ANTENNA RADIATION PATTERN ANALYSIS

&

CO-CHANNEL PROTECTION

by

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INTRODUCTION

Many CATV technicians, with otherwise well-rounded backgrounds, have been forced in the past and will be required in the future to make critical antenna or antenna-array selections to avoid annoying co-channel interference problems.

This paper has been prepared to clarify:

1. What are the basic terms and classifications of antenna radiation patterns.
2. Why radiation patterns must be taken on the antenna test range.
3. How to analyze antenna radiation patterns.
4. Why radiation pattern irregularities must be given special attention.

BASIC TERMS AND CLASSIFICATIONS OF RADIATION PATTERNS

Co-channel protection is basically an antenna performance problem which is characterized by the antenna specifications. Antenna manufacturers usually publish a more or less complete list of electric parameters of their products, such as antenna gain, input match, front to back ratio, beamwidth, etc. However, this qualitative information is not sufficient for co-channel protection evaluation. For a meaningful QUANTITATIVE evaluation we must have at our disposal the actual radiation patterns, as taken on the antenna test range.

Every antenna has a three dimensional radiation pattern because it is radiating into all angles of space. However, for co-channel evaluation purposes we can limit our investigation to the horizontal (E) plane. The different co-channel offenders arrive from different AZIMUTH ANGLES, thus a vertical radiation pattern would have no meaningful information.

The horizontal radiation pattern of an antenna describes the field intensity of the radiation as a function of the azimuth angle. The pattern may be presented in polar or rectangular coordinates. Polar presentation is preferred for popular publications. This information gives an easy to understand picture of the received or transmitted power distribution. By contrast, the RECTANGULAR radiation pattern permits a presentation of much finer detail including precise dB readings of peaks and nulls.

The radial deflections on the polar and rectangular charts may be arranged in:

* Linear scale
* Power scale
* dB scale.

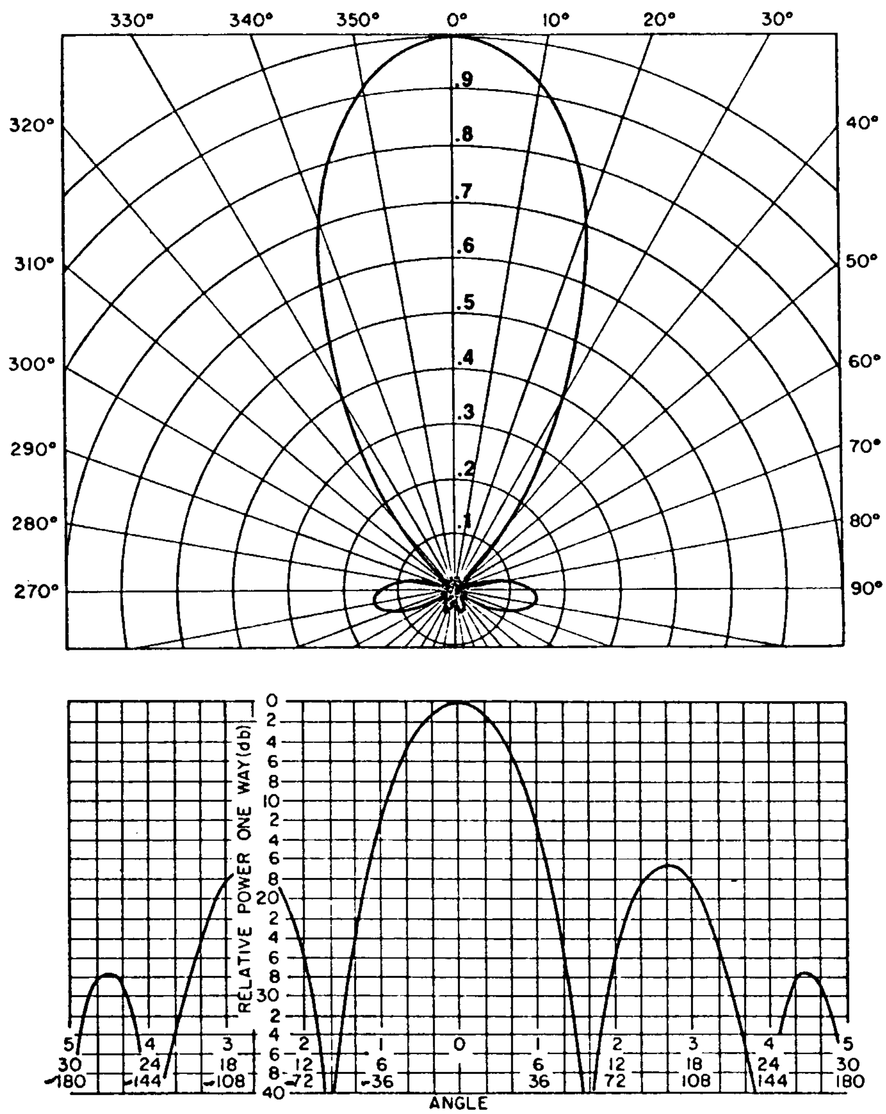

Figure 1

Compare the readability of a polar and horizontal radiation pattern presentation.

