INTERPRETATION OF AIRBORNE LEAKAGE DATA

Chris Duros
Edwin L. Dickinson

CableTrac, Inc.

ABSTRACT

Qualification of cable systems for leakage integrity is being performed by both ground and airborne procedures. A correlation of the airspace and ground measurements was established by the Advisory Committee on Cable Signal Leakage in the late 1970s. This data was taken on a relatively few cable systems and is, therefore, subject to refinement as more data is collected. Some initial observations of recent data provide certain insights into the leakage patterns observed in airborne observations and their sources on the ground. The effects of large single leaks on these patterns, some probable causes, and the implications on ground monitoring procedures are treated in this paper.

You would think that enough had been said about cable signal leakage to last a lifetime. Unfortunately, leakage control probably will last a lifetime and the discussion may never be done. When the FCC rules for qualification of cable systems to the leakage standards become effective in July, 1990 we will only be at the "first hurdle in the race" since qualification must be done yearly and perhaps forever. Leakage is a relatively simple subject on the surface, however, there are many nuances some of which we have yet to learn.

The cable industry has gathered considerable data taken both from ground and airborne measurements. There is a pressing need to investigate correlation between ground and air results. To date, little work has been done toward investigating correlations because of a lack of concurrent ground/airborne data plus the complexity of the situation. Analysis of data taken on a few systems has shown major disparities between ground and airborne results. In these cases the airborne data usually indicates more leakage signal in the airspace than predicted by the groundbased CLI. As a matter of fact, flyover measurements of some systems look very bleak indeed, with large sections of the system showing leakage in excess of the limit of ten microvolts per meter (10uV/m) at 1500 feet above the cable system.

THE FCC REQUIREMENTS AND THEIR IMPACT

In order to better understand the governing factors let us review some of the Part 76 rules and their implications.

Sections 76.605 and 76.611 of the FCC rules require limitation of leakage from any leak to 20 uV/m at a distance of 3 meters (10 feet), while 76.613 prohibits harmful interference regardless of the magnitude of the leak. Calculation of CLI per 76.611(a)(1) requires only that leaks of 50 uV/m or greater be included. Section 76.611(a)(2) perscribes a 10 uV/m total leakage limit at 450 meters (1500 feet) above the cable system.

The implications of these sections relevant to this discussion are:

1. Leaks greater than 20 uV/m at 3 meters are in violation. Smaller leaks are also in violation if they cause harmful interference.

2. In the calculation of CLI, leaks smaller than 50 uV/m need not be included. The reason for this is that these smaller leaks are of minimal significance in the total field.

3. In a flyover measurement the limit of 10 uV/m at 450 meters (1500 feet) above the cable system, could be caused by a single leak. Such a leak measured on the ground at 10 feet, would have to be 150 times larger, (the ratio of 450 meters to 3 meters) or 1500 uV/m in order to equal this threshold.

It is interesting to note that the 1500 uV/m field strength at 10 feet is 75 times the permissible value of 20 uV/m. This is equivalent to 5625 times the power or 37.5 dB excess. You must admit that this is a very wide and generous margin, courtesy of the FCC.

FLYOVER EXPERIENCE

Getting back to actual flyover results, the data from most systems shows at least one area where the 10 uV/m threshold is exceeded. This is in contrast to the ground monitoring and CLI data which usually indicates that the system complies. Although this may seem strange, several factors can contribute to the effect. Remember that the ground measurements for CLI probably required substantial elapsed time, so that it is likely that during the ride-out new leaks developed in the areas which were first measured. In fact, if the CLI was measured and computed and no further monitoring was done prior to a later flyover, the opportunity existed for many new leaks to develop in the interim.

Addressing the fact that most flyovers do show some areas where the leakage exceeds 10 uV/m, the FCC rules have made still another provision in the cable operators favor. This is known as the "90th percentile" and requires that only 90% of the points taken where digital recording is used, show values equal to or less than 10 uV/m. As a result of this provision a cable system showing a few areas of excessive leakage can still qualify. In review, it is fair to say that the FCC regulations are generous and allow for compounded problems without unduly penalizing the cable operator. Nevertheless, a flyover report showing substantial areas of excessive leakage can be very discomforting.

In some flyover reports areas of excessive leakage are seen as circular or eliptical patterns. Figure 1 illustrates this effect. The regularly spaced lines depict the path of the overflight to scale on a latitude/longitude plot. Areas of signal strengths greater than 10uV/m are shown by heavier lines. This plot is simulated because of the inability to reproduce the colors normally used to portray different signal strengths on the flight path.

