CLI MEASUREMENTS FOR LARGE SYSTEMS

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ABSTRACT

The following paper reviews Cumulative Leakage Index requirements and considers leakage program organizational methods and procedures as they relate to large systems.

Both ground-based Cumulative Leakage Index formulas were analyzed revealing the lack of any system size allowances. Flyover advantages and limitations were compared with system leakage strategy. Its intent is to emphasize the need for immediate planning which will ease the ordeal of passing the first FCC filing due July 1, 1990. Ultimate failure may result in a severe loss of channels.

LARGE SYSTEM CONSIDERATIONS

Large cable systems have an inherent disadvantage when attempting to submit a passing annual Cumulative Leakage Index to the FCC.

There is no mileage adjustment factor included in any of the three methods for collecting and computing a CLI. That means, for example, that a 3000-mile system cannot have any more leaks, which equal or exceed 50 microvolts per meter at a distance of ten feet, than a 10-mile system can if any channels between 108 mHz and 136 (soon to be 137) mHz or 225 mHz to 400 mHz are used.

A review of the following considerations and their possible implementation into your leakage program may make the task of filing a passing annual CLI to the FCC more pleasant, and may reduce the anxiety of the July 1, 1990 deadline.

If you do not presently have an aggressive, routine quarterly monitoring and repair program in place, DON'T EXPECT TO PASS YOUR FIRST ANNUAL CLI. The following list is an example of allowable leaks at various field strengths producing a CLI at the passing threshold:

# of leaks	level	CLI
1000	50 µv/m	63.9
250	100 µv/m	63.98
100	150 µv/m	63.52
1	1600 µv/m	64.08 (failure)

The CLI calculations were derived from this formula:

$$I_\infty = \frac{1}{\emptyset} \sum_{i=1}^{n} E_i^2$$

where:

$\emptyset$ is the fraction of the system cable length actually examined for leakage sources and is equal to the strand miles in the plant;

E_i is the electric field strength in microvolts per meter (µV/m) measured pursuant to Section 76.609(h) 3 meters from the leak i; and

n is the number of leaks found of field strength equal to or greater than 50 µV/m pursuant to Section 76.609(h).

where: $10 \log_{10} I_\infty$ must equal or be less than 64.

More simply stated:

$$CLI_\infty = 10 \log_{10} \left[\left(\frac{\text{plant miles}}{\text{miles monitored}} \right) \text{sum of (leaks}^2\text{)} \right]$$

As you can see from this formula, large systems have the same burden of a 1000 leak maximum limit if all leaks discovered emit a field strength of 50 microvolts per meter. As the leak levels increase, the number of allowable leaks decreases exponentially. Therefore, the larger the system, the more advanced planning is required to avoid the last minute panic of how to deal with a system that can not produce a passing CLI.

ROUTINE MONITORING

What is an effective routine quarterly monitoring and repair program? Docket 21006, as adopted in Part 76 of the FCC Rules, states that a sufficient number of vehicles must be equipped with leakage receivers sensitive enough to detect leaks at a field strength of 20 microvolts per meter at a distance of three meters (ten feet) to ensure 100% system coverage every three months. Repairs must be made at all locations which meet or exceed the 20 µv/m threshold and all objectionable leaks (an incident where complaints have been made no matter what the level) even though a minimum level of 50 µv/m is used for CLI computation.

Assess the resources you presently have. The monitoring can and should be included in routine daily work activities. Simply outfit a sufficient number of existing vehicles to provide system wide coverage. Large systems should never have a problem devising monitoring strategy, however, dealing with the initial repair backlog quickly develops into a serious demand on labor and material resources.

REPAIR DILEMMA

PREVENTION is the only path to a passing CLI and an eventual "Closed System" in my opinion. Until all appropriate staff are trained to understand the significance of all the tasks they perform on your coaxial cable plant and develop the necessary skills and professional ethics to deliver high quality work standards every time, your leakage repair backlog will remain an unmanageable problem. Properly preparing and tightening every trunk and feeder connector, as well as drop "F" fittings, will show results quickly. Developing cable configurations at poles which avoid frictional damage and fatigue is another beneficial example.

