EMP SHIELDING TEST PROCEDURES

CONTENTS PAGE

1. GENERAL

1.01 This section provides the necessary instructions for performing tests to determine whether Electromagnetic Pulse (EMP) shielding requirements have been met in accordance with specifications. Procedures are outlined for aiding in the determination of causes, and remedial action is specified in connection with problem areas. This section was previously 760-150-001.

1.02 A nuclear explosion at or near the surface of the earth causes the propagation of an electric and magnetic field outward from the point of the explosion. This phenomenon is called EMP.

1.03 EMP of sufficiently intensity can temporarily or permanently damage components of electronic communication equipment and result in system failure. Solid state devices such as diodes, transistors, and magnetic memories are particularly susceptible to EMP effects. Measures have been developed to protect some communications systems against EMP effects. The degree of protection required is based on the EMP sensitivity and tolerance of the equipment involved and the EMP level to which the equipment may be subjected.

2. PROTECTIVE METHODS

2.01 The three basic ways to provide EMP shielding for a structure are magnetic flux diversion, reflection, and absorption.

2.02 Flux diversion is practical only for small structures. It is effected by enclosing the structure in a shield of magnetic material which is thick enough to offer a low reluctance path relative to the magnetic path through the structure and must not saturate at expected magnetic flux levels.

2.03 A relatively high degree of flux reflection can be provided by enclosing the structure in a good electrically conducting material. This method provides a closed low-impedance electrical loop (shorted turn) around the structure. The outside magnetic flux generated by the EMP will induce a voltage, and related current, flowing in this conduction material. This induced current will set up a magnetic flux which is opposite to the polarity of the primary flux and, therefore, tends to exclude the primary field from entering the structure. The amount of shielding loss provided by this method increases logarithmically with the ratio of the dimensions of the structure. That is, the larger the structure, the higher the shielding attenuation.

2.04 The absorption method depends upon the provision of sufficient absorption loss to the outside flux by the use of magnetic material. Steel is the most effective material for this purpose. The degree of shielding provided by this method increases with the thickness of the absorbing material.

3. SHIELD PENETRATIONS

3.01 Shield penetrations from the outside can seriously affect the basic shielding effectiveness adversely, if not properly treated. Examples of such shield penetrations are conduits, pipes, cables, waveguides, and wire which penetrate the building shield and run for considerable distances within the structure.

3.02 The most efficient treatment of such penetrations is the effective short-path electrical bonding of the penetrations to the shield, thereby keeping the conducting loops outside of the structure.

3.03 Conduits and pipes entering the building should, where possible, be continuously welded to the shield at the point of ingress to the building. If for some reason this cannot be done, such as allowing for contraction or expansion of the pipe, conduits and pipes can be bonded by the use of four No. 6 copper bonding wires equally spaced around the pipe and connected between the conduit and the building shield at the point where the penetration first enters the shield. The length of the wires must not exceed that required to provide for the movement of the pipe or conduit.

3.04 The metallic sheaths of communication cables and metallic sheaths of power and control cables can be similarly treated.

3.05 All bonds must be made in a manner which will result in good solid low-resistance connections to the shield.

3.06 In some cases, filters may be required for insertion in power and signaling wires which enter the structure, in order to meet shielding requirements.

4. TEST EQUIPMENT

4.01 Compact battery-operated equipment is used to the maximum practicable extent for convenience and to minimize possible interfering effects in the measurements which might result from source and measuring equipment operating from a common ac power source.

4.02 The recommended list of required test equipment, or equivalents, is as follows:

(a) Signal Source Equipment:

Hewlett-Packard 204B Battery-Powered, Variable-Frequency Oscillator

McIntosh MC 75 Power Amplifier

Hewlett-Packard 5532A Electronic Frequency Counter

Ballantine Battery-Operated 302C Electronic Voltmeter

Tektronix 321A Battery-Operated Oscilloscope

Pearson Electronics Model 10 Wide Band Current Transformer, Pulse Current Transformer

General Radio Type W5MTS Variac

Special Decade Capacitor Box arranged to insert capacitance from .001 microfarad to 20 microfarads in increments of approximately .001 microfarads, or a short, in series with one side of the outside loop feed wires. (See Note.)

