# DETERMINING RADIATION LEVELS IN CATV CABLE SYSTEMS FOR COMPLIANCE WITH FCC REGULATIONS

Louis A. Marvin

Anaconda Electronics
Anaheim, Calif.

ABSTRACT - This paper presents an analysis regarding specific problems encountered in measuring radiation levels of CATV cable systems for FCC radiation compliance. Methods of testing and measurement techniques through the use of various types of test equipment are discussed in locating radiation sources. Many fault conditions are traced and analyzed. These are itemized and defined as to type of radiation and their characteristics.

Based upon information obtained from actual field measurements and examples, it is possible to identify and locate unrelated radiating sources. The possibility of multi-radiating sources causing readings in excess of specification, yet not necessarily adjacent to the measurement location, can be shown with physical layout diagrams. Additionally, it is possible to predict meaningful "effective shielding" factors for many CATV system components, including connectors, housings, and cable.

## INTRODUCTION

The FCC has set forth definitions and standards for cable television under Part 76 of the Federal Rules and Regulations. Sub-part K contains the technical standards and Paragraph 76.605 (12) outlines the maximum allowable radiation levels in microvolts/meter over the frequency spectrum at a specified distance. The radiation limits are:

| | |
|---|---|
| Up to and including 54 MHz | 15 uv/m @100' |
| Over 54 MHz up to and including 216 MHz | 20 uv/m @ 10' |
| Over 216 MHz | 15 uv/m @100' |

The cable television system operator must conduct performance tests at least once a year and maintain this data on file for at least five years.

In the process of measuring radiation, many pitfalls present themselves and thereby cause erroneous data to be recorded. This paper is not a theoretical study, rather a compendium of radiation sources and problems encountered in the process of radiation testing. A knowledgable cable system operator armed with this information should be able to locate, accurately measure, and correct any particular radiation problem relative to the CATV system.

## METHODS OF MEASURING

There are three basic instruments used to measure radiation:

1) Field Strength Meter

2) Spectrum Analyzer

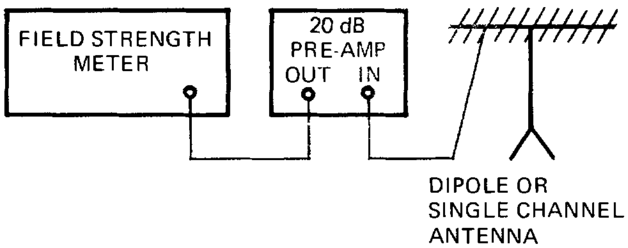
3) Field Intensity Meter

All three involve the use of a calibrated antenna. Depending upon the sensitivity of the instrument used, some may require a preamp also.

The use of a field strength meter such as a Jerrold Model 704 or 727, is illustrated by Figure 1. However, the basic sensitivity of this test equipment is inadequate and, therefore, a preamp with at least 20 dB gain is required. This method is the most economic and simple using components available to most cable systems. If a single channel antenna is used, its gain must also be entered in the calculation shown.

The diagram of the measurement set-up using a spectrum analyzer is illustrated by Figure 2. Again, because the sensitivity of some units falls short of that required, a preamp must be used. Since 20 uv/m at Channel 13 is equal to approximately 4.5 uv of signal, the instrument to be used must be able to measure at least half that level with some degree of accuracy.

The same calculation used with the FSM is used here. The main advantage of the spectrum analyzer is the ability to see the spectrum adjacent to the frequency of interest and thereby aid in rejecting false signal measurements.




$E_{FI} = E_{FSM} - [G_{PA} + G_{ANT}]$

$E_{\mu v/M} = E_{FI(\mu v)} \times .0207 \times f_{MHz}$

$E_{FI}$ = Field Intensity in dBmV

$E_{FSM}$ = Field Strength Meter Reading in dBmV

$G_{PA}$ = Gain of Pre-Amp in dB

$G_{ANT}$ = Gain of Antenna in dB

$E_{\mu v/M}$ = Field Intensity in $\mu$v/Meter

$E_{FI}$ = Field Strength Meter Reading in $\mu$v

$f_{MHz}$ = Freq Measured in MHz

Figure 1. Radiation Measurement Using Field Strength Meter.

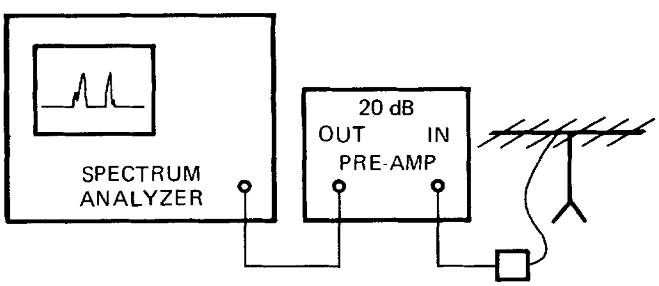



Figure 2. Radiation Measurement Using Spectrum Analyzer.

