Transmission System Evaluation for Two-Way Cable

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ABSTRACT

The installation and operation of a two-way cable system in London, Ontario is discussed.

The objectives of the "London Experiment", transmission techniques, design parameters and philosophy are described.

Various problems encountered during the installation and balancing of trunk and distribution reverse path and their solutions are presented.

RF ingress and noise problems in the trunk and distribution return system are analyzed. System components such as subscriber television sets, drop wires, high pass matching transformers, splices and connectors are evaluated for two-way services.

Recommendations for planning and installing a return feed system are suggested for future two-way services.

INTRODUCTION

During the past two years Cablesystems Engineering (a division of Canadian Cablesystems Limited) has been developing an experimental two-way communication system on the wired (cable) distribution system operated by London Cable TV.

The CATV plant in London consists of a total of 9 separate trunks leaving the hub head-end. Trunk and distribution system consists of two-way amplifiers with forward transmission from 50 to 300MHz and return capability from 5 to 30MHz. One of these trunks and ten distribution areas were selected for the London two-way experiment.

This two-way system consists of 25 trunk amplifiers, 90 line extender return amplifiers and 10 code operated switches with bridger filters. It utilizes technology invented by Broadband Technologies (Columbus, Ohio) and jointly developed with Canadian Cablesystems.

The objectives of the London experiment are to:

a) develop technical knowledge on the operation of a return feed system and determine its reliability and problems.

b) determine technical limitations of a two-way system.

c) monitor the parameters of the forward CATV system at various remote locations, providing an automatic indication of faults and pinpointing the location of the faulty section of the system.

d) determine what the value of the status monitoring system is the cable operator specifically:

   1. are operating costs reduced through decreased service calls, automatic quality control, preventive maintenance, response time to repair faults and decreased demand of the number of skilled technicians necessary to maintain the plant?

   2. is penetration increased as a result of greater reliability, shorter outages, better quality provided by the system, and a good services package?

e) provide a test bed and demonstration for other two-way services such as opinion polling, fire and security alarms, TV viewing patterns, etc.

The purpose of this paper is to analyze the technical problems involved in the design, installation and operation of a two-way cable communication system and present their solutions.

TRANSMISSION TECHNIQUES

The two-way portion of the CATV plant is subdivided into areas of approximately 300 homes connected to the remainder of the cable system by code operated switches (COS) at each bridger amplifier location which, when activated, turn on the return path.

The COS receiver has a unique address and it can be activated by an FSK transmitter located at the head-end. The FSK signal consists of two RF carriers spaced 200KHz apart and frequency shift keyed at a bit rate of 5Kbit/s. This signal, transmitted downstream on an unused frequency, is received and decoded by every COS receiver but only the one with the proper unique address will turn on.

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The COS will turn off whenever an improperly coded carrier is received, i.e. when another COS is being addressed. When a COS is enabled it performs two functions:

a) a built in return verification oscillator (RVO) in the frequency range from 7 to 11MHz is activated. This is transmitted upstream to the head-end thus allowing positive identification that the right COS has actually been addressed. The RVO is crystal controlled and is assigned a unique return frequency with a minimum carrier spacing of 20KHz.

b) a self-terminated reed relay switch in the bridger filter is closed thus allowing the upstream signals to be transmitted from the addressed distribution area through the upstream trunk path to the head-end. (see Figure 1).

The COS only controls the flow of upstream signals into the trunk system from each distribution area and does not affect the downstream transmission of signals at all.

This two-way system utilizes a combination of time and frequency division multiplexing. In fact, the FSK transmitter sequentially addresses each COS area, one at a time (TDM). Within one distribution area various transmitters are located. Each transmitter is on continuously but is assigned a unique return frequency. These upstream carriers are spaced at 20KHz intervals (FDM). When a COS is not being addressed, the switch in the bridger filter is in the open position and the isolation is in the order of 50dB. Therefore, the same frequency can be reassigned to another transmitter in a different COS area.

Many technical advantages result from this return system sectionalization. These are:

1. the reduction of ingress and noise accumulation since only the return trunk path and one distribution area is activated at a time.

2. the correct reception of upstream signals from a certain distribution area can only be affected by a fault in the same area.

3. the problem of locating a source of RF intrusion is confined within a COS area or the trunk lines.

