ADVANCES IN CLI FLYOVER MEASUREMENTS, THE HELICOPTER APPROACH.

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During 1988 many engineers and field technicians experienced irregularities when trying to correlate the fixed-wing airplane-type CLI FLYOVER test data with the results of their ground surveys. The inconsistencies seemed to be related to the fact that the test dipole was not operating in open space, the high cruising speed of the aircraft and the cockpit's limited visibility. During a helicopter flyover the test antenna is front-mounted, in open space. The helicopter can cruise at moderate speed and the cockpit's vertical visibility is unlimited.

The presentation compares and analyzes the radiation pattern characteristics of the test dipole under the fuselage and in front of the aircraft. This is followed by a discussion of the triangulation method to determine exact leakage source locations. Finally, a few observations are presented about digital leakage recordings and aircraft position identification methods.

RADIATION PATTERN ANALYSIS OF THE HALF-WAVELENGTH DIPOLE, MOUNTED UNDER THE FUSELAGE OF THE AIRPLANE

The "eye" of the CLI FLYOVER signal leakage detection system is the test antenna. If the "eye" is out of focus, the vision is blurred, then the test results become questionable. A radiation detecting antenna, which exhibits poor impedance match, low antenna-gain, or scattered and bi-directional radiation patterns, may produce extremely high or very low system leakage readings. It can also allocate high leakage intensities to areas which may prove to be clean later at the confirmation CLI FLYOVER.

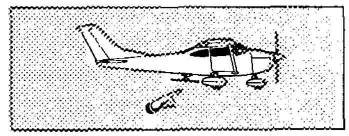

FIGURE 1

Fixed-wing airplane flyovers in the past used almost exclusively a half-wavelength GAMMA-MATCHED dipole mounted coaxially under the airplane's fuselage.(Figure 1). An open space half-wavelength dipole exhibits the well-known bi-directional 8-shape radiation pattern in the horizontal plane. (Figure 2).

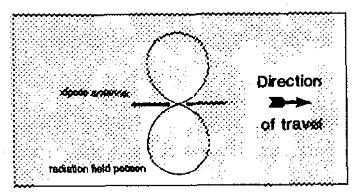

FIGURE 2

The coaxially installed gamma-matched dipole has a deep radiation pattern null in the travel direction while exhibiting two asymmetrical maxima perpendicular to the main axis of the airplane. The critical issue is not how the dipole was installed under the airplane. Rather, it is the fact that the dipole is **not operating** in open space. The fuselage of the airplane becomes an essential part of the antenna system, affecting the vertical radiation pattern of the dipole.

In the *first approximation* this is the classical example of a dipole, located parallel above the ground. In the case of the airplane, it is a dipole, mounted below a large and flat metal surface at a distance *d.*

Radiation pattern conditions can be analyzed by the application of a basic electromagnetic principal, the IMAGE THEORY. Figure 3 illustrates the position of the real antenna and its image on both sides of the metal plate. The current of the "image" dipole is equal in amplitude but 180° out-of phase, under ideal conditions.

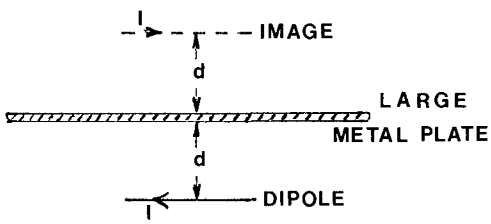

FIGURE 3

At a distant point in the far-field zone, the vertical component of the field intensity will be composed of the direct and *reflected signals*, as described by the following equation:

$$\mathcal{E}_v = 2E\sin\left(d_r \sin\alpha\right)$$

E = Maximum field intensity of the half-wavelength dipole in open space, in the = 90° direction.

$d_r = \frac{2\pi}{\lambda} d$, distance in electrical angles.

2E stipulates total reflection from the perfectly conducting metal surface.

Figure 4 illustrates vertical plane radiation patterns of a half-wavelength dipole, located at various distances under a perfectly conducting large metal plate.

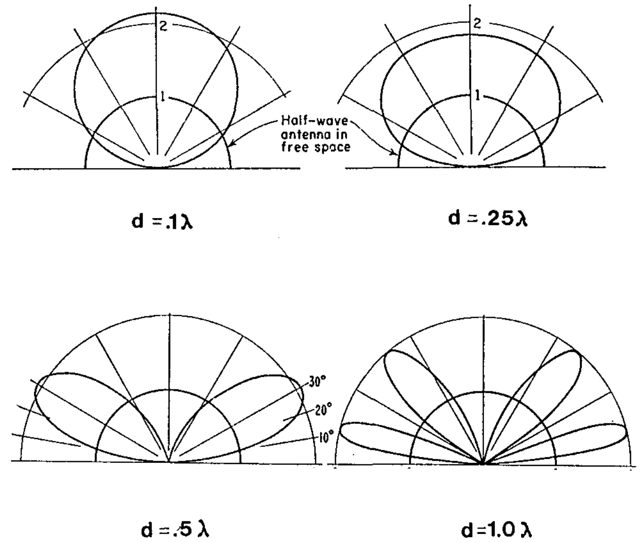

FIGURE 4

Below a distance of 0.25λ the pattern remains a single wide lobe. At 0.33λ it becomes three-directional. Then, between d = 0.5λ to d = 1.0λ the pattern breaks up rapidly into multi-lobes.