Multiple Dwelling Units are the single most common cause of excessive signal leakage in the majority of cable systems I have examined. Feeder cables usually present the greatest potential for high level leakage since the highest signal levels in a typical cable plant are present. Therefore, feeder cable in apartment houses, hotels, motels, etc. should be constructed with 5/8"x 24 thread ported amplifiers, aluminum cable and directional taps not 50dB gain amplifiers with an "F" fitting at the output port feeding residential splitters via a piece of single shielded RG 59U as an example. Typically, these bulk billed accounts are simply a result of attaching to an existing MATV system. The rules are clear. IF YOUR SIGNAL IS PRESENT ON A CABLE OR PIECE OF EQUIPMENT, IT'S YOUR RESPONSIBILITY. I recommend adopting the rule "aeronautical channel signal levels may not exceed 20 dBmv on any drop type cable", including short jumpers.

EFFECTIVE RECEIVERS

Leakage receivers should be equipped with some type of meter which can be calibrated. The Rules do not require level measurements during quarterly monitoring, however, the benefits justify the cost (especially to larger systems). Time spent during the locating process is shortened since the direction-finding properties of the receiver are enhanced. Repair time is more productive toward CLI reduction because leaks can be sorted by level for priority.

S meters, LCD bar meters, and LCD light bars can be calibrated just as effectively as a meter which reads microvolts per meter directly. The development of a graph similar to the one in fig. 1 will establish the relationship between various signals in dBmv and the appropriate field strengths in microvolts per meter for the monitoring frequency of your receivers. The graph was produced from calculations derived from the formula:

$$\text{dBmv} = 20 \log_{10} \left(\frac{\frac{E\ (\mu v/m)}{.021\ X\ f\ (mHz)}}{1000} \right)$$

where: f = frequency being measured

Example:

$$\text{dBmv} = 20 \log^{10} \frac{\frac{20}{.021\ X\ f\ (mHz)}}{1000} = -43.95$$

The example above demonstrates that a signal of -44 dBmv will represent a field strength of 20 microvolts per meter when the frequency measured is 150 mHz. The graph illustrated in fig. 1 shows similar relationships for a 150 mHz receiver including field strengths from 20 µv/m to 340 µv/m.

Comparison of field strengths vs. signals (measured at 150 MHz)

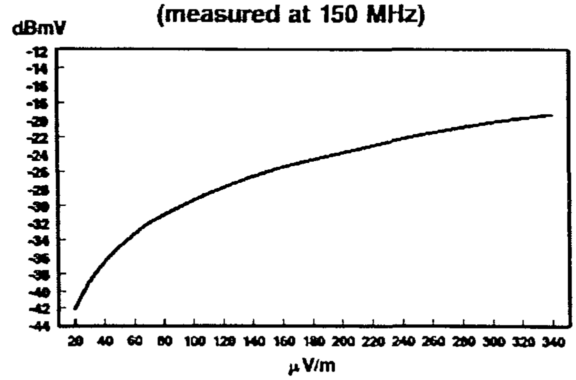
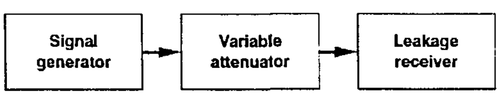


Fig. 1

A test arrangement similar to the one presented in fig. 2 can be used for calibration purposes. A lab quality signal generator is not necessary. Calibration signals from a Sam 1 field strength meter were used for this example along with a 2 meter amateur receiver since both will operate at 150 mHz. We will then assume that channel F will be used for monitoring the hypothetical system. The signal from the generator is fed into a variable attenuator. I recommend that the output of the signal source be adjusted or attenuated to produce 0 dBmv. This will facilitate the readings since a direct relationship will exist between the variable attenuator settings and the negative signals being exposed to the receiver under test.

Since the formula is based on measurements collected from a half-wave dipole, a correlation must be established if an alternative antenna is used. Place an appropriate in-line pad in the test lead to compensate for any antenna loss exhibited when compared to a half-wave dipole. The signal generator output must be adjusted above 0 dBmv an amount equal to the gain factor of any antenna used to maintain the attenuator's direct relationship. Various receiver meter readings are recorded against the field strengths indicated from the graph to serve as a calibration table. Employee participation during this procedure and future routine confirmations will improve their development in learning the relationship between dBmv and µv/m. A sense of confidence with the new skills required develops when various leaks are quantified in µv/m rather than pass/fail. The system's leakage program efficiency will improve parallel to the learning curve of its participants.