Special device for connection between output of oscillator and input of power amplifier to permit connection of frequency counter and to provide for either manual or motor-driven automatic periodic interruption of the oscillator signal output. (See Note.)

(b) Signal Detection and Measuring Equipment:

EMC 10 Interference Analyzer with remote meter manufactured by the Fairchild Electro-Metrics Corporation.

Special Three-Plane Pickup Loop (See Note).

Two Special 3-Inch, Multiturn Pickup Coils (Sniffers) (See Note).

Special rotary switch to select one of four inputs for connection to input of EMC Interference analyzer (See Note). Cords and Connectors as required.

(c) Other Equipment:

Portable 115-Volt, Gasoline Engine-Generator Set.

Geophysical Instrument Company GEOREEL, equipped with sufficient length of paired shielded telephone wire to reach from signal source test setup to any area of the building interior to be tested.

Two operators telephone sets.

4 1/2 volt battery

Portable Wheatstone Bridge

Note: One set of the special items mentioned above has been developed and fabricated locally by Bell Telephone Laboratories for EMP shielding tests. The Laboratories is willing to either furnish the necessary information or assist in the fabrication of these items, or improved versions of such items. The Electro-Magnetic Pulse Protection Group, Bell Telephone Laboratories, Whippany, New Jersey should be contacted for assistance in this matter.

5. TESTING PROCEDURES

General Procedures

5.01 The shielding requirements for a building, or building area, will be specified usually in terms of attenuation at 10 kHz, and most measurements will be made at this frequency. Frequency runs from 30 Hz to 50 kHz will also be used at times in evaluating the character of shielding performance. Particularly in problem area cases.

5.02 The fundamental testing procedure comprises the following principal steps:

(a) The energizing of an outside conducting wire loop for the generation of a symmetrical magnetic field around the building at each test frequency.

(b) The use of three-plane, pickup loop and an associated frequency-selective detection and measuring device to establish an outside reference figure, related to the magnetic field strength at each test frequency.

(c) The use of the same pickup loop and measuring set inside the shielded building to measure the internal signal strength of the reference figure used in (b). The algebraic difference between the measurements inside the building and the outside reference measurement, at any test frequency, is then the effective shield attenuation at the measurement location.

(d) Initially, in large buildings, inside measurements are made, insofar as possible, on 18-foot centers within all areas of the shielded building to characterize total building shielding.

Detailed Procedures

5.03 Install a horizontal, one-turn, circular loop around and centered on the shielded building as shown in Fig. 1. Twelve-pair, 19-gauge, E-rural telephone distribution wire with all wires connected in parallel is satisfactory for this purpose. The loop radius from the center of the building should be at least twice the distance from the center of the building to the vertical building wall in the longer horizontal plane of the building. Larger radius loops are preferable where the terrain permits. The loop radius should be constant within ±1 foot and supported by wooden stakes as required to keep the loop an average of 18 inches or higher above the ground. This is to reduce the capacitance to ground of the loop. Terminate both ends of the loop at a location where it will be convenient to connect with the signal source test set-up. All loop conductors at each end of the loop should be bunched and soldered so as to connect all conductors in parallel.

5.04 Set up the signal source equipment in a station wagon, truck, building, or shelter in a configuration as shown in block diagram, Fig. 2.

5.05 Set the special signal interrupter for manual operation. Set the Variac at 100 volts and the GAIN control of the power amplifier at about three-quarters of its maximum clockwise position. Energize the loop at each of the actual frequencies corresponding to the desired nominal frequency shown in Table A.

5.06 The actual frequencies were chosen to fall between any 60 Hz power harmonic frequencies in order to reduce the possibility of interference in making accurate shielding measurements within the building.

5.07 For each frequency generated by the oscillator the following steps should be taken:

(a) Check the frequency on the frequency counter.