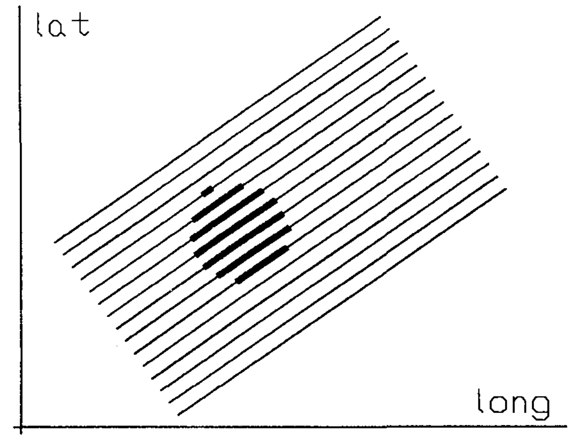

Figure 1

ANALYSIS OF THE EFFECT

To investigate this effect we will consider the area of excessive leakage generated at 1500 feet above the cable system by a single large leak. Assume that the leak radiates equally in all directions producing a hemispherical pattern (this assumption is unlikely but may be used for this simple example). Figure 2 illustrates this model. An airborne detector directly over the leak (point "A") would receive the maximum energy while in other locations the energy from the leak would have to travel further thereby reducing its effect. For instance, a single leak measuring 15 uV/m at 1500 feet directly above (point "A"), would measure only about 71% of that (about 10 uV/m) if the observer were 1500 feet away from the center (point "B"). This reduction in field strength is governed by the length of the hypotenuse of the triangle formed by the altitude and the radius. The hypotenuse is, in this case, 1.414 times the length of either leg. Signal traveling 1.414 times the distance will produce a received amplitude proportional to 1/1.414 or about 71%. Table 1 has been developed to illustrate the extent of this effect upon the signal strength at 1500 feet from a single large leak. The table records the radii and areas of the circles bounding the region of excessive signal at 1500 feet altitude.

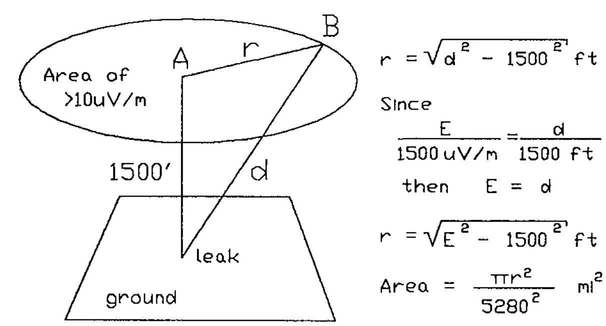

Figure 2

TABLE 1

Magnitude of leak uV/m	Circle of excess signal at 1500' radius (ft.)	area (sq.mi.)
1,500	0	0
2,000	1,323	.197
3,000	2,598	.761
4,000	3,708	1.55
5,000	4,770	2.56
10,000	9,887	11.0
20,000	19,944	44.8

As an example, a single leak of 1500 uV/m will cause only a single point of threshold level directly over the leak while a leak of 3000 uV/m generates a circle of excess single strength with a radius of 2598 feet and encompasses an area of about 0.76 square miles. The dimensions for larger leaks increase rapidly. From the table it can be seen that a single large leak can have a devastating effect on the overall survey results and, as a matter of fact, can be a serious threat to the aircraft navigation and communication circuits which we are trying to protect.

Experience has shown that hot spots observed from the air can often lead directly to the locations of large leaks when they are the sole cause. In very leaky systems where there are many intermediate size leaks the areas of excess signal shown in Figure 3, generally follow the areas of the plant which are in worse shape rather than circular or eliptical shapes illustrated in figure 1.

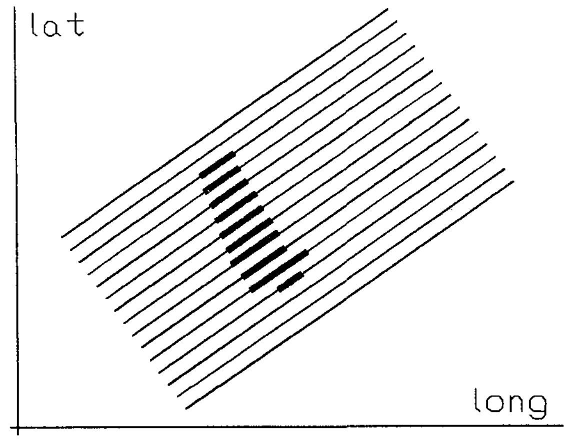

Figure 3

IMPLICATIONS

The implications of all this are a little more subtle. You may ask, "but, where is this large leak which I did not see in my monitoring?" It is possible that it developed since you rode out that area, however, it is also possible that it existed at a fair distance off of the right-of-way so that it was overlooked as you surveyed that area of the plant. Or, perhaps, it is in a high-rise building where you probably could not get close enough to observe it.

The good news is that if you have a relatively clean plant and one of these "blockbusters" has made your aerial survey look far worse than expected, you probably have a simple job to locate and repair. The bad news is that you may have to develop some other monitoring techniques in order to avoid missing these big ones in difficult to access locations.