The field intensity meter (FIM), as illustrated by Figure 3, is the only active item needed along with the tunable dipole. The FIM indicated directly in db/uv. On some field intensity meters, the antenna is an integral part of the meter. Such is the case with the compact and simple-to-use Rohde & Schwarz (R&S) VHF test receiver Model HFV 203.6018.04.

The features of the FIM, including the R&S, are:

1) Sensitivity is in the vicinity of 1 uv - well beyond that required.

2) Accuracy is kept constant over the spectrum by use of an internal calibrator.

3) Built-in audio allows monitoring of signals to help determine the actual frequency being measured.

4) Battery operation allows complete portability with the antenna being integral.

The R&S FIM mentioned is the instrument recommended and used to gather background information for this report. It is by far the simplest to use. The main disadvantage is the cost to purchase which is in excess of $4000.00.

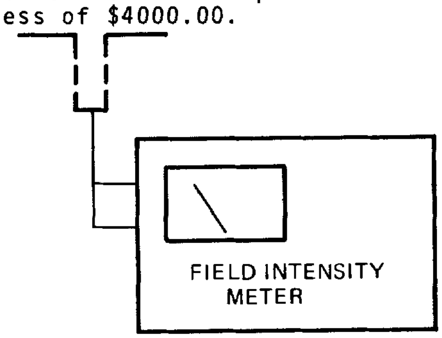



Figure 3. Radiation Measurement Using Field Intensity Meter.

An example of the data sheet used to record radiation levels in cable systems tested is illustrated by Figure 4. The meter reading in dB/uv is recorded and a correction factor is subsequently added which yields dB above a microvolt per meter.

This is then converted from dB's to microvolts per meter. Other pertinent information is also recorded such as equipment present (amplifiers, taps, splices, drops, feeders) and environmental conditions (power line noise, spark static, unknown sources). Pilot tone carriers may also be measured and recorded if deemed relevant, but should not be the sole criteria for radiation testing.

**RADIATION TESTS** θ__________

EQUIP. PRESENT ____________________ CITY __________

____________________ DATE __________

ADDRESS __________

| CHANNEL | $f_{MHz}$ | dB/μv | C.F. | dB/μv/M | μv/M | |
|---|---|---|---|---|---|---|
| 2 | 55.25 | | 1.16 | | | 20 μv/M MAXIMUM (channels 2–13) |
| 3 | 61.25 | | 2.16 | | | |
| 4 | 67.25 | | 2.88 | | | |
| 5 | 77.25 | | 4.06 | | | |
| 6 | 83.25 | | 4.72 | | | |
| 7 | 175.25 | | 11.18 | | | |
| 8 | 181.25 | | 11.48 | | | |
| 9 | 187.25 | | 11.72 | | | |
| 10 | 193.25 | | 12.06 | | | |
| 11 | 199.25 | | 12.30 | | | |
| 12 | 205.25 | | 12.56 | | | |
| 13 | 211.25 | | 12.86 | | | |

NOTES:

Figure 4. Radiation Test Form

RADIATION SOURCES & CAUSES

The cable system, which on the whole can be suspect of radiation, is divided into three areas for ease of discussion and attack. These are:

1. Headend Area
2. Trunk and Feeder Area
3. Drop and Subscriber Area

In that headend buildings are usually constructed with material to keep spurious signals out, the reciprocal is also true. The headend processors operate at levels between +50 and +60 dBmV making it a likely source for radiation, but buildings of concrete or steel generally preclude any concern for radiation. However, it is possible to have local oscillator radiation from antennae at the headend and should be checked. Processor and converter manufacturers generally specify this parameter and should be consulted if a high level of signal is found.

High signal levels operating in the combining process within the headend put strigent requirements on the coaxial cable used to interconnect the equipment. The ability of the coax to contain and not radiate signals is related to "shielding effectiveness" and is discussed subsequently. The point to bring out here is that most of the available economically priced drop cable is not adequate for headend use. Not only will they radiate in excess of FCC specifications, but are susceptible to external sources.

The area encompassing trunk and feeder cable equipment probably represents 80% of the radiation sources. Wherever a discontinuity is inserted in the cable, such as an amplifier, splice, tap, splitter, power inserter, or basically anything with connectors for cable, the possibility of radiation exists. With the higher signal levels operating in the feeder portions of the system, an even greater chance exists. Past experience in measuring cable system radiation has yielded the following distribution:

| AREA | % of TOTAL RADIATION FOUND |
|---|---|
| 1) Feeder Cable | 60% |
| 2) Subscriber (drop) | 20% |
| 3) Trunk Cable | 15% |
| 4) Headend | 5% |

As shown above, a good portion of cable system radiation is found to exist between the tap and the subscriber's TV set. The subscriber himself may cause radiation by altering his hook-up in some manner. The following list of radiation causes has been accumulated from testing and correcting problems in more than 15 cable systems throughout the U.S.

