ANTENNA SITE & HEAD-END SELECTION PROBLEMS IN BIG CITY CATV SYSTEMS

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There are at least three schools of thought on the success of Big City CATV. One is classified by pressing hard for two-way communication, emphasizing the need for customer oriented special services. Wall Street was sold on this idea, and the financial resources are available in most cases to invest and expand two-way communication facilities. No practical experience has proven or disproven the impact of two-way communication yet.

The second group of experts maintain that grand scale local origination, oriented toward local interests, local ethnic and political groups, is the answer for Big City CATV.

Still a third group of experts refuses to accept two-way communication and local origination as the only avenues to succeed in Big City CATV. They believe, and this consulting engineer is one of them, that while local origination and two-way communication represent significant contributions, the majority of Big City people will sign up for CATV if they experience off-the-air reception difficulties, such as ghosty pictures, RF or power line interference problems, missing or disappointing color fidelity, etc.

Thus, the next logical question is: Can CATV really offer better off-the-air reception in Big Cities? All parties must agree: if we do not ascertain ghost and interference free, true color fidelity picture at the head-end, the source of all cable signals, then the quality will not be improved after cascading 25 or 45 mainline amplifiers.

Selection of the proper antenna site, meaningful recommendations for the height and structure of antenna tower, size and configuration of the antenna arrays, can make or break any Big City CATV system.

Before any head-end site is considered for lease or purchase, a signal survey should be performed. Through a signal survey, and only through an on-site signal survey will the engineer be in the position to make recommendations based on actual picture quality and interference observations, not available through computer runs or theoretical signal strength speculations.

THE PREPARATION

Before leaving for a signal survey, it is good engineering practice:

a. To perform a paper study
b. To prepare a signal direction sheet
c. To calibrate and check the test instrumentation.

The need for a paper study may not be that obvious for a Big City survey, but it is a comfortable feeling to have all technical data, program information, distances and bearings available at your fingertips. This will enable the survey engineer to concentrate on testing, while spending less time searching for data and information.

The preparation of a Signal Direction Sheet may eliminate the continous and time consuming search for stations, and in a single 0^{o} to 360^{o} rotation all TV stations could be surveyed and properly recorded.

AT THE SURVEY SITE

Hourly video and sound carrier level recordings on distant stations are in order. However, there is no reason to make hourly interval readings on local channels; their strength will show no significant change during the period of signal survey.

Three day is the minimum recommended survey time for any Big City signal survey, but a 5 day survey could produce even more reliable results. A single day survey may lead to over-optimistic or over-pessimistic conclusions about picture quality, noise and interference problems.

Checking of a single site is false economy. Only several surveyed sites will permit the engineer to match engineering requirements with financial or zoning restrictions, when evaluating survey results.

Constant picture quality and interference observations are the most important survey objectives of any Big City Survey. For these observations the use of a big screen color TV receiver is mandatory. Ghosting and smearing of the picture, color distortions, the presence of interference signals are readily visible on a large picture tube color set. Double shielded cable from the test antenna will reduce direct pick-up problems. A well balanced, grounded balun at the antenna terminals of the monitor receiver will further reduce direct pick-up problems.

An 8 to 10 element Log-Periodic antenna is ideal for survey purposes. A well designed LP antenna exhibits good directivity, (single main lobe), will yield a minimum of 6 dB gain on low-band and more than 8 dB gain on high-band, while maintaining small back and sidelobe conditions.