The dB scale, containing the logarithmic variations in the received signals, is the most beneficial for the examination of CATV antenna array radiation patterns.

Figure 1 presents polar and rectangular radiation patterns taken from the same antenna. It should be noted that while location, depth, and width of the null at 168° is somewhat fuzzy on the polar pattern, the rectangular pattern offers good readability and accuracy.

ANTENNA TEST RANGE AND RECORDING EQUIPMENT CONDITIONS

We realize that 99% of the CATV operators and technicians have not been involved and will not participate in antenna test range operations. But in order to comprehend the physics of antenna radiation patterns one must have a greater understanding about antenna test range and recording equipment conditions.

Usually a big, open field is selected for antenna test range purposes. The transmitting gear is established at one end and the receiving/recording gear is located at the opposite end. (Figure 2)

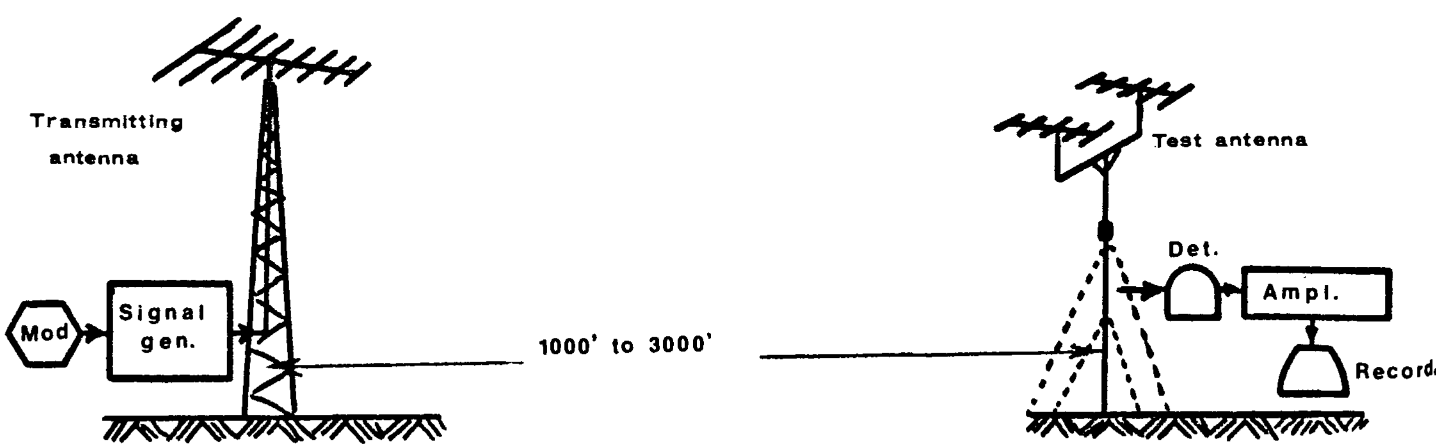

Figure 2

The modulated RF signal is beamed from the fixed high-gain antenna in the direction of the receiving (test) antenna. At the receiving end, the test antenna is rotated either manually or by motor. In both cases the rotor movement is syncronized with the recorder. The detected and amplified signal is processed through the recorder to produce a permanent chart of the radiation pattern.

There are several critical antenna test site conditions which may adversely effect the accuracy of the obtained test information :

* Separation between the transmitting and receiving antennas (1000' to 3000' represents adequate separation)
* Directivity of the transmitting antenna (a minimum of 45° beamwidth is required)
* Height of the transmitting and receiving antennas above ground (50' to 100' is a sufficient height)
* The surface quality of the antenna test range (rough surfaces are preferred).

A combination of the last two conditions contribute to reflection problems, the most serious source of errors. Ground reflection is a function of the surface configuration, type of soil, content of moisture, vegetation, weather, transmitting frequency, polarization, etc. Increasing the transmitting and test antenna heights well above ground and the installation of conductive fences perpendicular to the line of propagation are two practical means to reduce ground reflections.

A number of recording equipment conditions may also contribute to the limited accuracy of the radiation pattern:

* The instability of the transmitter and receiving equipment
* Calibration inaccuracies of the output power
* Problems inherent in the detector characteristic.