RADIATION CAUSES

A) HEADEND AREA

1. Local oscillator radiation
2. Non-shielded signal processors
3. Non-filtered power (115 VAC)
4. Defective or inadequate shielding on interconnecting cable.

B) TRUNK CABLE AREA

1. Loose connectors
2. Stripped connectors
3. Parts missing from connectors
4. Loose housing covers
5. Broken cables (cracked, kinked, scored)
6. Bonding defective
7. Unterminated lines

C) FEEDER AND SUBSCRIBER AREAS

1. Loose connectors
2. Stripped connectors
3. Parts missing from connectors
4. Loose covers on housings, splitters, DC's taps
5. Broken cable (cracked, kinked, scored)
6. Poorly installed "F" Fittings
7. Defective drop cable
8. Corroded ground blocks
9. Staples in drop cable
10. Indoor splitters used outdoors
11. Unterminated splitters
12. Outdoor/indoor antennae paralleled
13. Miscellaneous wires attached to TV
14. Corroded connections
15. Unterminated drop

METHODS OF LOCATING RADIATION

After trying several approaches that would give definitive answers as to suspect radiating component(s), the following method seems to be best. Radiation can be traced quite accurately using both a TV set and an FM receiver. First, a TV set, which can be powered from 12 vdc, is used to note radiation by observing both a high and a low band channel which are not local or off-air frequencies. Most TV sets have sensitivities that are near 10 uv or better on VHF channels. Signals radiated at this level (approximately 43 uv/m @ Channel 13) generally appear as sync bars slanted across the screen. In other words, most TV sets will not quite sync on this signal level. Since 10 uv is more than twice the radiation spec at Channel 13, one can see the TV set can only be used to locate medium to high levels of radiation. This method has worked quite well. When driving near the component which radiates, the picture will peak stronger and gradually disappear as the distance increases from the radiation source. Some sources radiate quite badly and blanket a 2 to 5 block area. It is then necessary to turn off or disconnect areas to zero in on the source. The TV set is very useful with this approach.

After reworking connectors, housings, and other related parts until the picture has disappeared from the TV set, a second test has proved helpful. An FM carrier introduced on the cable system at 109MHz will allow the use of a hand-held FM receiver to spot radiation sources more definitively as illustrated by Figure 5. The sensitivity of some FM receivers of this type will vary between 0.5 and 1 uv of signal. Using a 1000-Hz tone to modulate the 109-MHz carrier, and operating the carrier equal to or 2 to 3 db higher than the highband or highest level on the system, the signal can be picked up on the hand-held receiver at lower level radiation sources. The whip antenna can be used as a "sniffer" to spot radiation from sources such as groundblocks, loose fittings, leaky drop cable, etc. One is able to determine whether the signal is getting stronger or weaker by the intensity of the 1000-Hz tone.

When the cable system parts have been reworked until the signal vanishes from the FM receiver, one has some reasonable assurance of radiation levels being in the vicinity of specification limits. The operator is then ready to make absolute measurements with one of the methods described previously. There are some exceptions that would not necessarily be found by the above procedure, and will be discussed subsequently.

Radiation faults in the cable system are very much affected by temperature and humidity. Customer complaints often originate in the evening, but are unable to be located the next day on a trouble call. This is mainly due to temperature variations which cause cracks or gaps to increase at cold temperatures, and decrease when warmer ambients exist. Unfortunately, the converse is also true, ie., when heated ambients exist during the day, radiation faults are caused, but cooler air at night cause the faults to disappear. Loose connectors are usually the culprit greatly affected by temperature extremes.

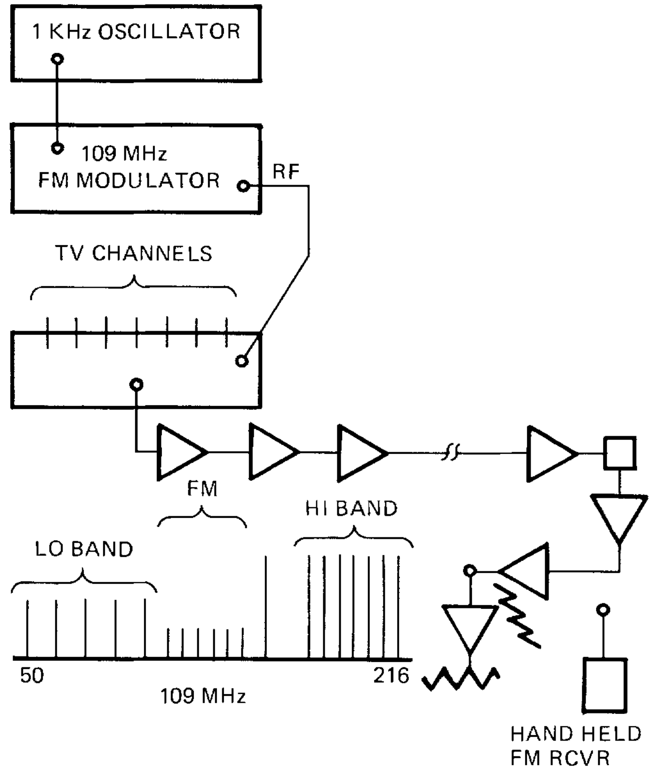



Figure 5. Test Signal System Configuration.

