RADIO FREQUENCY INTERFERENCE (RFI) SHIELDING TEST PROCEDURE

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1. GENERAL

1.01 This section provides the necessary guidance for the measurement of electromagnetic radiation fields from existing licensed transmitting stations. The purpose of such measurements in relation to telephone equipment buildings is:

(a) ***At a proposed site of a new telephone building***—To determine whether the normally radiated electromagnetic field environment from nearby radio, TV, or communication stations exceeds the tolerable level for the telephone equipment to be installed in the new building.

(b) ***In telephone buildings***—To determine whether such fields are of troublesome magnitude. Measurements can be made throughout the interior space preferably before equipment is installed. After installation, only the perimeter aisles adjacent to outside building walls provide meaningful results as a consequence of the effect on the fields of the frames, ducting, and cables which comprise any telephone central office installation.

(c) ***In a new building, especially one provided with RF shielding***—To measure the RF shielding effectiveness of the building and any installed shielding. This is best done before cables, cable racks, and frames are installed to eliminate their effect on the shielding effectiveness measurement. Perimeter aisle data can be retained for reference in connection with later measurements in the event that changes either in the building or in the local electromagnetic radiation environment require that new measurements be made. Determination of RF shielding effectiveness involves measurement or computation of field strengths outside the building and measurement of field strengths inside the building at selected locations. These fields, expressed in dB units, are subtracted for each measurement frequency and for each interior location to provide the quantitative information on shielding effectiveness. The data obtained is limited to those frequencies on which local transmitters are operating.

This information for the measurement of electromagnetic radiation contained in this practice can be used to qualify buildings constructed in accordance with design criteria specified in Section 760-220-100, Radio Frequency Interference (RFI) shielding.

1.02 Whenever this section is reissued, the reason for reissue will be listed in this paragraph.

2. TEST EQUIPMENT

2.01 The following paragraphs state general requirements on the test equipment.

Requirements

2.02 A field strength measuring set is a sensitive, portable, well shielded, calibrated, tunable receiving set provided with a calibrated attenuator and is used with calibrated antennas. The set has a known, usually adjustable, bandwidth and a detector circuit which can be adjusted to respond either to the peak value, or the RMS value of a signal. The detector operates a logarithmic scale indicating meter with a calibrated dB range of at least 35dB. Together with a calibrated antenna, selected input signals may be read in the units of decibels above 1 microvolt per meter. This is the usual indication for signals confined to the bandwidth of the set. Wider band signals, such as impulse noise spectra and radar signals, and TV picture channel signals are read out in terms of decibels above 1 microvolt per meter in a 1 megahertz band.

Frequency Range

2.03 The most probable sources of electromagnetic fields will depend on the location of the building. This defines the frequency range needed in the measuring set. As additional frequency range is expensive, some careful consideration of the necessary frequency range will save money.

(a) City locations can experience high fields from the usual cluster of FM or TV transmitters, and possibly police or private radio communications transmitters or citizens band, or coast guard navigational sites usually found on a site having a prominent elevation above local terrain.

(b) Suburban or rural locations more likely experience high electromagnetic fields from nearby AM broadcast transmitters, airport radar installations, and occasionally the passage nearby of a powerful mobile radio in a police or private automobile which happens to be transmitting at the time.

(c) Industrial area locations are characterized by a variety of sources ranging from welding setups to induction heating arrangements, and impulses from electrical controls on large electrical machinery. These are not amenable to the measurements described in this section and are excluded. A spectrum analyzer technique with a wide band sensor is required to detect and identify any degree of regularity in the highly variable character of these sources.

(d) Table of Frequency Ranges:

AM Broadcast	0.54 to 1.6 MHz
AM Short-Wave	4 to 25 MHz
FM Broadcast	88 to 108 MHz
TV Broadcast	54 to 88 MHz, 174 to 216 MHz, and 470 to 890 MHz

Antennas

2.04 In the frequency range below 25 MHz, separate antennas are used to measure the E field and the H field. Above 25 MHz, the antenna units used measure the electromagnetic field without distinguishing the electric and magnetic field components. Each antenna is provided with a calibration.

Accuracy

2.05 This is dependent on how well the set is operated and its state of calibration and maintenance. Aside from the general operating instructions given in this section, the manufacturer's detailed maintenance, calibration, and operating procedures for the specific type of set used should be followed to provide optimum results. If these are followed, field measurements should fall within ±4dB of the true value at that location. However, the fields may change quite rapidly, many times 4 dB, with small movements of the antenna relative to other conductors in the vicinity. For this reason, many measurements are made and the average and limit values are recorded.

