the test signal frequency. The rationale behind this technique is that if the test signal can leak out then external energy can leak into the system. The opposite method is also used which entails generating an electromagnetic field external to the system and monitoring the return path culmination point for the presence of this signal. Both of these methods have gained wide acceptance.

A more recent addition to the arsenal of the two-way system operator is return feeder switching which offers two opportunities. The first, from an operations standpoint, is that only the feeder systems requiring continuity at a given interval of time can be switched on, thereby minimizing the magnitude of the ingress. Also, from a maintenance standpoint, the feeder systems which permit unwanted energy to disrupt return path service can be identified by switching each feeder system on,one at a time, and monitoring for the magnitude of the ingress present at the return path culmination point. Both of these locating techniques and return feeder switching provide system maintenance personnel with reasonable means by which they can locate sources of ingress.

ANOTHER SOURCE OF RETURN SYSTEM INTERFERENCE

Unfortunately, there is another problem that affects two-way system operation which is relatively unknown. While ingress is associated primarily with the integrity of the outer conductor, this phenomenon is associated with both the outer and the inner conductors. The parameter of transfer impedance that was directed toward the outer conductor must now be considered with respect to both conductors. In addition, the linearity of the transfer characteristic as well as the magnitude of the impedance are important. This phenomenon is referred to as Common Path Distortion.

Common path distortion is a collective term which includes all beat products which are generated within a cable system, that fall in the return path frequency spectrum, excluding the beat energy which is generated by active components. This distortion is caused by a connection which has a nonlinear transfer characteristic. This condition typically develops when two metal members are not making intimate metal to metal contact and an oxide layer develops between them. It is this oxide that causes the nonlinear energy transfer. The beat energy generated that falls in the return system spectrum results when the forward system signals pass over this connection. Obviously, this unwanted energy which occupies the return system can be as troublesome as ingress. It is not suprising that when the return system is displayed on a spectrum analyzer, common path distortion is often misidentified as ingress. For this reason the expression "apparent ingress" has evolved. However, once the nature of this distortion is understood it is relatively easy to determine if common path distortion exists in a system. This is accomplished by inspecting the return system frequency spectrum, as displayed on a spectrum analyzer, for a comb of beat products spaced at six megahertz intervals while the forward signals are being transported by the system. The 6 MHz spacing observed between the return system beat products is due to the spacing of the forward system carriers.

COMMON PATH DISTORTION LOCATING TECHNIQUE

Due to the hetrodyning which occurs at an interface which has a nonlinear transfer characteristic, it is logical to assume that if one of the signals that is applied in the forward direction is coded in some way so as to indicate time interval, then distance could be calculated.

As it turns out this desirable capability can easily be acomplished.

If a continuous wave signal source is modulated by a short duration pulse and this signal is applied to the forward system along with the normal signal load, then the first requirement for a locating technique has been accomplished. Because if a common path distortion generator exists in a system of sufficient severity to cause return path interference, then the beat energy will be modulated with the timing pulses that are being sent out on the system in the forward direction. Therefore, if a receiver is connected to the return path at the same location as the forward pulse modulated signal is applied, then a time difference can be established between when the pulse was received relative to when it was transmitted. Obviously, one half of the total time gives the travel time to the source of the distortion. The conversion of travel time to physical distance can be accomplished by using the following formula:

$$D = T \bullet 984 \bullet VP$$

Where - T is the travel time in microseconds

D distance in feet

VP is the velocity of propagation of the cable

The test equipment required to apply the described technique is determined by the degree of accuracy and resolution that are desired when locating the nonlinear transfer points in a system. Basically, the narrower the modulating pulse is in terms of time the more sophisticated the equipment must be. An important consideration to keep in mind is that the usage of narrow pulse widths which have very fast rise and fall times can lead to subjective impairment of the forward system signals if steps are not taken to minimize interference.

The pulse width and resolution relationship is best explained by converting pulse width expressed in units of time to physical cable system length. A close approximation of this relationship can be seen in the following table.

PULSE WIDTH	PHYSICAL SYSTEM LENGTH
1000 nanoseconds	1000 feet
100 nanoseconds	100 feet
10 nanoseconds	10 feet
1 nanosecond	1 foot

The importance of using the narrowest pulse width possible can readily be appreciated when two sources of common path distortion are physically located close together. If, for example, the distance between two sources was twenty feet then a pulse width of approximately twenty nanoseconds would be the maximum width that should be used for reasonable resolution. Otherwise, the pulse energy which returns to the injection point will be misleading. The block diagram of a transceiver that has been used successfully in the field to locate sources of common path distortion is provided in Figure #1.