4. one (COS) receiver is shared by many home terminals. These can be simple transmitters which operated continuously thus reducing the complexity of the device.

The 5-30MHz spectrum has been divided into two bandwidths:

a) from 5 to 15MHz reserved for the return transmission of data with a maximum of 500 carriers (including an RVO) per COS area spaced at 20KHz.

b) from 18 to 30MHz for the upstream transmission of two television channels.

To date in this two-way experiment no tests have yet been performed evaluating plant hardware and ingress effects for upstream transmission of television signals from distribution areas. Therefore, this aspect will not be further considered in this paper. Selected sections of the plant have been used, however, for years, for local origination of two-way television signals.

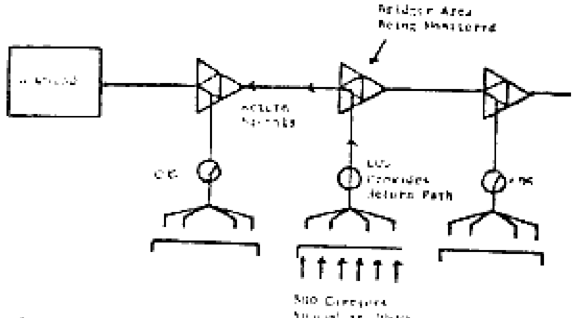

FIGURE 1. - SYSTEM DIAGRAM

DESIGN PHILOSOPHY AND PARAMETERS

A downstream CATV system consists of a common signal source which feeds several trunk and distribution lines and is designed so that a specified signal level is provided to each subscriber's TV set.

In an upstream system signals generated from various locations and carried on separate cables are combined onto one cable. To reduce variations between upstream levels, each signal transmitted from the end of any feeder line will have to arrive at the point of convergence with approximately the same level. Therefore, the return system has to be designed for a specified constant input rather than output level at each amplifier location. The output level will vary according to the amplifier gain needed to compensate for the losses on the following span.

In the London system the upstream distribution plant is designed for an input level of +11dBmV to each line extender with a minimum full gain of 22dB and fixed slope of +2dB from 5 to 30MHz. The upstream trunk is designed for 0dBmV input to each return amplifier module with a minimum full gain of 14dB and manual gain control of 6dB. Trunk amplifiers are also provided with cable and thermal equalizers for flatness and temperature compensation.

In spite of the fact that the upstream signal levels for the transmission of data are not as critical as the downstream ones in terms of signal to noise (SNR of 20dB over a 20KHz bandwidth can be easily tolerated) and signal to interference ratio, it is important to establish tight specifications for return level variations. The reason for this is to provide a method of checking the performance of upstream transmissions in order to locate faults (bad splices, corroded and loose connectors, etc.) which, being a less severe problem at VHF, can cause level instability of upstream signals due to VSWR problems.

The upstream plant is designed so that all signals transmitted from the end of any feeder line will arrive at the head-end within ±5dB of a specified reference level. These variations are due to level changes of ±3dB between signals converging on a bridger amplifier location from various feeder ends and of ±2dB difference between signals converging at the head-end from various bridger locations throughout the trunk (neglecting temperature changes which are predictable).

INSTALLATION AND BALANCING PROCEDURES

At the time of installation each trunk and distribution return amplifier is preset on the bench according to system design and installed at the appropriate location in the system. Also the output level of each transmitter at the end of any line is preset before installation.

This operation will result in level variations at the head-end between upstream signals arriving from the various bridger areas throughout the trunk. These variations are due to discrepancies between actual and theoretically calculated gains and losses. As a rule of thumb, the magnitude of these discrepancies, d, can be estimated according to the following equation (neglecting temperature changes):

$$d = \pm (0.5 \times M + 1 \times N) \text{ dB}$$

where M and N are the number of return trunk and line extender amplifiers in cascade respectively.

In the London system the longest two-way cascade consists of 12 trunk and 4 line extender amplifiers and variations of approximately ±10dB between upstream levels were observed at the head-end.

The long cascade of trunk amplifiers contributes most of the total accumulation of the predicted discrepancies. Therefore, in order to meet the design specification of ±2dB variation due to the upstream trunk, balancing prodedures have to be developed. The equipment needed consists of a portable oscillator with a calibrated output level tuned on a fixed frequency (i.e.10MHz) and a meter for sub-low frequencies. The following two methods can be employed.