Available Models of Field Strength Measuring Sets

2.06 For a listing of manufacturers, consult an electronic directory, such as Electronics Buyer's Guide (published by McGraw Hill), under the heading Meters-Field-Strength, R-F.

2.07 Economic Considerations:

(a) It is frequently cheaper to hire electromagnetic interference consultants to perform the measurements. These consultants maintain their own equipment and can be engaged to perform the measurements and write a report.

(b) A listing of such consultants can be found in the "Interference Technology Engineers Master" (ITEM) published manually by R and B Enterprises, P.O. Box 328, Plymouth Meeting, Penna., 19462. Another listing can be obtained from the Institute of Electronic Engineers at 345 East 47th Street, New York, New York, 10017. The suppliers of the test sets can also be asked for names of consultants in a locality.

(c) Rental of test sets for use by telephone company personnel—if telephone personnel are to make measurements, economies can be effected by renting the field strength equipment from one of the electronic equipment leasing services who rent, for short term usage, equipment in a good state of repair and calibration.

2.08 This section does not describe techniques for determining the shielding effectiveness of, or field penetrations into a telephone equipment building ***except*** at frequencies on which existing moderately powerful and local licensed stations are operating. The setting up of a special transmitter and antenna system just for the purpose of obtaining more complete data for other frequencies presents legal and technical difficulties and is an expensive undertaking. What really is needed is information as to whether local transmitters are producing electromagnetic fields of troublesome intensity at the site of a new proposed building, or penetrating into an existing telephone equipment building. If it is absolutely necessary that the measurements be made, which require use of special locally generated fields, the use of one of the established electromagnetic interference or radio engineering consultant firms is encouraged as this type of operation is probably within their experience.

3. MEASUREMENT PROCEDURE

3.01 Three classes of measurements are:

(a) Measurements at a site of a proposed building before construction is begun. (See 3.06 below.)

(b) Measurements inside a complete building to determine whether fields penetrating the building exceed a limit value. (See 3.13 below.)

(c) Measurements of the attenuation or shielding provided by a building to the external electromagnetic fields. (See 3.21 below.)

3.02 Fundamental to the measurement program are these precautions:

(a) Be certain that the field strength measuring equipment is complete and in good working order. For very important work, or if more than one year of average service has elapsed since prior overhaul and calibration, return the equipment to the manufacturer for maintenance, servicing, and calibration.

(b) Be certain that the personnel who will make the measurements are competent in the operation of the set. This can be accomplished by having these people visit the manufacturing plant for a training session, especially at the time the set to be used has been overhauled.

(c) Ship the set very carefully from place to place to minimize damage caused by undue rough handling. Special containers are recommended.

(d) Provide a data sheet. A typical data sheet used by BTL is shown in Fig. 1.

3.03 Selection of Stations to Measure:

(a) Listings of stations can be obtained from the following typical directories:

- ***AM***—Official List of Notified Assignments of Standard Broadcast stations of the United States of America, Federal Communications Commission, Washington, D.C. 20554.

- ***FM***—FM Table of Allocations Assignments and Rule Making Prepared by Selliman, Moffet and Kowalski, Consulting Radio Engineers, 711 14th Street, N.W., Washington, D.C. 20005.

- ***TV***—Television Factbook. Prepared by Television Digest, Inc, 1836 Jefferson Place, N.W., Washington, D.C. 20036.

- ***All Classes of Station AM/FM/TV***—North American Radio—TV Station Guide. Published by Howard Sams, Indianapolis, Indiana and available at larger electronic supply houses.

(b) Often the locality, power, distance, and antenna directivity of the few stations of sufficient expected local field strength at the measurement site are a matter of common knowledge among the technically informed communications people in the area. This information can be used economically with the Radio-TV Guide Book, a good road map, topographic map, or airways map to determine the necessary information as follows:

- Call letters
- Frequency
- AM/FM/ or TV
- Power radiated (Pr) in kilowatts in direction of measurement site

SITE _____ DATA SHEET:FIELD STRENGTH

GN-55-2 (12-55) LOCATION_____ DETECTOR MODE_____

TELCO_____ PERSONNEL_____

SET: MFR MODEL SERIAL SENSORS:MODEL SERIAL

	DATE_____ TIME_____ CALL SIGN	FREQ	E, H, OR EM SENSOR	LOCATION CODE	ATTEN DB	METER DB	SENSOR FACTOR DB	FIELD DB/MN/M					SHEET# REMARKS		
1															1
2															2
3															3
4															4
5															5
6															6
7															7
8															8
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37															37

Fig. 1—Typical Data Sheet

- Distance (d) of transmitting antenna from measurement site in kilofeet.