(b) Find the optimum combination of the decade capacitor box setting and power amplifier output impedance tap which will permit maximum loop current as noted on the electronic voltmeter connected to the Pearson current transformer.

(c) Increase the output power of the oscillator as high as possible without distorting the sine waveform as observed on the oscilloscope.

(d) Record the decade box capacitance, power amplifier output impedance tap and the dB scale indications on the electronic voltmeter.

(e) In general, the maximum loop current for the lower frequencies (30- to 500-Hz) will be obtained with the 4-ohm impedance tap and the short position of the decade capacitance box (zero capacitance). Higher impedance taps and various values of capacitance will be required for maximum loop current at the higher frequencies.

(f) Table B is an example of typical recorded information of this type.

5.08 Next, it is necessary to determine, with the use of the special three-plane pickup loop and EMC-10 measuring set, reference measurements related to the approximate maximum magnetic field strengths within the loop for each reference frequency used.

5.09 The total distance from the center of the test loop, centered on the building, to a point outside of the loop circumference where the magnetic field strength is approximately equal to that near the center of the loop is found by the following method:

$R_1 = R \times 1.2$

Where R = radius of loop in feet
R_1 = distance from center of loop to point of reference measurements in feet, or the point of measurement outside of loop circumference is equal to R (feet) × 1.2—R (feet)
For example, if a 350-foot radius test loop is centered on a building to be tested, the distance outside of the loop circumference for reference magnetic field measurements would be:
350 × 1.2 - 350 or 420 - 350 = 70 feet

5.10 Set up the special three-plane pickup loop interconnected with the EMC 10 test set through the special plane selector switch, as shown in Fig. 3, at the proper calculated point outside the test loop as described in paragraph 5.09. Face one of the vertical pickup loop planes perpendicular to the test loop circumference.

5.11 Prepare and calibrate the EMC 10 set in accordance with the EMC 10 operating manual.

5.12 Set the larger outer control knob located at the right of the set at the CARRIER position. Set the larger outer control knob, located to the left and immediately below the panel meter at the CAL TRACKING position. Set the BANDWIDTH switch at 5 cps. Set the input IMPEDANCE switch at the 50-ohm position. Set the FILTER switch at the 20 KC position for measurements up to 20 kHz and at the 50 KC position for measurements between 20 and 50 kHz.

5.13 Energize the outside circular test loop at each frequency to be used and establish the same test loop signal energy for each frequency as described in paragraphs 5.05, 5.06, 5.07, and Fig. 3.

5.14 For each test frequency, set the special signal interrupter for automatic operation. This operational mode provides for the signal to be on for eight seconds and off for two seconds. This affords a method of verifying that the actual signal has been selected on the EMC 10 test set.

5.15 For each test frequency used, select each pickup loop plane and tune the EMC 10, with the main tuning control, and adjust the IF control (frequency control) for maximum meter indication. This will give a reference indication in terms of dB above one microvolt on the test set meter. Record these measurements as shown in Table C.

5.16 The combined total number (last column in Table C) is representative of the total magnetic field strength as a vector sum of the individual strength picked up by each of the loop planes. It is calculated by the use of Table D. Take any two EMC 10 dB indications from any two pickup loop planes. Find the difference and add the combining term to the larger of the two indications. Take the difference between this new quantity and the third plane EMC 10 reading and add the related combining term to the larger number. This will give the number representing total reference field strength. The combined total number information in Table C has been rounded off to nearest higher whole number. For example, at 10 kHz (9,990 Hz) the X and Y planes resulted in readings on the EMC 10 test set of +45 and +53 dB above 1 microvolt, respectively. The difference between these two quantities is 8. From Table D, the combining term for a difference of 8 is 0.5. Adding 0.5 to +53 results in a new quantity of +53.5. The difference between +53.5 and +61, the value measured on the Z plane, is 7.5. From Table D, 0.5 should then be added to +61, or a combined number of +62, when rounded off.