Alternative "A"

The upstream trunk path is balanced moving towards the head-end. The portable oscillator is located at the end of the trunk i.e. at the input of return amplifier #1 (See Figure 2) and the signal level at the input of amplifier #2 is measured. Two situations of a combination of these two can occur:

1. if input level at amplifier #2 is the same as amplifier #1 then move the amplifier #3 and measure input level; if same as amplifier #1 and 2 move to amplifier #4 and so on following the cable back to the head-end.

2. if input level at amplifier #2 is different from amplifier #1, return to amplifier #1 and adjust the gain to compensate for the difference; then move the amplifier #3 and measure the input level; if it differs from amplifiers #1 and 2 go back to amplifier #2 and adjust the gain to compensate for the difference and so on until the head-end is reached.

When the final adjustments are performed, the output level should also be measured and the gain of each return amplifier noted on the plan. These adjustments can be done by one technician but he will find that he has to visit most amplifier locations twice. Basically, the same method can be followed with two technicians, one at one amplifier location and the second at the next one. The balancing can be done more quickly but the set up accuracy will probably be lower (two different meters and eyes) even though the error does not accumulate. They also need to communicate with one another.

Alternative "B"

The upstream trunk path is balanced moving away from the head-end. The portable oscillator is initially located at the input of the closest amplifier to the head-end (i.e. amplifier #10 in Figure 2). The upstream signal level from the portable oscillator is measured at the head-end. One of these two situations can occur:

1. the level at the head-end is equal to the portable oscillator output level. Then amplifier #10 gain does not need to be adjusted.

2. the level at the head-end differs. Then amplifier #10 gain has to be adjusted following the instruction given from the head-end.

The portable oscillator is then moved to amplifier #9 where either step 1 or 2 is repeated until the last trunk amplifier (amplifier #1 in Figure 2) is reached. This method involves two technicians, one at the head-end and the other in the field. It is the most accurate and logical one and therefore is recommended. A TV camera aimed at the meter at the head-end can be used to transmit on an unused downstream channel the information regarding the upstream signal level. This can be received in the field with a small portable TV set. The advantage of this method is that one technician can balance the upstream plant accurately. The same method can also be used to set up most two-way equipment like home terminals and status monitors.

Should much larger discrepancies than those estimated be found during the balancing procedure, the cause has to be investigated and the system repaired before proceeding to the next cable segment.

Slope adjustment can also be performed at the time of gain adjustment either by using two portable oscillators, i.e. one tuned to 10MHz and the second to 30MHz, or a summation sweep signal from 5 to 30MHz.

For maintenance purposes upstream signal levels should be continuously monitored at the head-end and if the level instability is greater than a specified window the cause should be located and repaired.

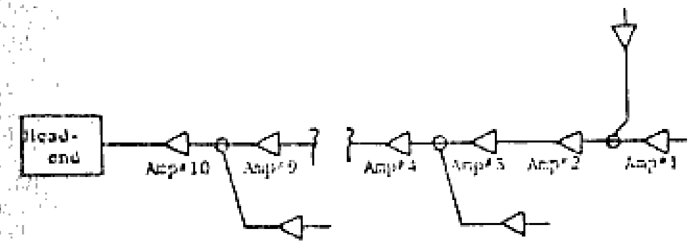

Figure 2 - Upstream Trunk Cascade

FACTORS AFFECTING TWO-WAY SYSTEM PERFORMANCE AND DEBUGGING PROCEDURES

After the installation of the upstream plant two major problems were encountered which adversely affect two-way system performance - radio frequency intrusion or RFI and impulse noise.

The sources of RFI in the radio spectrum from 5 to 30MHz are many; short wave transmissions, citizen band radios, amateur radio transmitters, industrial machinery and harmonics from various electrical devices in subscribers' homes. These signals enter the cable plant at many points and contaminate the upstream signals.

The use of a COS at each bridger amplifier location makes the process of locating ingress problems easier. In fact, the trunk and one distribution area or only the trunk can be turned on at a time. Signal intrusion can be monitored with a spectrum analyzer and a chart recorder at the head-end. After monitoring the trunk and each distribution area severe RF ingress was found from both CB and ham radios. Ingress levels in the range of +30 to +40dBmV from CB and ham radios and of 0 to +10dBmV from shortwave transmitters were recorded at the head-end.