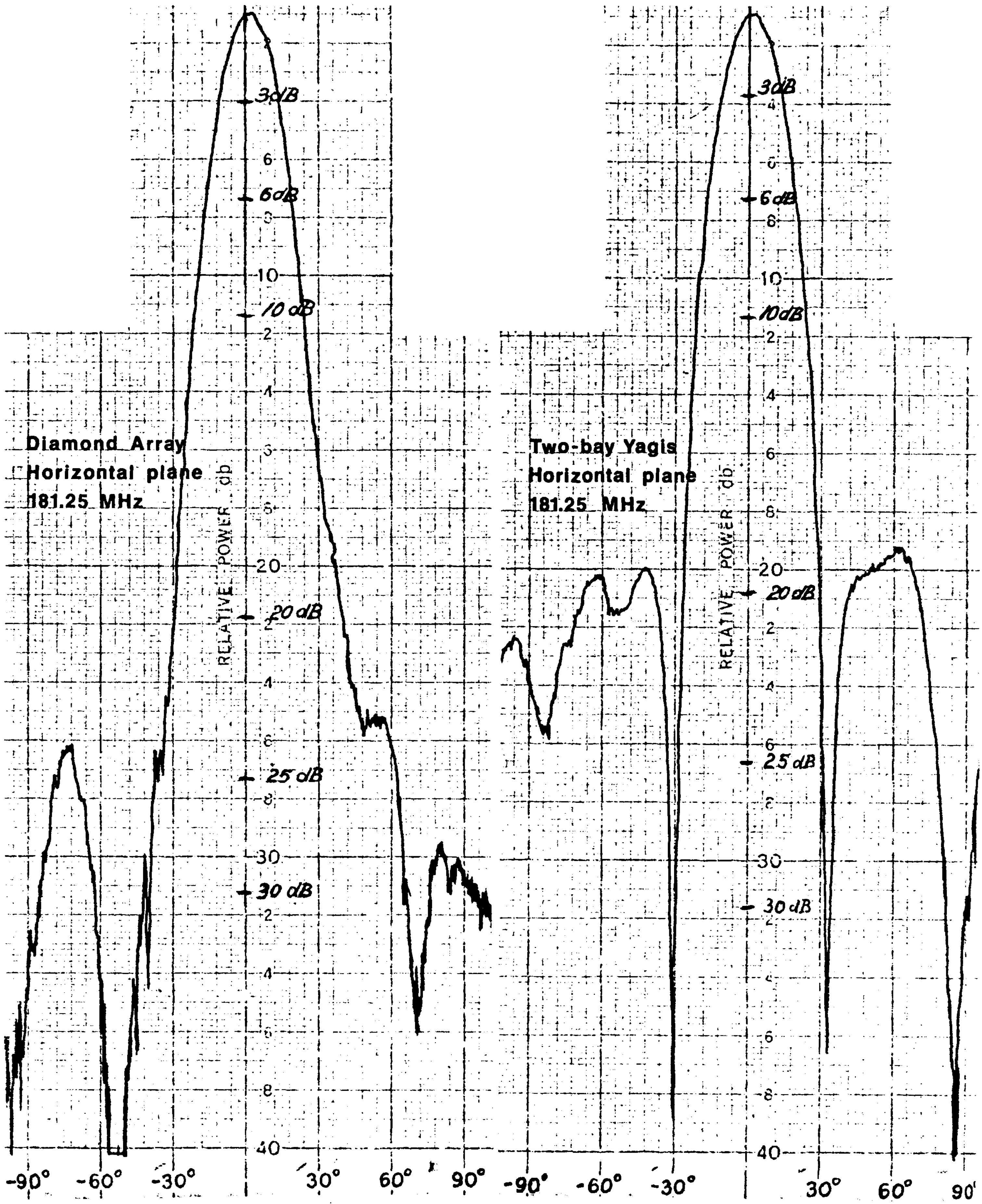
Diamond Array
Horizontal plane
181.25 MHz
RELATIVE POWER db
3dB
6dB
10 dB
20 dB
25 dB
30 dB
Two-bay Yagis
Horizontal plane
181.25 MHz
-90°
-60°
-30°
30°
60°
90°

Figure 3

Since detectors are non-linear devices, the detected signal depends largely on what portion of the characteristic is used for detection. This in turn is a function of the output power of the signal generator, the distance between the transmitting and test antenna, etc.