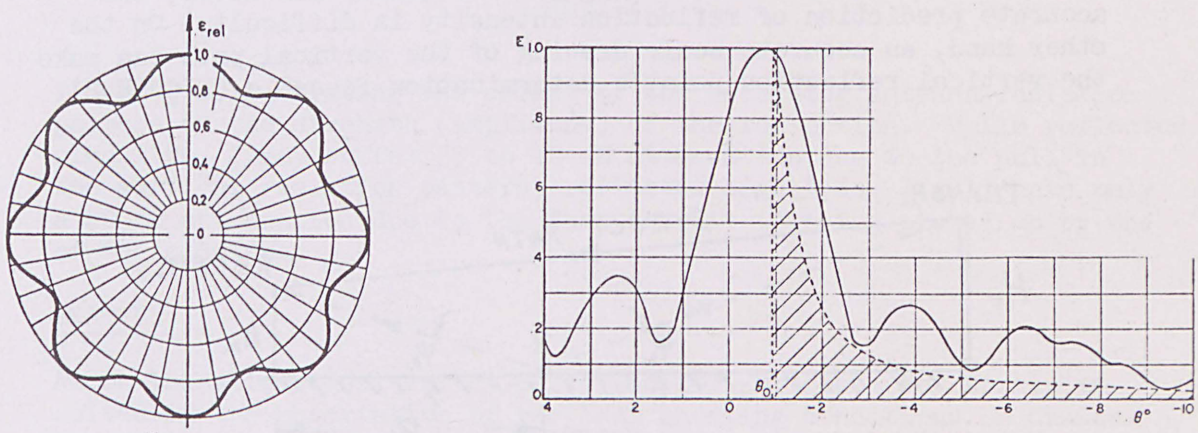
ANALYZING AND TESTING GHOSTING CONDITIONS

Ghosting is one of the most troublesome off-the-air picture interference in any Big City CATV. In order to perform meaningful measurements, to determine the nature, the source and the severity of ghosting, to conduct certain tests for their reduction or complete elimination, it is essential to clarify what are the parameters determining the strength (severity) and nature of ghosting.

Vertical (ground) reflection conditions are influenced by the following factors:

a. The transmitting antenna's radiation pattern.
b. The vertical path profile between the transmitter and the receiving antenna.
c. The reflection coefficient of the ground.
d. The receiving antenna's radiation pattern.

Most TV transmitting antenna radiation patterns are omnidirectional in the horizontal (E) plane. However, in the vertical (H) plane, the patterns show considerable directivity (FIGURE 1). Radiation into the direction of the reflecting ground surface may be significant or well attenuated, depending on the vertical radiation patterns of the TV transmitters. This is one reason why several TV transmitters, operating from the same antenna structure, do not generate the same ghosting conditions.



OMNIDIRECTIONAL PATTERN

HORIZONTAL (E) PLANE

HIGHLY DIRECTIVE PATTERN

VERTICAL (H) PLANE

FIGURE 1

To determine the location of possible ground reflection points it is necessary to construct a scale drawing of the vertical path profile between the transmitting antenna and the surveyed CATV site, showing the exact ground contours. This is best accomplished by using the $7\frac{1}{2}$ or 15 minute U.S. Geological Survey Maps for that area. The distance and elevation data obtained from the maps could be plotted to form a vertical profile by using range-in-feet and elevation-in-feet above sea level measurements for the two ordinates.

The reflection coefficient of the ground depends on surface roughness, type of soil, moisture content of the soil, vegetation growth, frequency of transmission, weather and season. It is also a function of the grazing angle, the angle between the incoming signal and the surface.

The ground reflection coefficient is a complex number, having a certain magnitude and phase, as described by the following mathematical expression:

$$\rho_h = \frac{\sin\psi - \sqrt{n^2 - \cos^2\psi}}{\sin\psi + \sqrt{n^2 - \cos^2\psi}} = |\rho_h| e^{j\psi_h}$$

where: ρ_h = The ground's reflection coefficient for horizontal polarization

ψ = The grazing angle

$n^2 = \varepsilon_r - j60\sigma\lambda$

ε_r = The relative permittivity of the ground

σ = The conductivity of the ground.

In view of the many variables and unknown quantities above, the accurate prediction of reflection intensity is difficult. On the other hand, an accurate scale drawing of the vertical path can make the vertical reflection point's determination feasable (FIGURE 2).