Humidity will generally attenuate radiation from a fault condition compared with a dry ambient. Therefore, radiation location in rain or snow/freezing conditions is more difficult if not, at times, impossible. Another parameter to consider is cable tensions during construction. If tensions are too tight, excessive strain and flexing of drip loops are caused. Eventually a gap or crack will appear and radiation starts. Tensions that are too slack will also cause similar radiation faults.

After reviewing the types of faults found and comparing the radiation levels with the fault, some characterization of radiation profiles can be made. Most leaks exhibit a capacitive type profile, i.e., the higher frequencies are attenuated less than the lower. Some other fault types have electrical "holes" in the spectrum.

A test set-up was made to simulate and more accurately analyze the spectral profile of the different fault types. Figure 6 shows the test diagram. The test results are definitely not absolute, but are relative to each other, and can be compared with good conditions versus a fault. The antenna used was a broadband VHF antenna with unknown gain. Figures

8 and 9 show the data from faults generated to simulate problems found in the cable system.

ing measured could be turned off at the headend for a moment while monitoring the FIM level. If the school has its own an-

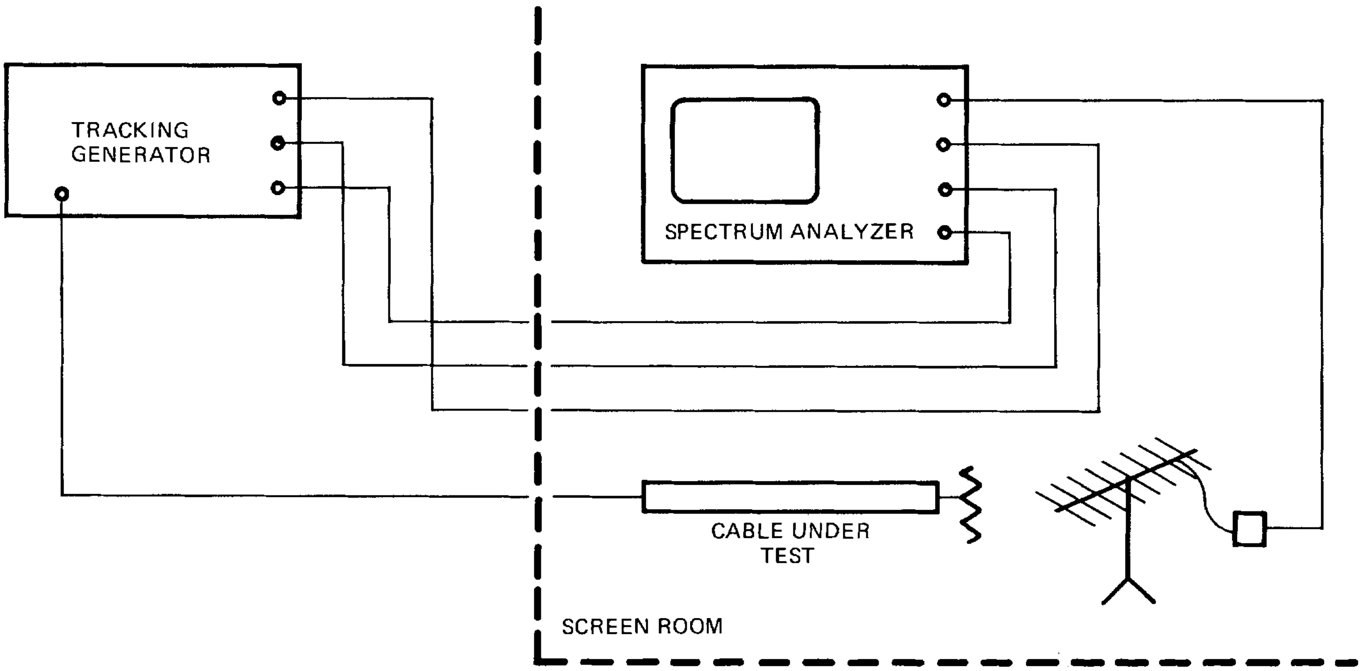



Figure 6. Fault Condition Simulator Test Set-Up

Some attention should be given to determining the source of a specific radiation level being measured. To just assume a signal level measured as emanating from the cable system is a bit naive. Figure 7 shows a plot plan of a radiation test set-up. Four possible sources of radiation are shown and their respective location (direction). Assume the following conditions:

f = Channel 13 (211.25 MHz)
CF = 12.82 dB

and

$E_1$ = 10 dB/uv
$E_2$ = 35 dB/uv
$E_3$ = 12 dB/uv
$E_4$ = 7 dB/uv

Then: The FIM will indicate the highest level received: $E_2$ at 35 dB/uv.