5.17 Obtain a reduced reproduction of each floor plan drawing for the building. For test reference purposes, designate one wall of the building as North. Draw North-South and East-West grid lines on the floor plan drawing on 18-foot centers. Give letter designations to the North-South grid coordinates and number designations to the East-West grid coordinates as shown in Fig. 4.

5.18 Set the outside loop frequency back to the nominal 10 kHz frequency (actual frequency, 9,990 Hz). Set the power amplifier output impedance tap and the decade capacitance box setting for this frequency and establish the loop energy level to the maximum value in accordance with the reference data recorded during the procedures outlined in 5.05, 5.06, and 5.07.

5.19 Take the three-plane pickup loop and EMC 10 set inside the building and make measurements at 9,990 Hz on each building level or floor, on 18-foot centers insofar as possible. For each measurement, verify that the actual outside signal has been selected by noting the periodic signal interruption each eight seconds provided by the automatic interrupter. For reference purposes, the two vertical planes of the pickup loop should be oriented in the same geographical directions during all measurements. That is, the X or the Y plane should always be pointed to the North side of the building.

5.20 The dB difference between the inside measurement for each plane the ***TOTAL OUTSIDE REFERENCE FIELD VALUE AT 9,990 Hz,*** as determined in accordance with 5.16, represents the shield attenuation in dB for each plane of the pickup loop.

5.21 Combine the shielding measurements for the three planes into a total shield figure by the use of Table D. ***In this case, the combining term for the difference in shield measurement for any two planes must be*** subtracted from the lower of the two figures. The new figure can now be combined with the shielding number for the third plane in the same manner. This will result in the ***total shield dB attenuation.***

5.22 It is desirable to take a measurement of the ambient noise signal at the test frequency while the test signal is interrupted. If the test signal level is 10 dB or higher than the ambient noise level. Then the test signal level can be considered as accurate and usable for determining total shielding attenuation. Some cases, where the test signal level for a pickup plane is near the ambient signal level, a true test signal level cannot be measured accurately. In such cases the measurement on this plane should be disregarded in computing total shielding.

5.23 Table E is an example of recording shielding test data. The letters and numbers, shown in the N-S and E-W columns, correspond to floor plan locations, using the grid line coordinates as shown in Fig. 4. The total shielding values can also be noted on the floor plan drawing as indicated within the circles in Fig. 4.

5.24 In the example given for location C-1, the total shield was computed with the use of Table D as follows:

X plane shielding = 85 dB

Y plane shielding = 85 dB

difference is 0

Combining term from Table D is 3

85 - 3 = 82 dB

82 dB combined with 88 dB for the Z plane

(6 dB difference)

combining term is 1.0

Therefore, 82 - 1 = 81 dB total shielding

5.25 The shielding character in the building area used in the example shows a pattern of diminishing shielding values from the center of the building toward the West wall area. Also, tests made along the wall area indicate shielding values of decreasing magnitudes to an extremely low focal point at location 1/2-A-5. These indications could be the result of a major penetration or irregularity in the basic shielding.

5.26 Shield spectrum runs are often helpful in determining whether the basic shielding performance is in accordance with the theoretical prediction. The shielding loss with the continuous copper method should increase approximately 20 dB for each decade of frequency increase. The welded reinforcing bar method of shielding gives an approximate 10 dB increase in shielding loss for each decade of frequency increase.

5.27 In a shielded building, a telephone line between the signal source location and the measurement location will be very useful, in permitting the measurement tester to tell the tester at the signal source when to change frequency. If possible, the metallic shield of the telephone line should be exposed and connected to an area ground plate which is bonded through the wall to building shield near the point of entrance to the building. This will reduce any effect that the telephone reel might have on measurements if the reel is placed near the pickup loop.

5.28 For each frequency used, the signal source equipment should be set for the same loop signal level as determined and recorded initially as covered in 5.05, 5.06, 5.07, and Fig. 3. The reference field strength values for each frequency will then be the same as measured as described in 5.14, 5.15, 5.16, and Table C.

5.29 Table F is an example of copper shield spectrum test data, taken in a building area where there is good shielding performance with a copper shield. Where signal levels are near ambient, the figures used for computing total shield are circled.