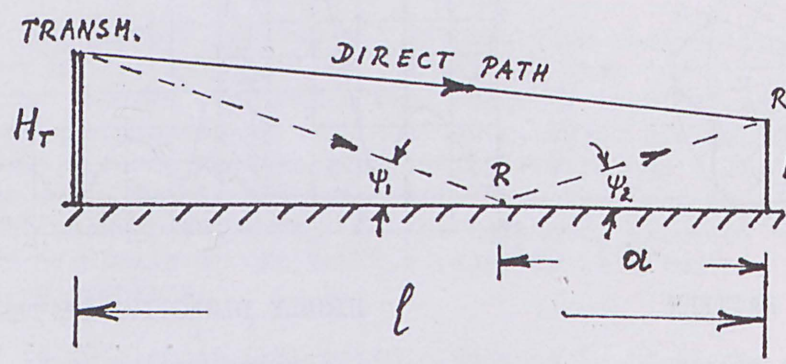


FIGURE 2

The distance of the reflection point from the receiving antenna may be calculated by:

$$a = \frac{h_r \ell}{H_T + h_r}$$

where R = Specular reflection point
ψ_1 = Angle of incident ray
ψ_2 = Angle of reflected ray.

By definition R is the point where $\psi_1 = \psi_2$

The vertical sidelobe structure of the test antenna may also have significant influence on ground reflections. This is exemplified by

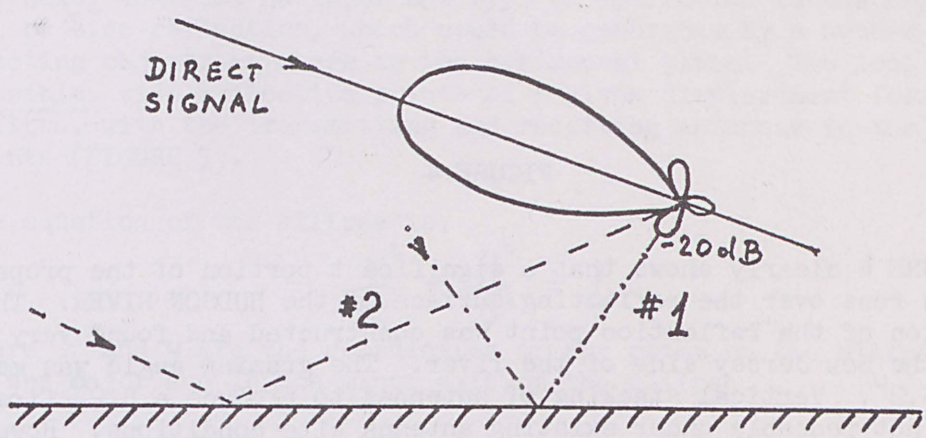


FIGURE 3

FIGURE 3, illustrating the effect of the receiving antenna radiation pattern on the strength (amplitude) of the reflection. While reflected signal No. 2 may suffer 35 to 40 dB attenuation due to the null in the vertical radiation pattern, reflected signal No. 1 will have only a 20 dB attenuation due to the fact that it is being picked up by one of the sidelobes.

EXAMPLE

An on-the-site signal survey performed for Fort Lee, New Jersey resulted in the observation of vertical ghosting conditions on Channel 5, New York.

Pertinent site and propagation information data:

Height of receiving site	:	250' ASL
Height of CATV antenna	:	550' ASL
Distance to Channel 5 transmitting site (Computer calculated)	:	6.35 miles (33,600 feet)
Height of Channel 5 antenna	:	1330' ASL

A signal path profile was constructed based on information obtained from a $7\frac{1}{2}$ minute U.S. Geographical Survey Map (FIGURE 4).