3.04 The estimated maximum field strength (E) at any site from a nearby AM transmitter is given by

$$E = \frac{\sqrt{P_r}}{d} \times 10^6 \text{ microvolts per meter}$$

Similarly from FM or TV stations,

$$E = 0.6\,\frac{\sqrt{P_r}}{d} \times 10^6 \text{ microvolts per meter}$$

where P_r is the radiated power in kilowatts multiplied by the antenna gain in the direction of the measurement site, and d is the distance between transmitting antenna and the measurement site in kilofeet. In FM/TV bands, the term is ERP (effective radiated power) which includes the antenna gain.

To convert to decibels above 1 microvolt per meter, take 20 log E as calculated above.

3.05 Compile a list of the stations as follows:

(a) For measurements at the site of a proposed building, or for measurements inside an existing building (see 3.06 and 3.13 below)—List all stations having a computed field strength of greater than 0.32 volts per meter which is 110dB above 1 microvolt per meter.

(b) For measurements of building shielding (see 3.13) list all stations having a computed field strength greater than 0.01 volts per meter which is 80dB above 1 microvolt per meter.

3.06 This listing should include:

- Call letters of the station

Frequency
AM/FM/ or TV

- Distance between transmitter location and measurement site azimuth angle (bearing from north) of line towards transmitter from measurement site.

- Computed field strength at measurement site (dB above 1 microvolt per meter).

3.07 Generalized operating instructions for field strength measuring sets:

(a) These instructions are general to the class of field strength measuring sets listed in 2.06. The manufacturer's detailed instructions for specific models of set are the final word and should be followed for best results. These instructions are for a manual, nonsweeping type of measurement and, with a properly operated and properly maintained set, represent the standard measurement. If sweep-frequency or other automated-type tests are used, the results from the automated tests should agree with the results obtained with these manual procedures.

(b) ***Place*** the antenna on the tripod, or another suitable nonconducting support, at the location where the measurement is to be made. For H field measurements below 25 MHz use the shielded loop antenna with the loop in a vertical plane for vertically polarized signals. It will have to be oriented by rotation about a vertical axis for maximum pickup for each station to be measured. For E field measurements below 25 MHz, use the vertical rod and its ground plane. For vertically polarized signals it need not be oriented as it is nondirectional in the horizontal plane. For electromagnetic field measurements between 25 MHz and 200 MHz, use the biconical antenna. For measurement of FM/TV stations (horizontally polarized), arrange the major axis of the bicone horizontally and it will have to be rotated about a vertical axis for maximum pickup for each station to be measured. Some FM stations now use circularly polarized radiations, so both horizontal and vertical polarizations of antenna are required. For measurement of vertically polarized fields from communications equipment (mobile transmitters) 20 to 200 MHz, arrange the major axis of the bicone vertically. It will not have to be rotated for maximum pickup in this case. For measurement of

electromagnetic fields between 200 and 1000 MHz, use the conical log spiral antenna which will have to be pointed towards maximum field, usually in the direction of the transmitter, but not always as a reflected signal may be stronger. For signals above 1000 MHz, use the antenna which comes with the set either log spiral, discone, or horn type. These are all directional and will have to be rotated for maximum pickup. In addition, the discone and the horn will have to be oriented to receive the maximum due to polarization of the signal for each station to be measured.

(c) Connect the antenna to the set, operate the set on internal batteries to avoid field distortion by AC line cords, plug in the earphone to assist in identifying the station to be selected, adjust the detector switch to "RMS" or "Carrier," the demodulation switch to "AM" or "FM" as needed.

(d) ***Tune*** the set with moderately high sensitivity (attenuator) setting to the station to be measured. Adjust the attenuator to bring the meter deflection to the upper 1/3 of the scale and carefully tune the signal for maximum on the meter. Rotate or orient the antenna for maximum pickup of the selected signal. Verify this by identification in the headphones.