E dB/uv + CF = E dB/uv/m
35 dB/uv + 12.82 dB = 47.82 dB/uv/m
47.82 dB/uv/m = 246 uv/m

This would lead the operator to believe the cable system to be at fault. To verify this, the specific channel be-

tenna system, the answer would become apparent immediately. If the school is a subscriber with their own distribution system, the answer is not so apparent. The next step might be to look at the radiated signal with a TV set and rabbit ears. This too would lead one to believe the cable system was radiating. The only possible indication of error might be the fact that the FIM dipole would peak at an angle not parallel to the cable system as is the case in most radiation examples. However, this factor has not been very reliable in tracing radiation in the past.

The best method to locate radiation of this type is by using the hand-held FM receiver as described previously. By walking the area near the measurement site, the RF leak could be "sniffed" out and located almost exactly.

It should be remembered at this point that all radiation sources, if in excess of FCC limits, must be located and corrected before a "true" system radiation measurement can be made.

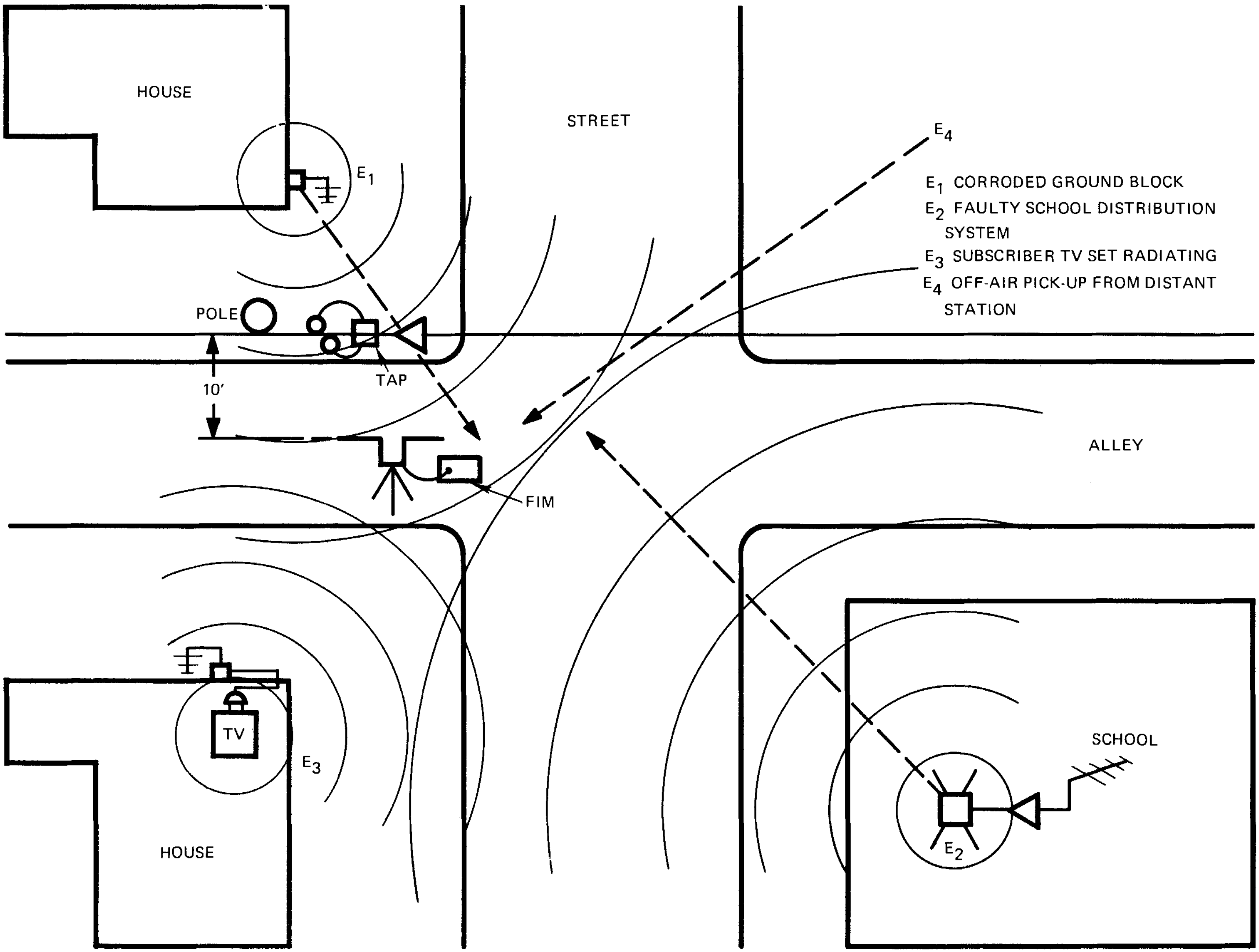



Figure 7. Multi-Source Radiation Plot Diagram

Another symptom to watch, as an indicator of multi-source radiation, is co-channel beat. Using the R & S FIM, the video signal coupled to the built-in speaker will indicate a high pitched squeal (co-channel beat). This should alert the operator to check for more than one source. Usually the second source is a distant station which is either too weak to be considered local or, on low channels, is received under skip conditions which exist occasionally. If the field intensity is high enough to cause indications, the actual radiation cannot be measured until the distant station either fades or goes off the air.