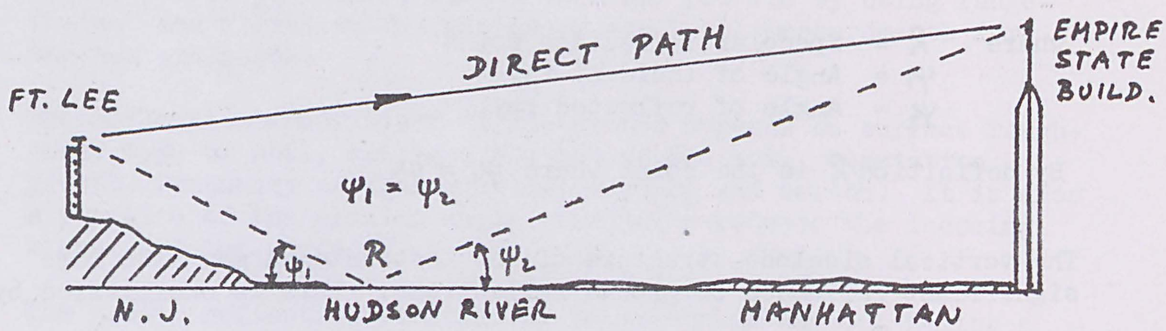


FIGURE 4

FIGURE 4 clearly shows that a significant portion of the propagation path runs over the reflecting surface of the HUDSON RIVER. The location of the reflection point was constructed and found very close to the New Jersey side of the river. The grazing angle was measured as 5.2°. Vertical stacking of antennas to produce a 5.2° first null was not feasable under existing antenna site conditions. However, movement of the antenna away from the edge of the roof resulted in considerable improvements: a portion of the roof shielded the reflection spot while permitting undisturbed propagation of the direct signal.

Note: The vertical scale on this figure has been distorted versus the horizontal scale, thus the reflection angles are considerably magnified.

REFLECTION CALCULATIONS

The reflected signal, whether it is a vertical or horizontal reflection, must always negotiate a longer path than the direct signal. Therefore, the reflected signal will be delayed. Any horizontal displacement on the TV screen is directly related to the time delay, which in turn, can be converted to path length differences between the reflected and direct signals. TABLE 1 is a tabulation of calculated time delays and delay paths as a function of horizontal displacement and screenwidth. Delay path is defined as the difference (in feet) between the reflected and direct path.

	14" SCREEN		17" SCREEN		20" SCREEN	
	TIME DELAY	PATH	TIME DELAY	PATH	TIME DELAY	PATH
1/4" GHOST	1.14 μsec	1125'	0.93 μsec	920'	0.8 μsec	783'
1/2" GHOST	2.28 μsec	2250'	1.87 μsec	1840'	1.59 μsec	1565'
1" GHOST	4.57 μsec	4500'	3.74 μsec	3680'	3.18 μsec	3130'
2" GHOST	9.14 μsec	9000'	7.48 μsec	7360'	6.36 μsec	6260'

TABLE 1

The next, and just as important type of reflection is the horizontal or side-reflection, which could be generated by a number of reflecting objects anywhere in the horizontal plane. The loci of possible side-reflection points of a given displacement form an ellipse, with the transmitting and receiving antennas in the focal points (FIGURE 5).

The equation of the ellipse is:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

where x and y are the coordinates of any point on the ellipse, $2a$ is the major and $2b$ the minor axis of the ellipse.

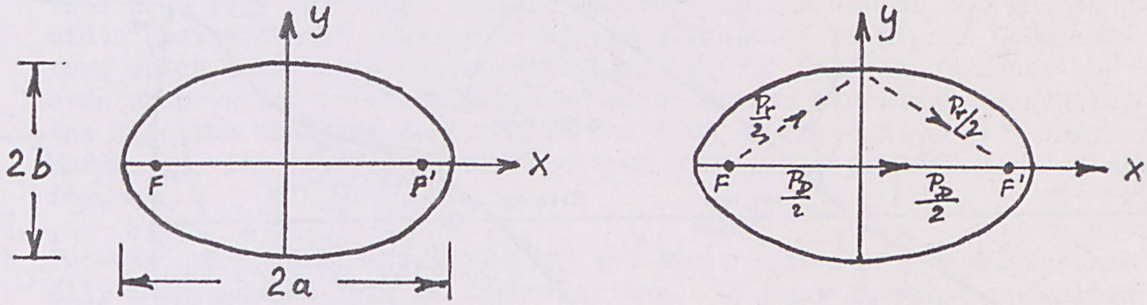


FIGURE 5

Substituting a and b in the equation with P_D (Direct signal path) and P_r (Reflected signal path) as the major and minor dimensions, FIGURE 5, the new equation will be:

$$\frac{x^2}{\left(\frac{P_r}{2}\right)^2} + \frac{y^2}{\left(\frac{P_r}{2}\right)^2 - \left(\frac{P_D}{2}\right)^2} = 1$$

EXAMPLE

The construction of the reflection ellipse is illustrated by the information obtained during the HICKSVILLE, New York signal survey.