The following problems were found:

Trunk:
- seven loose non-integral sleeve splices
- one splice not properly installed, these were replaced with integral sleeve splices which resolved trunk intrusion problems.

Distribution:
- loose non-integral sleeve connectors on multitaps
- broken cable sheaths
- loose connectors on multitap spiggots
- loose or corroded splices
- defective drop wires
- improper grounding
- defective matching transforme
- illegal and unused extensions
- internal antennas hooked-up c FM and TV sets.

The following two methods to locate int sion problems were developed and evaluated:

a) drive along the two-way cable plant with a radiation monitor until a point of leakage is determined.

b) drive along the two-way system with a CB transmitter installed on a tru until a point of ingress is determined. With a meter or a spectrum analyzer at the head-end ingress levels of -3-dBmV can be measured.

Trunk cables were first patrolled with radiation monitors but no point of leakage was determined. By using the CB transmitter the p of ingress were immediately located.

The most stringent technical standard radiation from CATV systems[3] requires that a field strength of 10µV/m at 3 meters from the plant is not exceeded in the frequency range 108 to 174MHz. In Appendix A, it is shown th radiation monitor can detect out of specifica emissions at 13.45m, if it is calibrated for imum sensitivity. Therefore, for remote (bac cable plant, a street front radiation patrol adequate and the use of a portable radiation itor is required. Radiation from a CATV syst is a function of the signal level carried wit the co-axial cable and of shielding effective Hence the lower the signal level, the less th possibility of detecting radiation.

In Appendix B, for the signal level ra found in different sections of cable plant, t shielding effectiveness corresponding to the imum detectable radiation is calculated. If t radiation monitor is calibrated to detect emi which exceed B.P.23 radiation standards at a tance of 3m, the shielding of the cable plant 13dB lower than calculated in Appendix B when iation is detected. It must be noted that a plant can have a shielding effectiveness of o 36dB in the trunk and of 26dB in the drop wir still comply with B.P.23 radiation standards. would occur only in the worst case condition input of trunk amplifiers.

Ingress level from the CB trasmitter i a function of cable plant shielding effective (assuming constant distance). This is calcul in Appendix C.

A comparison of the effectiveness and limitations of the radiation monitor and CB transmitter method is shown in Table 1. It is observed that the radiation monitor at 3m from the cable plant is more effective than the CB transmitter at 30m only where the radiation pilop level is in the order of +40 to +50dBmV, i.e. at the output of a distribution amplifier. If the two methods are compared at the same distance of 3m from the cable plant the ingress level from the CB transmitter increases 20dB. In this case, the CB transmitter is the most sensitive method in absolute terms. It must be noted that it is possible to have unsatisfactory ingress levels in any section of cable plant without being able to locate the intrusion problem when only the radiation monitoring system is used. In these cases a CB like transmitter needs to be used. Therefore, it is necessary to obtain a suitable test frequency.

Table 1

	Radiation Pilot Level (dBmV)	Shielding* Effectiveness (dB)	Ingress** Level (dBmV)
TRUNK	+10	49	-1
	+30	69	-21
DISTRIBUTION	+15	54	-6
	+50	89	+11
DROP WIRE	+10	49	-1
	0	39	+9

* Shielding effectiveness corresponding to the minimum detectable radiation at a distance of 3 m.

** Ingress level due to the CB transmitter at a distance of 30 m.

On the other hand, because of high output levels from distribution amplifiers, it is possible to detect radiation even though the shielding if fairly high (in the order of 80-90dB) and ingress level is satisfactory. Radiation monitoring is a very valid system for detecting out of specification emissions from a cable plant but it was not designed to determine ingress problems. Attempts to make the radiation monitoring system more effectibe by using a more sensitive receiver or a higher radiation pilot level within the co-axial cable would make the radiation monitoring method almost unusable because the receiver would continuously detect radiation from the output of distribution amplifiers. In fact, if for example the sensitivity is increased by 10dB or more to make the radiation monitoring more effective at locating ingress problems in the trunk and drop cable, the shielding effectiveness would have to be 100dB or higher in order not to detect radiation in the vicinity of distribution amplifiers. Such a shielding effectiveness is not easily maintained in a distribution cable plant.