Power line noise, or random spark noise, may create a situation which on the surface may make a radiation test look impossible. The R & S FIM has a feature which aids immensely in this predicament. An option of measuring peak or average potential is available to the operator. Normally, the peak function is used. But in the case of high ambient noise, the average function can be used along with a correction factor. The correction factor is the addition of 6 dB to the reading. This is equal to the average modulation (87.5%) of a TV signal measured in peak function. The correction factor is an approximation and usually not more than ± 1 dB from peak or true value.

ATTENUATION FACTOR AND SHIELDING EFFECTIVENESS

It is now apparent that keeping radiation at a minimum in a cable system requires attention to details at every point

TABLE 1

ATTENUATION FACTORS FOR 5-300 MHz

| | dB/uv | CF | dB/uv/m | uv/m* | dBmV | u/v | A.F. dB |
|---|---|---|---|---|---|---|---|
| 5 MHz | 43.41 | 0.09 | 43.5 | 150 | -16.5 | 147.9 | 61.5 |
| 30 MHz | 42.98 | 0.52 | 43.5 | 150 | -17.0 | 140.9 | 62 |
| Ch 2 | 24.86 | 1.16 | 26.02 | 20 | -35 | 17.50 | 80 |
| Ch 3 | 23.96 | 2.06 | 26.02 | 20 | -36 | 15.78 | 81 |
| Ch 4 | 23.14 | 2.88 | 26.02 | 20 | -37 | 14.35 | 82 |
| Ch 5 | 21.96 | 4.06 | 26.02 | 20 | -38 | 12.53 | 83 |
| Ch 6 | 21.30 | 4.72 | 26.02 | 20 | -39 | 11.61 | 84 |
| Ch 7 | 14.84 | 11.18 | 26.02 | 20 | -45 | 5.52 | 90 |
| Ch 8 | 14.54 | 11.48 | 26.02 | 20 | -45 | 5.33 | 90 |
| Ch 9 | 14.30 | 11.72 | 26.02 | 20 | -45 | 5.18 | 90 |
| Ch 10 | 13.96 | 12.06 | 26.02 | 20 | -46 | 4.98 | 91 |
| Ch 11 | 13.72 | 12.30 | 26.02 | 20 | -46 | 4.85 | 91 |
| Ch 12 | 13.46 | 12.56 | 26.02 | 20 | -46 | 4.71 | 91 |
| Ch 13 | 12.20 | 12.82 | 26.02 | 20 | -47 | 4.57 | 92 |
| 250 MHz | 29.22 | 14.28 | 45.5 | 150 | -31 | 28.91 | 76 |
| 270 MHz | 28.56 | 14.94 | 43.5 | 150 | -32 | 26.79 | 77 |
| 300 MHz | 27.64 | 15.86 | 43.5 | 150 | -32 | 24.10 | 77 |

*ALL uv/m LEVELS ARE AT 10' FOR EASE OF COMPARING NUMBERS

$$E_R = \frac{D1}{D2} Em$$

$E_R$ = Intensity Required in uv/m

$D_1$ = Measuring Distance

$D_2$ = Required Distance

$E_m$ = Intensity Measured

a connection is made. This means that the connection and the equipment being spliced or connected must have a certain attenuation factor to maintain radiation levels within FCC requirements. Table 1 lists the minimum attenuation factors for frequencies between 5 and 300 MHz. It should be noted that the maximum attenuation is required at Channel 13 where 20 uv/m at 10' is the most stringent.

Assuming +45 dBmV to be the highest signal level ever required, 92 dB at Channel 13 is the absolute minimum attenuation to remain within FCC levels. A 10-to-15 dB margin is usually considered to be minimal, yielding a number of 107 to 102 dB. Most systems have been specifying on the order of 110 to 120 dB, which is safer yet. Most housings will pass this requirement without much trouble. The connectors require more attention during construction with respect to repeatability and ease of assembly.

Crosstalk and shielding effectiveness become factors to consider also. Many papers have been written on these subjects and are referenced herein. These parameters are important when considering dual cable and bidirectional systems. They are only mentioned here for reference and indication of importance. No attempt to relate the material of this report and these parameters was made.

CONCLUSION

It becomes quite apparent that for a cable operator to maintain and accurately measure the level of system radiation, he must be aware of many factors which can cause and/or create the illusion of unacceptable radiation levels.