Good antenna engineering practices dictate the calibration of every chart before starting a series of radiation pattern tests. (See Figure 3) By inserting 3-6-10-20-25-30 dB pads into the transmitter's output, the detected voltages can be precisely marked on the chart. Figure 3 demonstrates the need for calibration. At the -22 dB chart-paper mark the calibration yielded an actaul -20 dB reading. In co-channel protection analysis the -20 to -30 dB region contains the most important segment of the chart, and calibration should not be omitted.

RADIATION PATTERN ANALYSIS

There are a number of paramount factors determining the co-channel protection capability of an antenna-array, all readable from the radiation pattern:

* The exact azimuth angle of the nulls
* The depth of the nulls
* The width of the nulls
* The shape of the main beam.

Potential co-channel offenders should be identified during the signal survey. The azimuth angles of these actual co-channel interference stations may then be determined accurately by a computer run.

Should a fixed structure array be employed, such as a diamond array of log-periodic antennas, its actual radiation patterns must be very closely examined: are the null directions coinciding with the azimuth angles of the co-channel offenders?

The other popular approach is to custom design antenna arrays to force nulls in those particular directions from where the interfering signals are arriving. In these cases actual radiation patterns may prove that the nulls are right on the target, or perhaps a few degrees off. In the latter case a slight reorientation of the tower mounted array may swing the null into the desired position without significantly decreasing the antenna gain.

THE DEPTH OF THE RADIATION PATTERN nulls may also be conveniently identified from a rectangular radiation pattern with a dB scale, enabling the CATV technician to affirm manufacturers' specifications or to discover overoptimistic claims.

Nulls exhibiting 20 dB depth cannot be considered adequate co-channel protection. 40 dB deep nulls are highly desired but seldom demonstrated on actual radiation patterns.

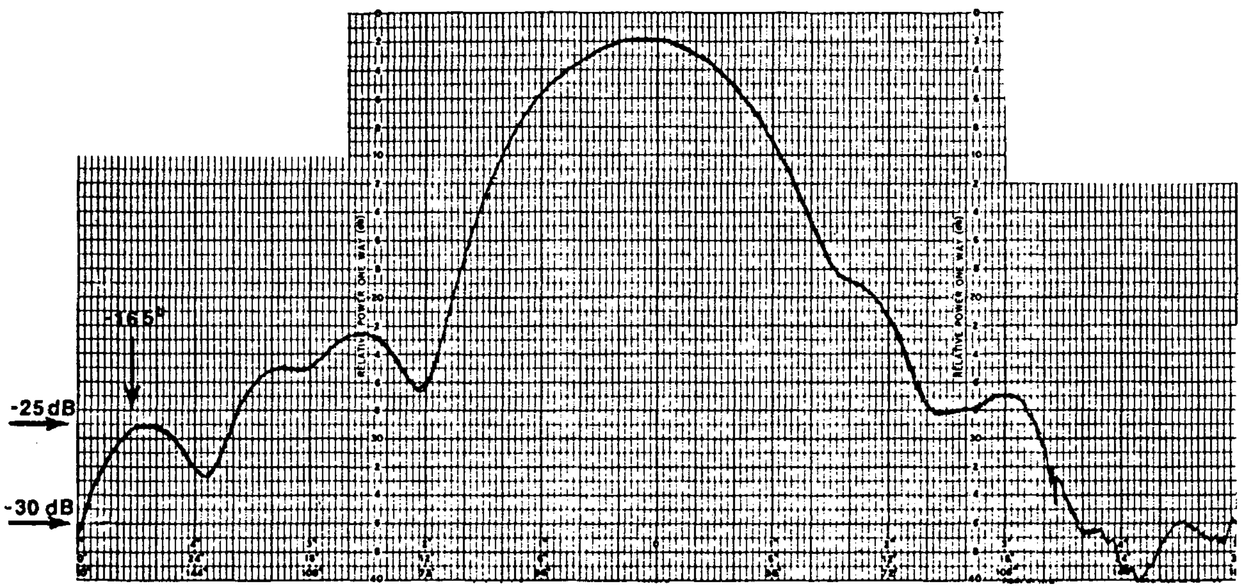

Figure 4

Figure 4 illustrates the need for F/B ratio specifications and radiation pattern comparison. The manufacturer's specifications stated 30 dB protection from the back. The radiation pattern indicates that indeed the diamond quad provides 30 dB protection from 180°. However, the co-channel offender arriving from -165° azimuth--and we can still call this "from the back"--will be attenuated only by 25 dB. This is a 5 dB deviation from published specifications.

THE WIDTH OF THE NULL is an additional important characteristic with which to be concerned. From a rectangular radiation pattern with dB scale, this parameter may be precisely measured at any null location.

