CENTRALIZED CABLE LEAKAGE DETECTION, LOCATION AND MEASUREMENT

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ABSTRACT

Continuous leakage monitoring is a firm requirement under the FCC rules. Meeting this requirement may well become a very expensive and time consuming routine. Centralizing and automating the necessary procedures would be a welcomed relief for the cable industry. This goal will be achieved only after numerous technical problems are solved. This paper discusses several possible mechanisms which might be employed to reach it.

INTRODUCTION

CATV signal leakage needs no introduction, in fact, it is the focus of intense interest in the CATV technical community. CATV leakage has always been with us. Starting from an annoyance as a source of "off-the air cable signals" it has become a national concern, first to aeronautical communication and navigation circuits in the mid '70's, and later to ground-based radiocommmunication systems (early 1980's). The die appears to be cast in the FCC's Second Report and Order on Docket 21006 with rigorous monitoring, measurement and record-keeping requirements. Now the monitoring problem is not, "Must we do it"?, but, "How can we do it efficiently and economically"?

Traditional monitoring techniques are based largely upon the use of leakage detection equipment in vehicles. Once leaks are located measurements must be made and indices calculated according to Part 76, Subpart K of the FCC rules and regulations. In considering this matter the first thing that becomes apparent is that these requirements could be "forever". Under the FCC rules monitoring must go on day after week, after month after year; and indeed it should to protect other services from cable leakage as well as cable systems from ingress by over-the-air services.

Some feel that the costs of this on-going monitoring program will be excessive and most believe that it will become a part of life better done without. Streamlining of implementation of these requirements would relieve the system operator of manpower, and equipment expenditures allowing him to do things which, from a business point of view, are more important. It certainly would be nice to have a "black box" in the headend that would automatically detect leaks, alarm their presence, pin-point the locations, and calculate intensities without need for constant human attention. It is to this end that this paper is addressed. It is probably better to state it is to this "beginning" that this paper is addressed, since ultimate development of such a system, although inevitable, may be a long and complex task. At this time we can only discuss "some possibilities" for centralized automatic leakage monitoring.

BASIC PRINCIPLES

With a problem like this the first cut at a solution usually suggests some kind of automation of the basic tasks, which now are manually performed. This conjures up pictures of robot vans without drivers; antennas which automatically rise from the top of the vehicle, and seek-out leakage plus data systems that automatically record or transfer data to computers at a centralized location. These do make good science fiction stories, however, in the main, do not apply.

There are some basic considerations which do apply. For instance reciprocal effects. Wherever there is leakage out of the cable system there is a potential for leakage in. In such reciprocal situations measurement of the inverse effect may often be translated to a measurement of the primary effect. In leakage monitoring and measurement, working with ingress, maybe a good way of quantifying egress.

One factor that bears on remote monitoring possibilities in a cable network is the fact that leakage signals from the CATV spectrum are present on the outside of the cable, not only at the exact point of egress, but for some distance from this point due to the transmission line (or antenna) effects of the suspended cable. These signals vary in amplitude due to the local impedance of the cable structure, the distance from the leak, and the contribution of other leaks. Coping with these variations presents certain problems.

A cable system is a distributed communications medium. Even in a basic one-way downstream system effects such ingress, usually leave their tell-tail sign as a signal which propagates from the point of origin to the end of the cable plant. Therefore, in many cases, monitoring can be done effectively at a few points which encompass a substantial portion of the network. With two-way plant upstream ingress in the entire network can usually be sensed from the headend due to the collection of upstream signals by the tree- and branch structure.

All radio frequencies, however, do not propagate in all portions of the cable plant, so that direct ingress measurements are not always possible. For instance, ingress in the downstream path cannot be turned around and sent to the headend. However, localized monitoring and translating devices can communicate over the network to strategic monitoring locations. Bridger and feeder switches are already used by some to isolate the location of the ingress sources.

The goal then is to juggle these various factors and converge upon one or more possible remote monitoring configurations.

DISTRIBUTED RECEIVERS

The first and most straight-forward approach is the concept of receivers distributed about the cable system and arranged to detect leakage of a specific carrier frequency(s) from within the cable. Such a receiver could use a dipole or other type of receiving antenna to intercept the radiation. However, it might be simpler and mechanically more acceptable to measure the current flow on the outside of the cable, converting or calibrating this to indicate the radiation field.

There are a number of inherent problems with these external measurements. First, the frequencies chosen must be "clear channels" in the local over-the-air frequency allocations. The standing wave pattern on the cable will provide different indications, depending upon the configurations of cables, grounds, etc., and the distance from the leak. In addition, it must be determined what the rate of fall-off of the current intensity is at distances far removed from the leak, so that the spacing between adjacent detection devices can be established to provide the required detection and measurement tolerances. Due to wavelength effects, greater spacings can probably be tolerated when using lower monitoring frequencies.

Let's consider the mechanism for coupling energy from inside the cable through a flaw to the outside of the cable. First of all, the amount of energy coupled will be determined by the impedance match between the source (the flaw allowing the leakage to occur) and the impedance of the outer conductor structure as modified by turns and branches of the cable plant, the powerline neutral to which the plant is bonded, system grounds, etc. As in any source/sink situation, maximum power will be transferred when there is a conjugate match between source and load and less power is transferred when a mismatch is encountered. In addition, since the antenna formed by the coax shield and associated conductors radiates and the impedance will seldom be totally resistive, standing waves will exist along the cable.