Thus conditions under the airplane are a function of the dipole's distance from the fuselage. If the distance is less than 0.33λ, two important antenna parameters, the impedance match and the antenna gain suffer. At 0.33λ or greater distances the radiation pattern breaks up into bi-directional multi-lobe modes, a highly undesirable situation.

Actually, radiation pattern conditions are not even close to those ideal assumptions of the simplistic image theory.

* The conductivity of the fuselage is less than extremely high.

* The fuselage is not flat, nor infinitely large.

* The surface of the fuselage cannot be considered perfectly smooth.

* The space above the dipole is not a single metal sheet. It is loaded with additional material of metal and non-metal substance.

Therefore, the current of the "image" dipole will not be equal with the amplitude of the real dipole, nor will be the "image" current exactly 180° out-of-phase. Also, the leakage signals emanating from the system below may not be perfectly horizontally polarized, or horizontally polarized at all, resulting in extremely complicated and uncontrolled phase cancellations. The real world radiation patterns of the dipole will be transformed into configurations similar to those of Figure 5.

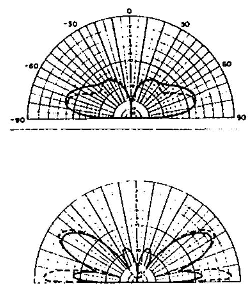

FIGURE 5

THE MULTI-ELEMENT TEST ANTENNA APPROACH, MAST-MOUNTED IN FRONT OF THE HELICOPTER

If the test dipole mounted below the fixed-wing airplane's fuselage develops impedance match, antenna gain, and radiation pattern difficulties why not avoid these problems by moving the test antenna away from the aircraft? Figure 6 shows the solution. The test antenna is mounted in *front* of the helicopter, operating in OPEN SPACE. Neither the impedance match and antenna gain, nor the radiation pattern characteristics will be affected by the cockpit and fuselage of the helicopter. They are located way behind the antenna.

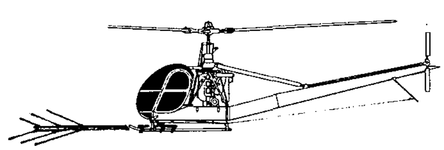

FIGURE 6

The application of a multi-element log-periodic antenna (Figure 7) eliminates an additional difficulty observed in the case of the test dipole: the bi-directional characteristics of the radiation pattern.

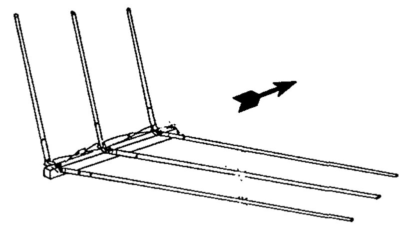

FIGURE 7

A three-element log-periodic antenna, tuned to the relatively narrow 108 to 136 MHz frequency range, has 3 dB gain over a half-wavelength dipole, a *single* 60° wide main-beam toward the front, (70° wide in the vertical plane), and a very favorable 20 dB front/back ratio. (Figure 8).

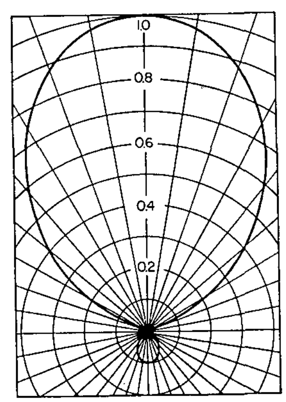

FIGURE 8

The high front/back ratio of the log-periodic multi-element antenna mast-mounted *in front* of the helicopter reduces the coupling between the mainframe and the antenna to a minimum. Consequently, the radiation pattern of the multi-element test antenna remains practically intact.

The helicopter mounted test antenna will "sweep" the cable plant with a single beam, about 60° wide. Also, due to the 3 dB antenna gain, (-3 dB points at 30°) the antenna will deliver the same signal levels obtained from the half-wavelength dipole in open space.

LEAKAGE SOURCE IDENTIFICATION

BY THE TRIANGULATION METHOD

The helicopter-type CLI FLYOVER testing has another tremendous advantage: its superior mobility and ability to pinpoint the exact location of the leakage source.