Very narrow (1° to 3°) nulls should warn the CATV technician of two imminent problems:

1. It is difficult to orient a tower mounted CATV array with such accuracy under normal working conditions.
2. Under medium to heavy wind conditions the twisting of the CATV tower, combined with the movements of the antenna gates and pipes, could skew the the nulls of the radiation pattern by several degrees, thus significantly decreasing co-channel protection.

Nulls of 5° to 8° width are considered optimum for CATV application.

RADIATION PATTERN IRREGULARITIES

It is not uncommon to encounter asymmetrical radiation patterns. A reexamination of the diamond array pattern and horizontally stacked two-bay pattern (Figure 3) shows a number of asymmetrical features. These include a missing null at -90° on the two-bay pattern, or the development of a broad shoulder on the diamond array pattern at +50°. These are warning signs indicating that either the antenna test range or the constructed arrays have hidden inadequacies. If co-channel conditions warrant the need for extreme caution, the radiation pattern testing should be repeated on a slightly altered test range or with a different mounting in order to identify the nature of the asymmetrical pattern performance.

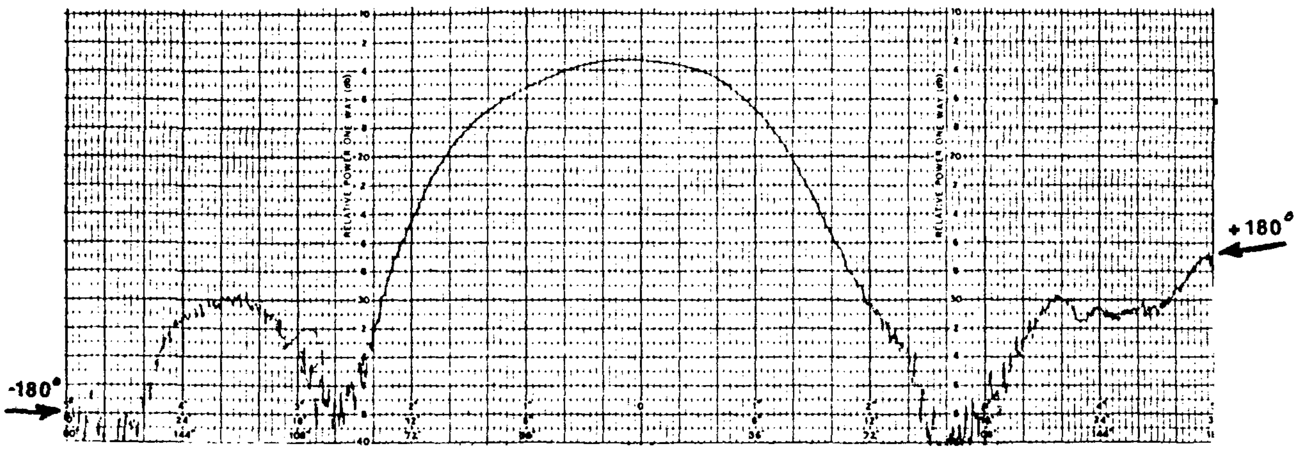

Figure 5

Figure 5 is a classical example of a faulty radiation pattern, not to be accepted for evaluation purposes. The radiation pattern of a log-periodic antenna is presented in this chart. Note that the signal level responses differ considerably at 180°. On the left side, the curve dips to -22 dB, while on the right side it levels off at -13 dB. The resulting 9 dB difference between the left and right side could be a serious impairment of the recording equipment or the result of transmitter/receiver instability.

The frequency of radiation pattern testing is also an important qualifying parameter. Co-channel beats are generated by the video carrier frequencies of two or more stations. Therefore, for co-channel testing purposes, the radiation patterns must be tested on the respective video carrier frequencies. The pattern response may or may not change within a couple of MHz; however, the bearings of the nulls, the depth of the nulls, and their width may shift considerably, warranting on-video-carrier testing.

Antenna arrays mounted on small diameter pipes on the top of the wooden test tower may exhibit perfect radiation patterns with deep nulls. But mounted on metal antenna gates, in the vicinity of a 48" face tower, they may not perform as well. Reflections from the horizontal braces of the tower and the long horizontal pipes of the antenna gates will generate phase sensitive cancellations: filling in the deep nulls in the pattern or causing null-shifts. There is little point for example to publish a "mast mounted" radiation pattern for a diamond array, if the array must be mounted on a CATV tower with 40" to 60" tower face.

CONCLUSION

It has been shown that co-channel protection can be evaluated by analyzing the actual radiation patterns of the array. What often stands in the way of such effective evaluation is the missing information: the properly taken radiation pattern itself. It is up to the CATV operator and technician to ask for and obtain that information.