In the presence of standing waves, a probe to measure either voltage or current will give different results when moved fractional wavelengths along the cable. This would dictate that in order to be sure of detecting any leak, at least two detectors would be necessary, spaced to assure that no situation could exist where simultaneous nulls could cause the leak to go unnoticed. Moreover, the spacing plus amplitude readings (assuming the impedence is known) should allow computation of the maximum value of the standing wave. It can be seem that some interesting and difficult problems are encountered in this detection and measurement procedure. Manually, one moves his detection dipole to find the maximum area and then the peak within that area. To accomplish this automatically some innovative approaches towards smart but economical equipment are required.

MULTIPLE FREQUENCIES

Very little work has been done to correlate leakage intensities produced by a given system flaw, over a range of frequencies. It can be hypothesized that two largely different frequencies applied to a given leak will produce very different standing wave patterns and radiation efficiencies and therefore resultant field strengths, etc. If this is indeed true, it would behoove the monitoring system to employ two or more frequencies. In addition, monitoring frequency relationships should be established that would tend to complement one another so that leaks that might produce nulls at one frequency would be accentuated at another. Frequency agility of the detection receivers could also provide a means for checking leakage at a specific frequency where an interference problem exists.

INGRESS DETECTION

Being the reciprocal of egress, ingress detection holds some promise. This is a sophistication of using a mobile CB transmitter to find a leak by noting where it interferes with cable TV reception. There are two types of sources to be considered for ingress detection. These could be categorized as global and local sources. A global source would be one having an r.f. field that engulfs all or a large portion of the cable network, such as that developed by a local radio broadcast station.

Local sources might be signal generators installed along the cable system (on the outside), which would produce small currents at specific points, thereby offering the ability to locally check for signals leaking in. This approach has some promise since the local sources could be controlled by a data stream and switched "ON" one at a time. Measurements of ingress could be correlated with which unit was switched "ON" and give a good indication of the areas where leaks were present. In addition, the levels of these sources could be remotely controlled to more effectively calibrate the magnitude of the leak.

A basic drawback is that a local source radiates when in use. It would therefore, be manditory, that such sources be limited in maximum amplitude to remain below the specified radiation criteria for the particular band of operation. One might dream of the FCC allocating standard frequencies that could be used nationwide. In such cases, many advantages would be derived such as standarized equipment, standardized listening frequencies, interference immunity from frequencies used in conventional monitoring; plus the ability to do experimentation with larger signals allowing even better margins, easier to detect thresholds and the like.

One also could use the global field approach. Unfortunately, there are very few, if any signal sources that are available every place and at all times. In a given system one might use an FM transmitter nearby, however this frequency, power-level, etc., would be unique to that system precluding broad standardization. In addition, the power densities over the CATV system could be expected to vary greatly, requiring individual thresholds and a good deal of calibration complication between locations.

There are certain very low frequency signals that have large areas of uniform field and might be of use throughout the country, however, they are operating at frequencies which are not usually propagated by the cable system. Therefore, detection of these signals would not only require distributed receivers but conversion of the received signal information to amplitude data to be collected. The approach would work but the complexity would be greater. One advantage associated with these low frequency groundwave signals, is that the fields throughout a local CATV would be relatively uniform at any instant. A single receiver and external antenna tuned to the selected frequency could be used to provide instantaneous amplitude calibration.

CALIBRATION

It can be seen from the above that these suggested approaches are relatively complex in that there are many variables which are difficult to calibrate, and some which seem to be so elusive as to threaten the viability of the approach. Suffice it to say that a good deal of development is required to perfect any of the above. On the other hand, it must be realized that many of these same pitfalls are inherent in the present methods as encompassed by Part 76. For instance, measurements of leakage are now required to be at a single frequency within an aeronautical band. Carrying through on the previous discussion, it is reasonable to assume that grossly different frequencies probably have grossly different leakage and radiation characteristics from a given fault. Therefore, there is the possibility of experiencing not only nulls, but significantly higher levels of leakage at other frequencies which may be of public concern. Even a crude system configured to measure multiple frequencies will contribute a great deal of imperical understanding to the overall CATV leakage phenomena.

"Calibration" may be the wrong heading for this paragraph, since the first work to be done is more like "investigation", such as determining the fall-off rates of signals, relative to the distance from the leak. Should this fall-off be too rapid, it would require the deployment of too many remotely located receivers, switches, and/or generators, and make the system too complex and expensive. For this reason, investigation of lower frequencies should be undertaken since the fall-off should be less rapid with distance, due to the longer wavelengths.

Assume that it was determined that some frequency below the minimum propagated by the cable network was required to obtain reasonable spacing of the remote units. At this point, some correlation must be made between the performance of the leakage fault at standard monitoring frequencies, and at the new lower frequency. A measurement program could easily be instituted to at least determine the qualitative relationships between vastly different frequency ranges in generalized cable system configurations.

Ultimate calibration must be performed by simply setting up conditions that produce threshold leakage levels as recognized by Part 76 and relating these to the particular ingress or egress detection and measurement scheme. The FCC will require this type of information presented with a thorough engineering statement before allowing use of any alternate method.

SUMMARY

In summary, "there is more than one-way to skin a cat"! That is, there are many tools available to us to approach an automatic leak detection, and possibly measurement system. A system that simply alarmed the presence of a new leak and located it to within one-thousand feet would be a major step forward.

A lot of work in the industry will be necessary to reach the goal of centralized automated leakage detection, location and measurement. As a matter of fact, one of the most important phases in this development is going on at this very moment. The routine, and hopefully, continuous monitoring that you are doing at your system can be the source of a good deal of important data which could materially add to the early arrival of semi-automated monitoring systems. Are you carefully collecting and recording your data? Have you considered using two or more frequencies? Perhaps you have a little spare time in which to run some simple tests of the various techniques described above. This industry need, like others in the past, will be met by a few who will rise to the task and reach the goal.