5.30 Fig. 5 shows this spectrum test run plotted between nominal frequency points on semi-logarithmic graph paper. Note the generally straight line slope, increasing approximately 20 dB per frequency decade, for example, the shielding loss at 10 kHz is 85 dB while at 1 kHz it is 65 dB.

5.31 Table G is a typical example of a spectrum test at a point where there is a major irregularity in the shield. The data from Table G is used to plot the curve shown in Fig. 6. Note the peaks and valleys and the absence of a 20 dB/decade trend.

5.32 In cases where a penetration is suspected as contributing significantly to a low shielding area, the small pickup coils (sniffers) will be helpful.

5.33 One of these sniffers can be used to probe along pipes, conduits, cable sheaths, etc, as shown in Fig. 7. Any 10 kHz measured value on the EMC 10 test set, which is a minimum of 55 dB below the 10 kHz outside loop reference value indicates a penetration where treatment is normally required.

5.34 It is sometimes advantageous to determine relative polarities of instantaneous current values of two or more influencing penetrations, since two of these penetrations may form a closed conducting loop within the building. The direction of the turns on each sniffer is indicated by an arrow.

5.35 Two sniffers may be connected to provide a combined signal to the EMC 10 test set as shown in Fig. 8.

5.36 If the combined reading on the test set is lower when the arrows are oriented in the same direction that it is with the coils placed so that the arrows are in opposing directions, the current in the two penetrations is of opposite instantaneous polarities. This indicates that the two penetrations form a closed loop of relatively low impedance within the building. If such a loop can be found and broken in a practical manner, the influence may be reduced to a tolerable magnitude.

5.37 If a higher magnitude signal is detected with the two loop arrows pointing in the same direction as opposed to the signal magnitude with the two arrows pointing in opposite directions, then the current in the two penetrations is of the same instantaneous polarities. This indicates that each penetration is providing a separate conducting loop to ground within the building.

5.38 The total recorded test data for a building including shield spectrum test data, is used to detérmine whether there are problem areas and what remedial action should be recommended.

5.39 Completed data of this type should be forwarded to the cognizant Area Engineering Department for analysis and recommendation.

5.40 The Engineering Department should also be consulted, as required, during tests for any assistance needed.

6. TESTS DURING BUILDING CONSTRUCTION

6.01 Certain tests should be made during building construction progress to ensure that the shielding job is being done effectively and that no deterioration occurs as the building progress continues.

6.02 Diligent visual inspection is required during the placing of the shield, the welding of seams and the placing of bonds to the shield.

6.03 Electrical resistance measurements with a portable Wheatstone Bridge should be made between penetrations and area ground plates during construction and prior to backfilling. These measurements should be made on penetrations just inside the interior wall where the penetration occurs. Any resistance of ohm or higher indicates a bond from the penetration to the shield which is electrically inadequate.

6.04 After each level is backfilled the tests described in 6.01 through 6.03 should be remade to make certain that no deterioration occurred during the backfilling operation.

6.05 After the building has been completed, yearly shield measurements should be made and the results compared to the initial test data. In this manner, it can be determined if any deterioration has occurred over a long-term period.