The examples and data contained here should aid in determining the true radiation and also help in locating sources of radiation which might cause trouble calls for the system operator.

The main item to remember in maintaining a system which will pass FCC requirements is to keep ALL connections in the system tight - including equipment covers and grounding. The second item is to require the use of equipment which can pass the 92 dB minimum attenuation factor.

Last, is to educate the subscriber not to alter his installation in any manner. Subscribers should be made aware that any disturbance of the cable installation could cause improper performance.

With these three factors under control, the cable system operator has a good chance of passing FCC radiation tests at any location in the system at any time.

REFERENCES

1. J. D. Meindl & E. R. Schatz, "The External Electromagnetic Fields of Shielded Transmission Lines", Procedure of the Sixth Conference on RFI Reduction and Electronic Compatibility, pp. 388-405, 10-4, 5, 6, 1960.

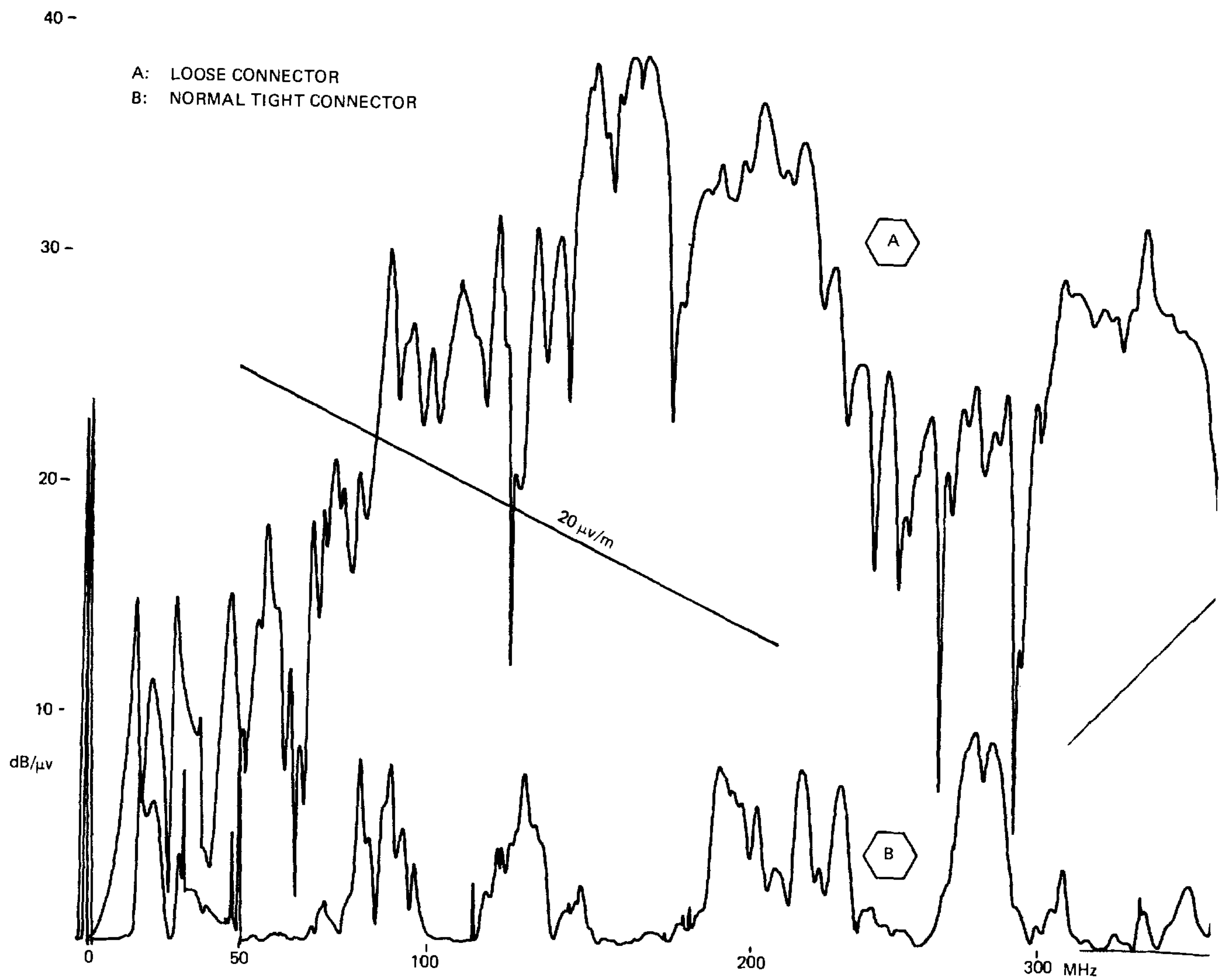
2. J. A. Allen, "A Proposed Standard for Testing the Shielding Effectiveness of Coaxial Cables & Shielding Materials", same as #1, pp. 372-387.