(e) ***Calibrate***—Adjust the attenuator to a calibrate zone or mark. Put the detector on "Peak," the bandwidth on "Wide," and push the calibrate button; thereby operating the broadband impulse generator. Adjust the calibrate gain control of the receiver to place the indicating meter at the calibration level for the particular frequency that the set is tuned to. This number is usually read from a chart supplied by the manufacturer and shows the calibrate "level" as a function of frequency for each band in the tuning range of the set. On some sets, for the peak setting of the detector, one has to use the "dump" button if a momentary impulse or an overshoot of calibrate gain control places the meter inadvertently above the desired calibrate level point. If this happens, reduce calibrate gain, operate "dump" button, and approach the desired calibration level from the low side.

(f) ***Measure***—Restore the detector to the RMS (or carrier) position, retouch the fine tuning control for a maximum on the meter, and record the meter dB reading and attenuator setting on a data sheet line which also contains the station, frequency, and antenna calibration dB value.

(g) ***Compute*** the field in dB above 1 microvolt per meter by adding algebraically the meter reading, the attenuator setting, and the antenna factor.

(h) Proceed to the next radio station and frequency to be measured at the location, following steps (d), (e), (f), and (g) above for each measurement.

Field Strength Measurements at the Site of a Proposed Building Before Construction

3.08 This paragraph assumes that the stations to be measured have been selected according to 3.03 above, that equipment is complete and in good order at the site, and that competent personnel are on hand to make the measurements, record, analyze, and report the data. This measurement and data recording process requires two persons, so that the work is not slowed down unduly.

Measurements at Suburban or Rural Sites (These are usually uncongested compared to urban locations.)

3.09 Select a location for the measurement antenna tripod to be placed. Keep as far as possible on the property, from overhead lines, from adjacent buildings with metal frames, underground pipe lines, and from other large metallic objects, such as vans, construction machinery, automobiles, and stored metallic construction materials. Try to approximate a location in the area where the building is to be placed. If the area is already congested, a more practical arrangement would be to place the tripod on a platform—roofed van such as are used for mobile television operating centers. If another telephone equipment building is already on the property, the best location may well be on the roof of this building. If the local situation is too congested, access to nearby less congested measurement sites should be obtained. Measurements in both sites can be made and compared.

3.10 Following the directions in 3.05, and the instruction material for the specific measuring set in use, make the field measurements for the list of stations previously prepared according to 3.03. Make measurements of both E fields and

H fields below 25 MHz, and make measurements of EM fields above that frequency range. Use a data sheet similar to Fig. 1 and record the data for each measurement as described in 3.05.

3.11 Measurements at urban sites:

(a) Residential area sites can be handled the same as the suburban, rural situation described in 3.09 with a somewhat greater probability that the measurement location will be elevated off ground either in the upper floor or roof of a building which will be demolished for the new telephone building, or at a higher location on top of a nearby building. Measurements made on the upper floor of a wood frame building are subject to negligible shielding and will suffice if a large quantity of metal furniture, cabinets, or the like is not stored there.

(b) "Downtown" area sites are likely to encounter high field strengths if located near the usual cluster of FM/TV transmitters on a single tall building in the central business area of a city. Unless measurements can be made on the open roof of a building near the proposed site of a new telephone building, calculation of the field strength will provide a most useful indicator of the expected magnitude. This is also true if the interfering station is AM or perhaps a police or private communications transmitter.

(c) Measurements at street level in downtown areas are useful: (1) only if multiple reflections are expected to occur to direct FM/TV energy down to this level or (2) if interference to equipment on the lower levels of the telephone building is expected from powerful police or private mobile transmitters operating in the streets adjacent to the proposed new telephone building. If interference from police or private mobile transmitters is anticipated [see paragraph 3.09(c)(2)], arrangements should be made during measurement to have transmitters operated at the nearest point where it would normally be expected.

(d) If computations are to be relied upon, use the formulae given above in 3.03 as if compiling a list of stations to measure.

(e) If measurements are to be made, follow the directions in 3.07 and in the manufacturer's instruction material for the specific measuring set in use to make the field measurements for the list of stations previously prepared according to 3.03. Make measurements of both E and H fields below 25 MHz and make measurements of EM fields above that frequency range. Use a data sheet as in Fig. 1 and record data for each measurement as described in 3.07.