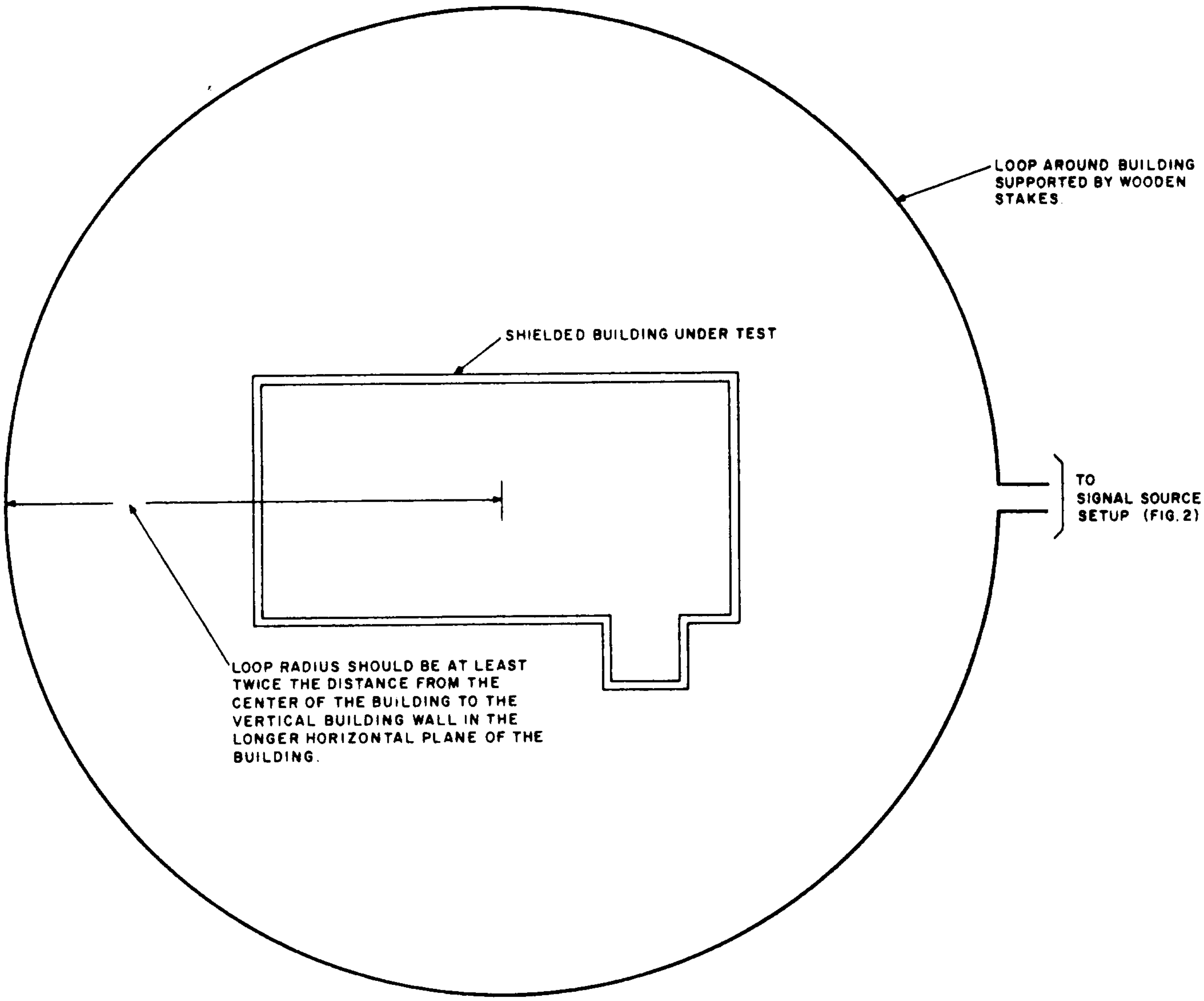

Fig. 1—Loop Installed Around Building

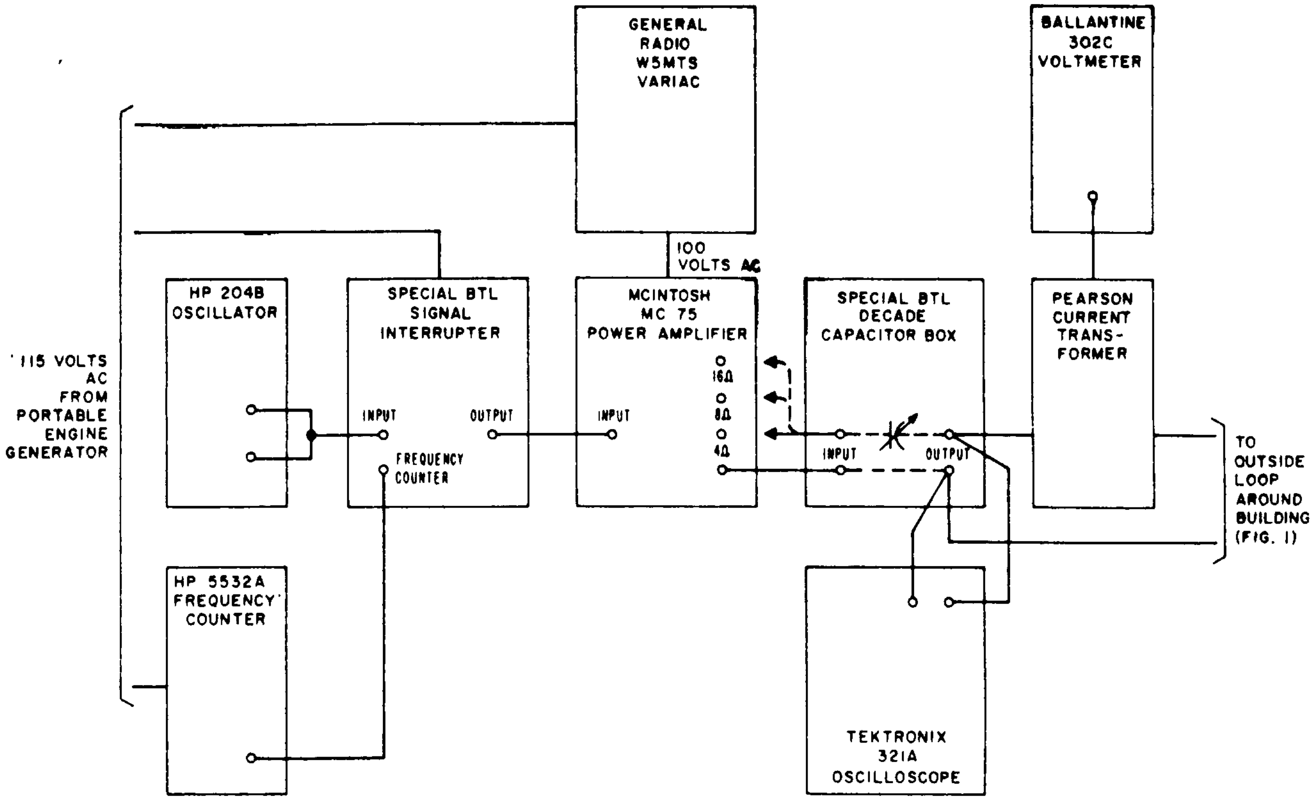