3. S. A. Shelkunoff & T. M. Odarenko, "Crosstalk Between Coaxial Transmission Lines", Bell Sys. Tech. J., Vol. XVI, No 2, pp. 144-164, April 1937.

4. R. P. Booth and T. M. Odarenko, "Crosstalk Between Coaxial Conductors in Cable", Bell Sys. Tech. J., 19, 358, (1940).

ACKNOWLEDGEMENT

Special appreciation is given to Mr. Frank Baxter of General Electric Cablevision Corp. in Schenectady, New York, for the loan of their field intensity meter which was used in gathering data and background information for this report.



40 -
30 -
20 -
10 -
dB/μv
A: LOOSE CONNECTOR
B: NORMAL TIGHT CONNECTOR
A
B
20 μv/m
0
50
100
200
300 MHz


Figure 8

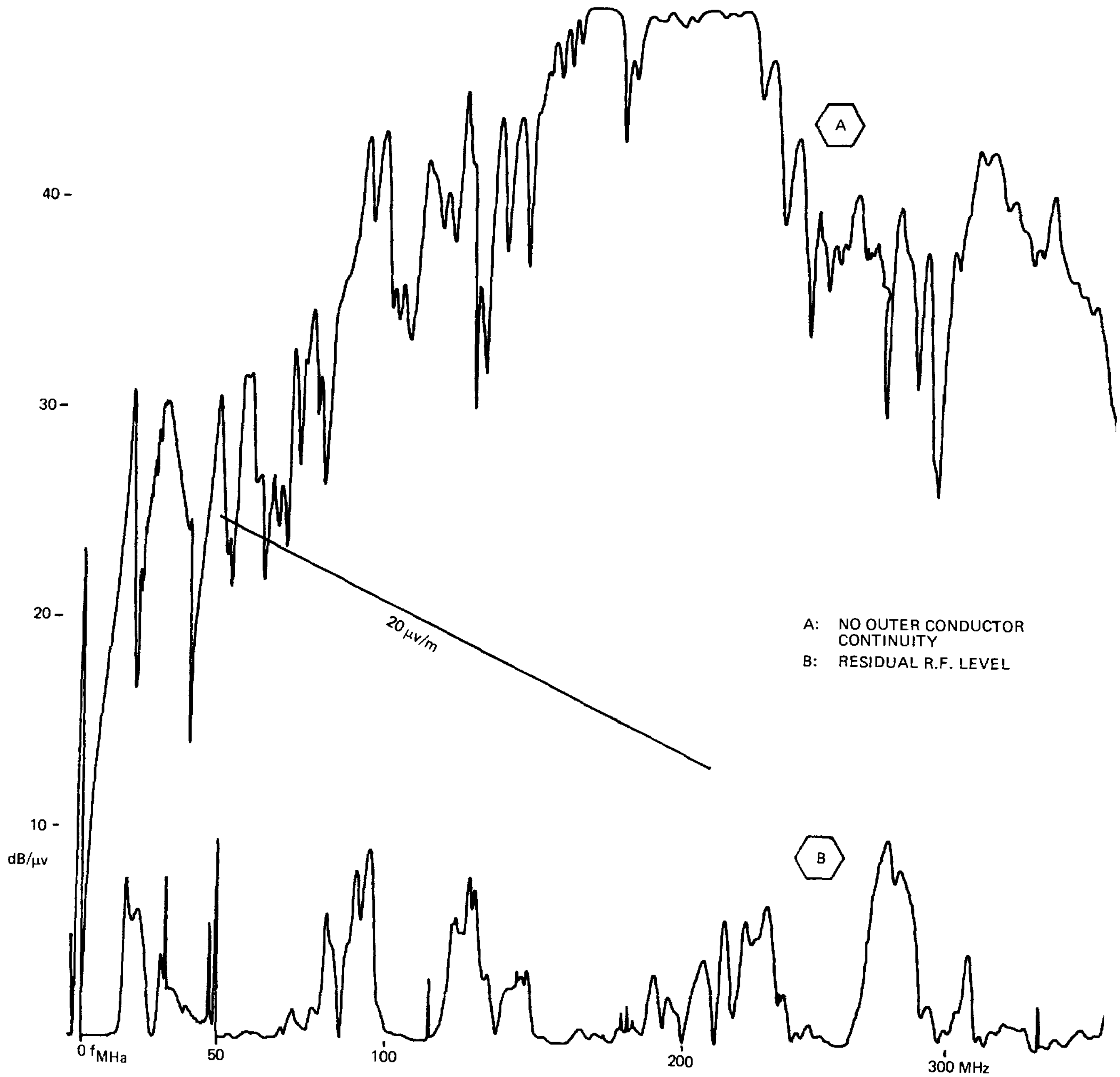

40 -
30 -
20 -
10 -
dB/µv
0 fMHa
50
100
200
300 MHz
A
B
20 µv/m
A: NO OUTER CONDUCTOR CONTINUITY
B: RESIDUAL R.F. LEVEL

Figure 9