We measured a horizontal displacement of 2" on a 14" wide TV screen, representing 9 microseconds in time-delay, or 9,000' in path difference ($P_r - P_D$) between reflected and direct signal path. The computer calculated distance between the transmitter and receiving antenna site was found P_D =23,7 miles = 124,136 feet. Thus, the reflected signal path should be:

$$P_r = P_D + 9{,}000 = 133{,}136 \text{ feet}$$

The major axis of the reflection ellipse is: $a = \frac{P_r}{2} = 66{,}568$ feet

The minor axis of the reflection ellipse is: $b = \frac{\sqrt{P_r^2 - P_D^2}}{2} = 21{,}800$ feet

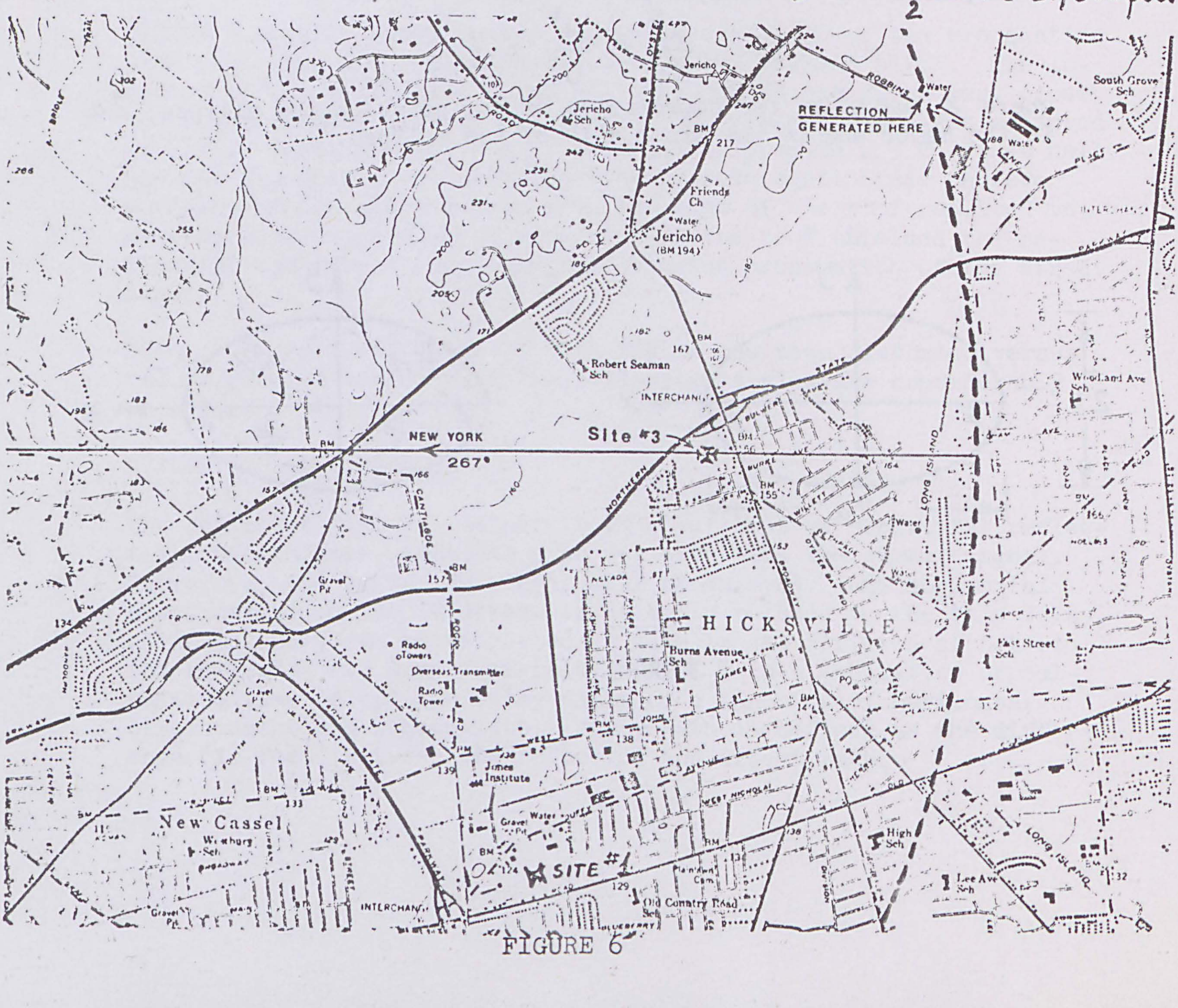


FIGURE 6

On FIGURE 6, the reflection ellipse is transferred to the pertinent section of the HICKSVILLE $7\frac{1}{2}$ minute topographical map. Note that the ellipse crosses a watertank located at 30° Azimuth from the survey site. Reflections were generated by this watertank. This has been proven by rotating the survey antenna into the direction of this watertank. The 2" ghost became strong and clear. With other words, while the main lobe of the test antenna was receiving the reflected signal the direct signal became strongly attenuated by the limited side-lobe pick-up of the survey antenna, resulting in a ghost dominated picture. The measured and calculated reflection information provided the basis for straight forward horizontal array-stacking information in order to achieve protection against ghosting.

INTERFERENCE SURVEY

RF interference may occur anywhere in the CATV frequency spectrum, and the problem of checking for its presence and intensity is manyfold. The old approach has been to tune a Signal Level Meter through its frequency range, searching for interference signals. However, the need for frequent band-switching, changing of meter scales, calibration of the meter with varying frequencies, and last but not least, the constant concern that short period transmissions were missed, made the SLM process tedeous and unreliable.

For RF interference surveillance work the spectrum analyzer, with its fast sweep over a wide or very narrow spectrum, less than 1 microvolt sensitivity, 60 to 70 dB dynamic range presentation is a far superior instrument. Better quality spectrum analyzers provide a continous visual coverage of the RF spectrum up to 1200 MHz, they exhibit all signals amplitude and frequency calibrated, easily distinguishing small and large (60 dB) signals next to each other. This is a very important feature compared to the 400 to 600 kHz bandwidth (between half power points) specifications of Signal Level Meters which make those instruments unusable for the measurements or even observation of closely spaced interference signals. Meanwhile, the spectrum analyzer can zoom in and display (investigate) a very narrow portion (5 kHz) of the spectrum with great precision and clarity.