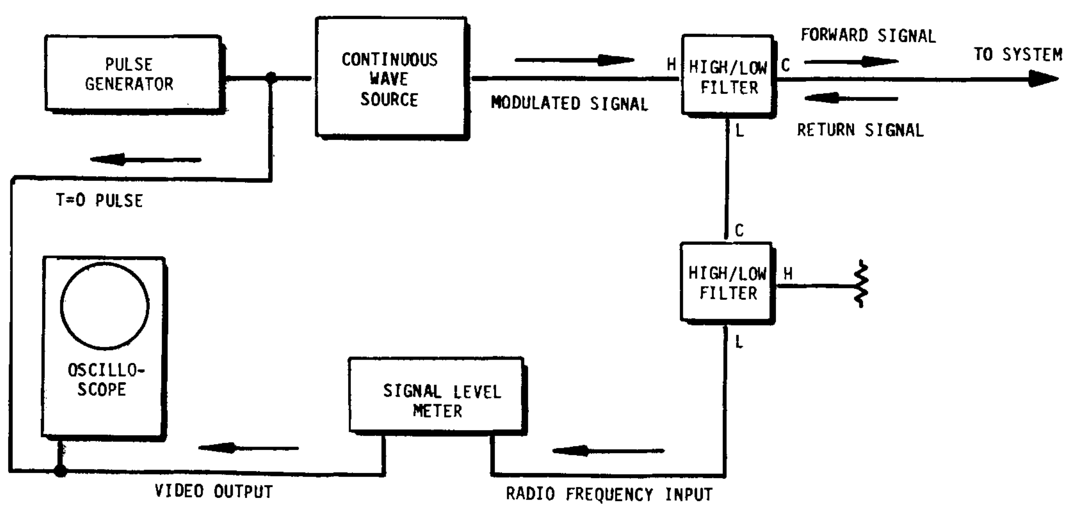

FIGURE 1.

While there are many test equipment configurations that can be utilized to accomplish the objective of locating a source of common path distortion, the method illustrated is one of the most readily achievable in terms of equipment availability to system personnel. With this particular method pulse width and repetition rate are selected via the pulse generator. This signal is then used to synchronize the scope thereby establishing the start time and to modulate a radio frequency source that can be used to fill the gap between channel 4 and 5 or any unused channel allocation that exists in the forward system signal spectrum. The signal level meter is then tuned across the return system spectrum while viewing the oscilloscope. When a member of the comb of beat products that occupy the return system is received, a vertical deflection will occur at the time interval along the X axis which corresponds to the round trip travel time of the applied pulse. The actual travel time is measured by using the graticle and the scan time per division that the oscilloscope is adjusted to.

The pulse repetition rate that is used can be a source of confusing presentations on the oscilloscope. Therefore, it is very important that the minimum repetition rate is calculated and never exceeded. The minimum repetition rate is a function of the round trip travel time that would be required for a pulse to travel from the injection point to the most distant system extremity and back to the injection point. The following formula can be used for this purpose:

$$T = \frac{2D}{984 \bullet VP}$$

Where - T is the round trip time in microseconds

VP is the velocity of propagation of the cable

D distance in feet to most distant system extremity

The value of T found by performing this calculation is the minimum time interval between modulating pulses that should be used. There is no limit to the maximum time interval between pulses. As a matter of fact, when very narrow pulse widths are needed with fast rise and fall times, it is very beneficial to use a storage oscilloscope and manually trigger the pulse generator thereby minimizing subjective impairment that could result due to the wide spectrum of energy which results when pulses having very fast level transitions are used.

THE NATURE OF COMMON PATH DISTORTION

Due to the physical characteristics of the typical common path distortion generator, intermittent amplitude variations will occur. This condition develops due to insufficient pressure between two metal members relied on to carry radio frequency current. The activity of the generator is influenced by temperature changes, vibration and abnormal signal levels. Therefore, it is important to have the locating technique mastered if an efficient maintenance program is to be effected. Field reports indicate that the sources of common path distortion are most active around sunrise, sunset and on days which are relatively wind free. Apparently, as the system is subjected to vibration as a result of wind loading, potential sources of common path distortion are eliminated when one metal member moves across its mating member thereby breaking through the oxide film.

SUMMARY

Clearly, one of the most burdensome problems associated with the return path of a bidirectional system is ingress. It is for this reason that many studies have been conducted to determine the causes of ingress and to develop solutions to this problem. One of the results of these studies is the parameter known as Transfer Impedance which can be used to qualify equipment in terms of the shielding it will provide. Transfer impedance is defined as the opposition to the flow of radio frequency current. Typically, the more resistance or impedance a system component relied on for shielding offers to the flow of radio frequency current, the poorer its performance will be as a shield against ingress. Another consideration that influences shielding effectiveness is radio frequency current density. Because connectors and equipment housings provide more surface area on which the current being carried by the cable can flow, a slightly higher transfer impedance is acceptable without the overall shielding of the system being degraded. In order to minimize the transfer impedance of their equipment, manufacturers have made significant modifications to their products. However, inordinate ambient electromagnetic field intensities, the ravages of vibration and thermal cycling require that an efficient maintenance program is implemented and followed. This objective can be achieved by using the methods that have been developed to establish the

locations in a system which are providing inadequate shielding.

Common Path Distortion is another problem which affects return system performance. This distortion includes all of the beat products which are generated within a cable system that fall in the return system frequency spectrum, excluding the beat energy which is generated by active components. Obviously, this unwanted energy which occupies the return system can be as troublesome as ingress. Interestingly enough, when the return system is displayed on a spectrum analyzer, common path distortion is often misidentified as ingress. For this reason the expression "apparent ingress" has evolved. Fortunately, there has been a technique developed to locate the sources of common path distortion.

This technique uses a pulse modulated radio frequency carrier to accomplish the desired objective.

The pulse width is selected based on the degree of distance resolution desired and the pulse repetition rate is chosen based on the time interval required for the pulse to travel from the injection point to the farthest system extremity and back to the injection point. Due to the physical characteristics of the typical common path distortion generator, intermittent amplitude variations will occur. The activity of the generator is influenced by temperature changes, vibration and abnormal signal levels. Therefore, it is important to have the locating technique mastered if an efficient maintenance program is to be effected.