Analysis of Data

3.12 Compared to the mass of data obtained in the inside building measurement of 3.15 and 3.22, there are relatively few data points resulting from the site field strength measurements. The analysis can consist of one tabular listing of E field and H field strengths for each measurement frequency below 25 MHz, and another tabular listing of EM fields for each measurement frequency above 25 MHz.

3.13 If, as is usual, the primary sources are in the entertainment bands, the data can be grouped for further analysis as follows:

- Group I—0.5 MHz to 1.5 MHz

  E Field
  H Field

- Group II—50 MHz to 100 MHz, EM Field
- Group III—100 MHz to 220 MHz, EM Field
- Group IV—470 MHz to 1000 MHz, EM Field

Within each group, combine the measured field strengths dB/uv/m on a power basis, using Fig. 2 as a guide.

3.14 If any of these combined values exceed the tolerable limit for the telephone equipment to be installed, refer to Section 760-220-100, Radio Frequency Interference (RFI) Shielding for further guidance as to how to shield the building or rearrange the equipment to obtain a higher tolerance level to RFI.

Field Strength Measurements Inside An Existing Telephone Equipment Building

3.15 The purpose of field strength measurements, inside the telephone equipment building of externally generated fields from licensed transmitters, is to determine whether the more powerful local

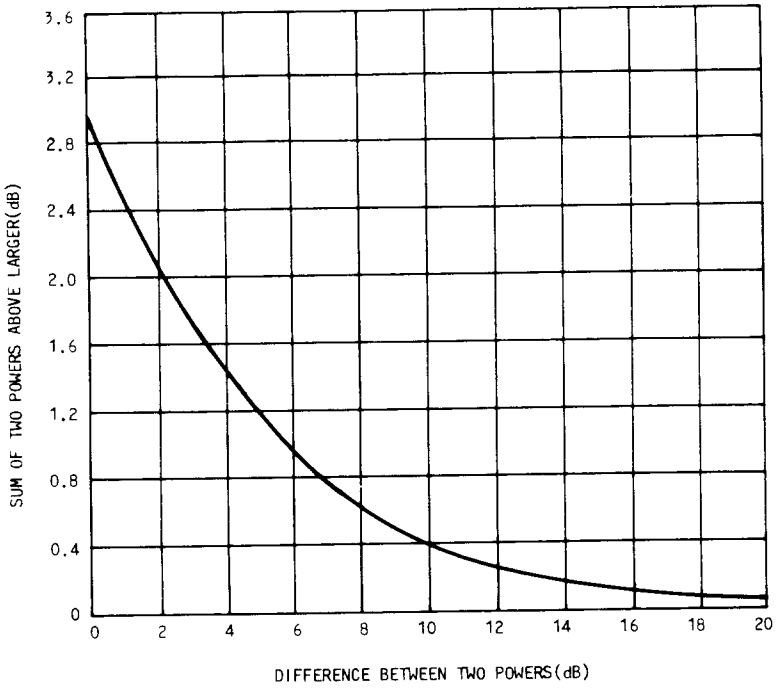
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
SUM OF TWO POWERS ABOVE LARGER(dB)
0
2
4
6
8
10
12
14
16
18
20
DIFFERENCE BETWEEN TWO POWERS(dB)

Fig. 2—Guide

transmitters are radiating a field that penetrates the wall of the building with enough strength to produce fields inside the building that can cause malfunctions in the telephone equipment. This type of measurement is most meaningful where the field measurement locations are at the outer wall of the building. Measurements at more interior locations are possible in new buildings before telephone equipment is installed. However, these results will be greatly altered by the presence, after installation, of all the metallic frames, ducting, cables, and air-cooling ventilation equipment usually in a central office. The data taken in the perimeter aisles is, therefore, of more lasting value.

3.16 This paragraph assumes that the stations to measure have been selected according to 3.03 above and that the equipment is in good order at the site and that competent personnel are on hand to make the measurements, record, analyze, and report the data. The mesurement and data recording task requires two persons so that the work is not slowed down unduly.

Selection of Interior Field Measurement Locations—Perimeter Aisles

3.17 Telephone buildings are usually constructed on an approximate module of 20 feet, the distance between adjacent vertical support columns. For this reason the preferred measuring locations are defined as:

(a) Centered on the perimeter aisle between the inside surface of an outer wall, and the edge of the outer row of equipment frames.