Radiation monitoring is still a viable technique for preventive maintainance and it is capable of taking the most severe ingress problems. This method can be performed by one person only whereas the CB transmitter method requires two people. Normally intrusion problems can be quickly located by the CB transmitter within a small segment of cable plant. However, the use of an external source to locate points of ingress is presently illegal and cannot be recommended for system maintainance, unless a test frequency is assigned to this purpose.

The second major problem affecting two-way system performance is the generation of electrical noise bursts within the CATV system. When the return path was activated two noise problems of different natures had to be analyzed.

a) a burst of noise affected the low-end of the 5 to 30MHz spectrum. The burst was 4 to 5MHz wide, its peak was around 5MHz and the amplitude in the range of 0 to +10dBmV over a 100KHz bandwidth. Through a series of laboratory tests the cause has been found in the emission of high frequency harmonics from the switching dc power pack used in the trunk stations. This problem has been solved by modifying the dc power supply in each trunk amplifier with the addition of an L-C filtering network which reduced the emissions amplitude by 35dB. Also, emissions from various types of ac power supplies used for remote powering of CATV equipment have been examined. The results showed that ferro-resonant ac supplies can have frequency content over 5MHz. These high harmonics can leak into the RF section of the active devices and be amplified. In these instances additional filtering should be added in the power line to reduce the harmonics amplitude.

b) an impulse and intermittent broadband noise affected the performance of the upstream system over the whole sub-low band. This noise can be observed on a spectrum analyzer at the head-end. The thermal noise floor increases by 20 or 30dB and sometimes these are spikes in the order of 10 to 20dB higher. The peak level often exceeds 0dBmV with occasional peaks to +20dBmV or greater. This impulse noise is due to the current carried within the co-axial cable for remote powering which can cause an electrical discharge when an intermittent connection is found along the transmission path. This electrical discharge can have frequency content in the whole HF bandwidth or higher. The noise has been monitored for days but no significant pattern in time of occurrence or frequency has been established. It can last for seconds, minutes or hours. Due to this very intermittent nature the source is difficult to locate and the noise may disappear before the cause is determined by a maintenance crew. Sometimes the noise problem is related to RF intrusion and radiation and can be located with the same procedures used to determine a point of ingress. Sources of noise have been located throughout the trunk and distribution plant and they were all related to some loose section of connectors or splices. Vibrations and cable movements make this phenomenon very intermittent. The noise problem will more likely occur where non-integral sleeve connectors, even when installed properly and tight, will deteriorate as soon as cold flow of the cable sheath occur. After repeated tightening it eventually becomes impossible to make a good connection between connector and cable. The cold flow problem cannot be overcome unless connectors having a built-in support sleeve are used. The noise problem can also occur when integral sleeve connectors are improperly installed or loosen because of thermal expansion and contraction. To date, the effect of this inpulse noise on the correct transmission and reception of data has not been evaluated.

SYSTEM COMPONENTS EVALUATION

A test plan has been developed to determine the most susceptible system components to radio frequency intrusion. This included ingress evaluation in trunk versus distribution cables and ingress evaluation in distribution cables versus drop wires and subscriber's terminal.

Two important factors have been established. One is that ingress comes primarily from the distribution portion of a cable system as opposed to the trunk, and two, is that the trunk portion of the plant can be kept tight after the initial debugging without too much maintenance effort. This is due to the fact that the trunk system does not feed any subscriber directly and does not have hundreds of multitaps and connectors like distribution areas.

It is difficult to measure RF intrusion in absolute terms because the sources of ingress are not the same all the time and are of varying intensity. Therefore, in order to carry out the evaluation process a constant source of intrusion to be used as reference was required.

One bridger amplifier area was selected for the evaluation of the distribution system components. The area was first patrolled with an external source of intrusion (CB transmitter) and the ingress level in each distribution segment was recorded. The first step was to determine whether the ingress susceptibility of the distribution system as a whole could be decreased with a high maintenance effort. For this purpose the test area was patrolled segment by segment with a portable radiation monitor and all detected problems were repaired. Also a project called "Zero Defects" was applied at all homes. This included checking each drop wire for grounding and integrity and replacing all the ones with more than two splices. After this clean-up process, the distribution area was again patrolled with the CB transmitter. Comparison of the ingress levels just measured with the ones previously recorded showed that no significant improvement in ingress susceptibility had been accomplished. This may be related to the previously discussed effectiveness of the radiation monitoring system at locating ingress problems. In fact the ingress susceptibility will not decrease if only one bad connector is missed.