Fig. 2—Signal Source Setup

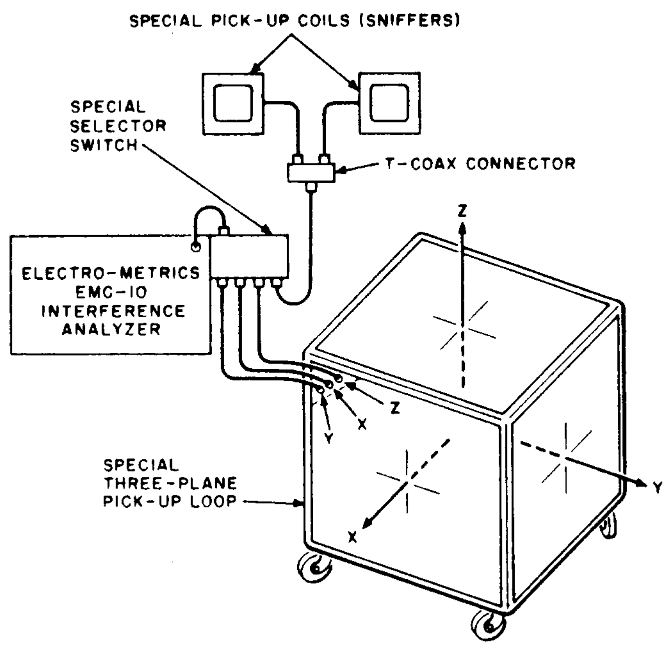

Fig. 3—Signal Detection