Two-way communication traffic, CB and amateur communication are usually intermittent type of transmissions. If they generate undesired harmonics falling into the frequency range of our interest, the amplitude and frequency of these transmissions can be reliably determined with the aid of a spectrum analyzer.

AM and FM transmitters may also radiate spurious signals, or their strong carriers could overload preamplifiers and converters. Again, a spectrum analyzer will exhibit desired and undesired signals simultaneously, and amplitude/frequency calibrated permitting fast and reliable recording of interference conditions.

Powerline (AC) noise should be first observed on the screen of the monitor receiver as random white spots, or wide bands of lines moving up or down. Again, the spectrum analyzer will not only demonstrate which of the channels suffer the most of AC noise, but the amplitude of the fast moving pulses could be read in dB, thus establishing a firm level of existing AC interference conditions.

TIPS FOR A SUCCESSFUL ON-SITE SURVEY

* DO NOT settle with a single site survey. That might be false economy. Only several surveyed sites will provide the option of matching engineering requirements with financial limitations.

* DO your homework before starting an on-site survey. Computer runs, local maps, $7\frac{1}{2}$ or 15 minute series topographic maps, signal direction sheets should be at your fingertips at the start of the survey.

* DO NOT spend your time taking hourly signal level readings on the local stations if you are within a 15 to 20 mile radius of the transmitters. Their video and audio carriers (within that distance) will be solid like a rock.

* DO spend some time observing pecularities of the environment. This visual observation should include tall buildings, billboards, watertanks, high voltage transmission lines, neon signs, industrial plants, AM-FM transmitting towers, two-way communications antennas, etc. You may find an excellent correlation between the observed picture quality irregularities and the geographical location of the reflection or noise sources.

* When you CAN, arrange for the participation of the future CATV operator or his representatives on the last day of the survey. This will permit you to get them acquainted with actual picture quality conditions demonstrating some of the experienced reception problems.

There is no written scenario for a Big City Signal Survey. No two signal surveys are alike. A well documented survey, conducted by experts, may bring considerable financial rewards for the Big City CATV operator.