During the ingress evaluation at the subscriber's terminal, spurious signals have been found to be generated from some circuits used in domestic TV sets. The harmonic content can extend into the HF spectrum up to 10MHz or higher and varies from one TV set to another. The amplitude of these harmonics can be in the order of -10 to 0dBmV.

To evaluate ingress in distribution cables versus ingress in drop wires, a special filter will be installed on each multitap spigot. These filters introduce negligible effect on the forward signals but block the interfering carriers from getting into the distribution lines. To date, this phase has not been completed. However, a small test performed on one distribution line with all the drops disconnected showed that intrusion levels into subscriber's drop are well below those caused by distribution system faults.

STATUS MONITORING

The status monitoring system developed by Broadband Technologies and proposed for the Syracuse Cablesystems is currently being tested in the "London Experiment". Fifty status monitors have been installed at the end of selected feeder lines throughout the ten distribution areas provided with two-way equipment.

The purpose of this system is to allow the cable operator to monitor from the head-end the electrical parameters (signal level and sweep frequency response) of the forward transmission system at the extremities of the CATV plant.

The information regarding the electrical status of the downstream plant is then transmitted from the monitor locations through the upstream path back to a microprocessor at the head-end. The theory of operation of the status monitoring system is described in detail by D.S. McVoy[2].

This system will provide an automatic indication of faults and pinpoint the location of the faulty section of the system. This should improve the reliability and quality of the regular CATV service and reduce preventive maintenance and service calls. A system for the collection of information from the status monitors is currently being developed and no technical data are available at the present time.

Future plans for the London Two-way project include the installation of two hundred home terminals and the monitoring of smoke detectors, TV viewing patterns and opinions.

CONCLUSIONS AND RECOMMENDATIONS

Return signals are continuously transmitted from the trunk and the ends of feeder lines and the performance of the upstream plant can be easily checked at one single location, the head-end, by using a spectrum analyzer. The monitoring of the upstream plant also helps monitor the downstream plant and faults such as cut cables, power failures, etc., that affect both forward and return signals can be immediately detected and located.

The use of a code operated switch at each bridger amplifier location is strongly recommended. This will reduce ingress and noise accumulation and make the process of locating problems easier.

Significant changes in signal levels are often related to VSWR problems which are associated to loose connectors and ingress. Therefore, upstream signal levels should be continuously monitored to detect these problems.

The radiation monitoring system can be used for two-way system preventive maintenance. However, to allow the cable operator to locate intrusion problems that cannot be detected by the radiation monitor, the assignment of the suitable test frequency to generate an external source of ingress is required.

The use of integral sleeve connectors and splices is recommended for trunk and distribution plant to reduce the possibility of having loose connectors, cold flow of the cable sheath and corrosion which are the main sources of impulse noise and signal intrusion.

Subscribers' filters, although not required for the upstream transmission of data, may be used to decrease the spurious signals which can enter the subscriber terminal or be generated from some circuits in domestic TV sets.

Ingress problems may be overcome initially by simply selecting frequency bands for return transmissions where high level ingress does not occur. There are probably sufficient frequencies available to satisfy a significant number of "upstream" subscribers. Therefore, a large plant debugging expense is not required to initially offer two-way services.

ACKNOWLEDGMENTS

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APPENDIX A

DETERMINATION OF MINIMUM DETECTABLE RADIATION

Assume that the maximum input sensitivity of a radiation monitor is 1μV across 75Ω. The power intercepted (Pr) by the antenna to give an input signal of 1μV is given by:

$Pr = V^2/75 = (1 \times 10^{-6})^2/75 = 1.33 \times 10^{-14}$ Watts.

Assume that the receiving antenna is a λ/2 dipole of gain G = 1.64. The power density P_d (in Watts $/m^2$) is given by: P_d = Pr/antenna area. Where antenna area = $G\,\lambda^2/4\pi$. Assuming the radiation carrier frequency = 108MHz, $\lambda = 2.78m$ $\lambda^2 = 7.73$

Therefore, $P_d = (1.33 \times 10^{-14} \times 4\pi)/1.64 \times 7.73 = 1.32 \times 10^{-14}$ Watts/m^2

The field strength for any given power density is

$E = (120\pi \times P_d)^{1/2}$ where 120π is known as the resistance of free space

This yields: $E = (120\pi \times 1.32 \times 10^{-14})^{1/2} = 2.23 \times 10^{-6}$ V/m = 2.23μV/m

Therefore the minimum radiation the monitor can detect is 2.23μV/m.