The helicopter can fly at a reduced speed and turn around quickly in a small circle. Then, with the aid of the front-mounted, highly directive antenna the source of leakage can be found by the triangulation method. Follow the flight of the helicopter of Figure 9. The helicopter approaches a strong leakage area (#1). The pilot is directed to make a right turn (#2). Finally, a new right turn verifies the leakage source (#3). This is in sharp contrast to the high cruising speed and limited turn-around capability of the fixed-wing airplane, compounded with the symmetrical and bi-directional pattern of the dipole. Leakage source identification, which is impractical with the fixed-wing airplane, is a high value benefit of the helicopter-type CLI FLYOVER, assisting CATV operators and field engineers in the fast and efficient identification of major system leakages.

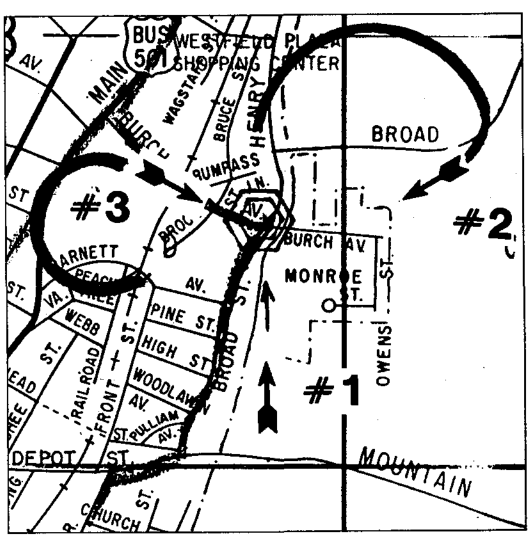

FIGURE 9

VERTICAL VISIBILITY & CRUISING SPEED

CONSIDERATIONS

From the fixed-wing airplane's cockpit the view is limited to one side and to the front of the airplane. (Figure 10). Neither the pilot nor the testing engineer is in a position to follow and observe the terrain below. Therefore, the fixed-wing airplane must fly parallel patterns to cover the entire area, using LORAN for position identification and recording purposes.

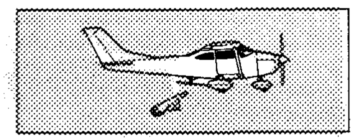

FIGURE 10

Then, due to the high speed of the aircraft which prevents the use of analog instrumentation, the signals from the receiver must be digitally processed, feeding the results into a chart recorder.

This enthusiastic reliance on the LORAN-C and a chart recorder has two serious flaws.

The first one, discussed briefly before, is the fact that the LORAN indicates the aircraft's vertical position over the ground, while the test dipole may receive the strongest leakage from completely different directions. The discrepancy, due to the bi-directional and scattered nature of the radiation pattern can be as high as 2500'.

The second problem area: the chart recorder's inability to differentiate between desired and undesired signals. For a chart recorder every received transmission is a potential leakage problem. The most frequently received spurious signals include harmonics of broadcast stations, two-way radios or CB transmitters, and interference from high voltage transmission lines, welding shops, lightning or other statics.

Observe the excellent vertical visibility from the helicopter's cockpit (Fig. 11). Helped by the low cruising speed of the rotary wing airplane, the test engineer can follow the trunk and distribution lines and mark the exigencies of the cable plant on the system map *directly* in front of him.

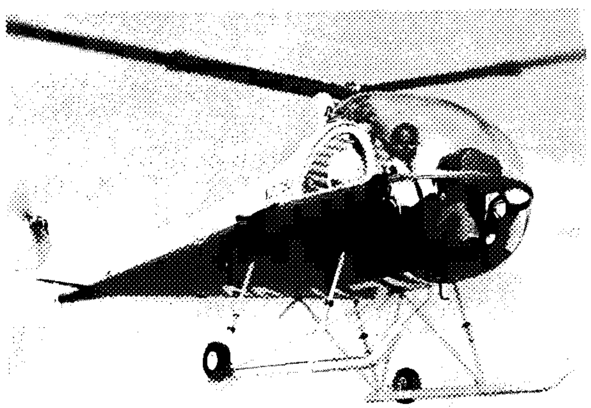

FIGURE 11

The system will be surveyed exactly the same way as conducted during the ground survey. The test results will be marked on a *real system map*, easily understood and appreciated by the system engineer in charge of system leakage integrity.

Major potential aeronautical leakage sources such as high-rise buildings, hotels, and skyscrapers which cannot be checked from the street level are pinpointed from the low cruising speed helicopter. The leakage concentrations can be then identified by the triangulation method.

Last but not least, the helicopter CLI FLYOVER engineer can reliably read the meter of his ANALOG COMMUNICATIONS RECEIVER in the slow moving aircraft. Only those meter movements will be recorded which were accompanied by the 1000 Hz tone modulation of the test signal. All other meter movements will be discounted because they did not emanate from the cable plant.

A receiving antenna, 1500 feet above ground, can pick-up an enormous variety of spurious transmissions which, if taken by their face value, can skew the test results.