Test setup to determine signal level

Fig. 2

To confirm the proper operation of leakage receivers, build a "test zone" at some frequently visited location such as the company gas pump or parking lot entrance. A typical example is the use of a half-wave dipole mounted on a pole fed by signals from your system and adjusted to produce a 20 µv/m leak at a specific location painted on the parking lot pavement. Regular visits to that spot will develop operator confidence in the correct operation of their leakage receivers and save valuable monitoring and repair time avoiding the use faulty equipment.

LOGGING

Prior to the development of logging procedures, careful consideration to some aspects of these records may mean the difference between passing or failing your first CLI, even though you may have collected identical data.

It is advantageous to divide a system for leakage calculations whenever legally possible. John Wong has stated at recent NCTA seminars on leakage that sections of cable systems fed by a separate headend, microwave signals, or fiberoptic cables that are not connected by coaxial cable in any way may be considered as separate systems for the purpose of CLI computation. By no means am I giving permission to make divisions of your system based on any of these criteria, however division is worth consideration with interpretation confirmation from the Cable Branch of the FCC if necessary.

Computation based on the:

$$I_{3000} = \frac{1}{\beta} \sum_{i=1}^{n} \frac{E_i^2}{R_i^2}$$

where:

$$R_i^2 = r_i^2 + (3000)^2$$

r_i *is the distance (in meters) between the leakage source and the center of the cable television system;*

β *is the fraction of the system cable length actually examined for leakage sources and is equal to the strand miles of plant tested divided by the total strand miles in the plant;*

R_i *is the slant height distance (in meters) from leakage source i to a point 3000 meters above the center of the cable television system;*

E_i *is the electric field strength in microvolts per meter (µV/m) measured pursuant to Section 76.609(h) 3 meters from the leak i; and*

n *is the number of leaks found of field strength equal to or greater than 50 µV/m pursuant to Section 76.609(h).*

may provide some relief since the slant height is used to determine the effect of individual leaks upon aircraft. Larger systems potentially offer greater advantages since the distance adjustment may be significant. In order to use this formula, distances from each leak to the theoretical center of the system must be added to the list of information collected while on leakage patrol. Distance averaging may be used as long as an advantage is not derived from its use. The advance development of distance contour lines about the system center and the use of a common distance for all leaks within each contour band may provide a useful tool to ease collection of this information.

Without proper logging of leakage monitoring and repair activities, all your efforts will have been wasted when faced with an FCC inspection. The responsibility of proper documentation is to ensure a "Good Faith Effort" can be demonstrated. Large systems may have the advantages of various computer aided service programs. Inclusion of leakage logging and CLI computation tasks into these programs may streamline the process.

FLYOVERS?

Finally, you must deal with the question, "Do I use aircraft to determine system cumulative leakage?". Consideration of the following information may make that decision easier.

The FCC considers a CLI as a snapshot of your system to determine its total cumulative contribution to potential aircraft interference. Recent question and answer sessions have indicated that they would like the annual CLI pass of the system to take about two weeks with a four week maximum. System size coupled with available staff may make a flyover the only practical means to accomplish this task within that time frame.

Additionally, a ground based CLI must cover a minimum of 75% of your system. Both the I_{∞} and the I_{3000} formulas contain correction for partial rideouts, therefore it may be a disadvantage to miss up to 25% of the plant. Inaccessible easements, rough terrain, fenced property, etc. may make sufficient coverage impractical.

The simple estimate of cost to conduct a quick pass of the system and compute the data when compared with a flyover estimate may make the decision for you. Distributing flyover costs among neighboring systems should also be factored within these estimates.

It is very important to remember that a system that cannot pass a ground-based CLI calculation, due to unrepaired quarterly monitoring backlogs, is unlikely to pass a flyover. Be sure the system is tight before spending time and money in aircraft.

LEAKAGE IS A MANAGEMENT PROBLEM

You must gain the support of management to provide the labor and material resources necessary to accomplish this task. Without a cooperative effort, the expectation of failing your first CLI is almost certain. Managers take note. The Cable Branch of the FCC has clearly stated that submission of a failing CLI on or before the July 1, 1990 deadline requires the immediate voluntary shut down of all channels within the aeronautical bands until a passing CLI submission can be produced. Upon receipt of the failing report, the FCC will dispatch an inspector to confirm the discontinuance of their use and report any noncompliance conditions which may result in the possible assessment of fines.

In conclusion, plan the implementation of an aggressive, routine leakage monitoring and repair program including an annual CLI computation strategy or a plan for the operation of a 20-CHANNEL SYSTEM. The choice is yours. If you have not already started, it may be too late.

REFERENCES

FCC Rules, Part 76.