The most stringent B.P.23 specification for radiation is: 10μV/m at 3m. The radiation monitor is 20 log 10/2.23 = 20 log 4.48 = 13.03dB more sensitive than minimum required or it can detect out of specification emissions at a maximum distance of 3 x 4.48 = 13.45m (44.14 feet).

APPENDIX B

DETERMINATION OF CABLE PLANT SHIELDING EFFECTIVENESS FOR MINIMUM DETECTABLE RADIATION AT 3 METERS

For an isotropic radiator the relationship between transmitted power in watts (P_t) and field strength (E in V/m) at any distance (R in meters) is: $E = (30 \times P_t)^{1/2}/R$ (1).

In our case $E = 2.23 \times 10^{-6}$ V/m and R=3m. The power transmitted to give a field strength of 2.23×10^{-6} V/m at 3m is given from (1): $P_t = (E \times R)^2/30 = (2.23 \times 10^{-6} \times 3)^2/30 = 1.49 \times 10^{-12}$ Watts.

The power transmitted P_t can be expressed in dBm 1.49×10^{-12} Watts = 1.49×10^{-9} mW.

$[P_t]$ dBm = $10 \times \log_{10} 1.49 \times 10^{-9} = -88.26$dBm

The radiated power P_t from the cable plant is a function of signal level within the co-axial cable and shielding effectiveness. The forward signal level range in each section of the cable plant is known and the shielding effectiveness for minimum detectable radiation can be calculated.

Trunk: Typical signal level range +10 to +30dBmV

a) at +10dBmV (-38.75dBm)
   shielding effectiveness = -38.75-(-88.26)=49.51dB

b) at +30dBmV (-18.75dBm)
   shielding effectiveness = -18.75-(-88.26)=69.51dB

Distribution: Typical signal level range 0 to +50dBmV

a) at 0dBmV (-48.75dBm)
   shielding effectiveness = -48.75-(-88.26)=39.51dB

b) at +50dBmV (+1.25dBm)
   shielding effectiveness = +1.25-(-88.26)=89.51dB

APPENDIX C

DETERMINATION OF INGRESS LEVEL FROM CB TRANSMITTER AT 30 METERS FROM THE CABLE PLANT

Assuming the effective radiated power from the CB transmitter = 1 Watt (+30dBm), the path loss is: P.L. = -27.55 + 20 log R + 20 log f = 30.62dB.

where R = distance between transmitter and cable plant in meters = 30m
f = frequency = 27MHz

The RFI level in dBmV can be calculated as:
$[RFI]_{dBmV}$ = (+30 - 30.62) - (shielding effectiveness) + 48.75. Note: 0dBm = +48.75dBmV

Assuming the shielding effectiveness calculated in Appendix B (note that frequency difference may change shielding effectiveness) the ingress level from the CB transmitter in the various sections of the plant is:

Trunk: a) RFI = -0.62 - 49.51 + 48.75 = -1.38dBmV

b) RFI = -0.62 - 69.51 + 48.75 = -21.38dBmV

Distribution:
c) RFI = -0.62 - 39.51 + 48.75 = +8.62dBmV

d) RFI = -0.62 - 89.51 + 48.75 = -41.38dBmV

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Giorgio Allora-Abbondi was born in Masserano (Vercelli) Italy on February 15, 1950. He attended a five year program of studies in the Dept. of Engineering at the Politecnico di Torino and in 1976 he graduated in Electrical Engineering. His thesis project, partly developed at Philips' Company in Italy, was a study of a CATV system. He also spent six months at the "Instituto Elettrotechnico Nazionale Galileo Ferraris" in Torino, Italy as research assistant in MATV-CATV systems.

In 1977 he came to Canada where he attended postgraduate courses in the area of image processing at the University of Windsor.

In October, 1977 he accepted a position with Cablesystems Engineering in London, Ontario. He has conducted spectrum management studies for CATV networks and has developed the implementation techniques for upstream HF transmissions in CATV networks.

Giorgio is a member of the IEEE and he is now registered part-time at the University of Western Ontario completing the requirements for an M.E.Sc. degree.