(b) At three measurement points between each pair of vertical columns in this perimeter aisle. Two points each to be 3 feet from the column, and one point centered between the columns. Measurement points in the perimeter aisles are, therefore, approximately 6 feet apart and not directly behind the columns. If a coarser arrangement of measurement points is sufficient, make measurements only in the perimeter aisles at points centered between vertical columns. This reduces the data and the effort by two-thirds. Obtain a floor plan of the building, or sketch one showing only enough perimeter wall, corner, column, and entrance way detail to permit identification of each measurement point. Mark the points at which measurements are made, and identify these by a grid, such as N, E, S, W for locations along the north, east, etc, walls, and a clockwise numeral beginning in the northeast corner continuing along the east wall, across the south wall, etc, on up and across the north wall to the starting corner.

Measurement

3.18 Following the directions in 3.07 and in the manufacturer's detailed instructions for the specific measuring set in use, make the field measurements for the list of stations previously prepared according to 3.03. This would be the group of stations having field strengths greater than 0.32 volts per meter (110dB/μv/m. Make measurements of both E fields and H fields below 25 MHz, and make measurements of EM fields above that frequency. Record the data on a sheet similar to Fig. 1 using one line for each measurement.

3.19 Interior building measurements are subject to the normal fields resulting from the operation of the telephone equipment. For this reason, the use of the headphones with the measuring set is urged to be certain that each measurement is of the field from the external station and is not a tone emanating from the telephone equipment.

Analysis of Data

3.20 As most of the measurements will be of entertainment broadcasting stations, the data from these can be grouped for analysis as follows:

- Group I—0.5 MHz to 1.6 MHz

  E-Field
  H-Field

- Group II—50 MHz to 100 MHz EM Field
- Group III—100 MHz to 220 MHz EM Field
- Group IV—470 MHz to 1000 MHz EM Field

Within each group, combine the measured field strengths dB/μv/m on a power basis, using Fig. 2 as a guide.

3.21 If any of the individual field strengths measured at any frequency, or any of these combined values exceed the tolerable limit of the telephone equipment to be installed, refer to Section 760-220-110, Radio Frequency Interference (RFI)

Shielding, for further guidance as to how to shield the building or the equipment to obtain a higher tolerance level to RFI.

Measurement of Shielding Provided by the Building to Externally Generated Electromagnetic Fields

3.22 The purpose of measurements of shielding provided by a building is to permit an estimate to be made of the possible field levels interior to the building resulting from a change in the external electromagnetic environment.

(a) Ideally, data would be collected at all frequencies of interest, say from 14 KHz to 1000 MHz. This is impractical because it would require setting up a known electromagnetic field incident on the building and measuring its level both inside and outside the building as the frequency of the incident field is changed over the frequency range of interest. Such a program would involve licensing problems and would be expensive and time consuming.

(b) A more practical method of obtaining shielding data is to use the fields available from existing licensed transmitters. The same transmitters are measured at a site outside the building as in 3.08 above, and again at locations in the perimeter aisles as in 3.15. To provide enough data, the list of stations to measure for this type of measurement is comprised of all stations having an on-site field of 80 dB/μv/m (0.01 volts per meter or greater).

(c) The shielding of the building is computed at each frequency, and for each measurement point in the perimeter aisle, as the difference in decibels between the outside field strength and the inside point field strength.

Analysis of Data

3.23 The shielding of a building, even an empty one in which telephone equipment has not yet been installed, cannot be expressed as a single dB value because the shielding will depend on the direction to the station, its frequency, major metallic structural components, heating and ventilating ducts, electrical power panels, and water piping. The data form of most wide usage is a tabular presentation of the shielding measured to each point in the perimeter aisle.

3.24 If this contains too many numerals to permit ready comprehension, a grouping of the data (an indication of average and minimum shielding) will condense the information as shown in 3.23.

3.25 At each perimeter aisle measurement point, arrange the shielding data in four groups as follows:

- Group I—0.5 MHz to 1.6 MHz

  E-Field
  H-Field

- Group II—50 MHz to 100 MHz, EM Field
- Group III—100 MHz to 220 MHz, EM Field
- Group IV—470 MHz to 1000 MHz, EM Field

For the stations in each group, and for each perimeter aisle measurement point, average the shielding in dB and state the minimum shielding in dB.

3.26 A list of these averages and minimum shielding data states the shielding effectiveness of the building as measured in the perimeter aisles.