and Measuring Setup

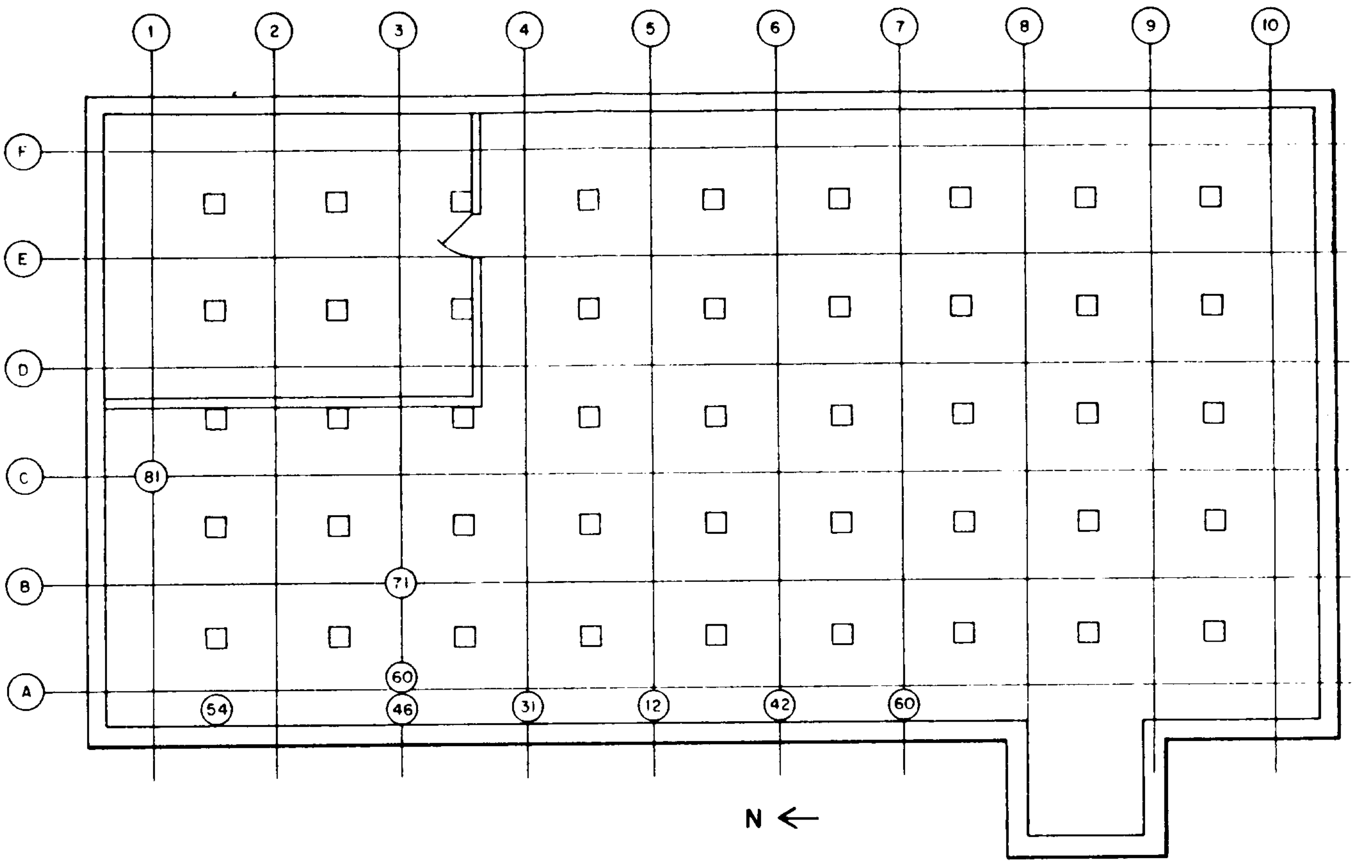

Fig. 4—Building Floor Plan With Grid Lines

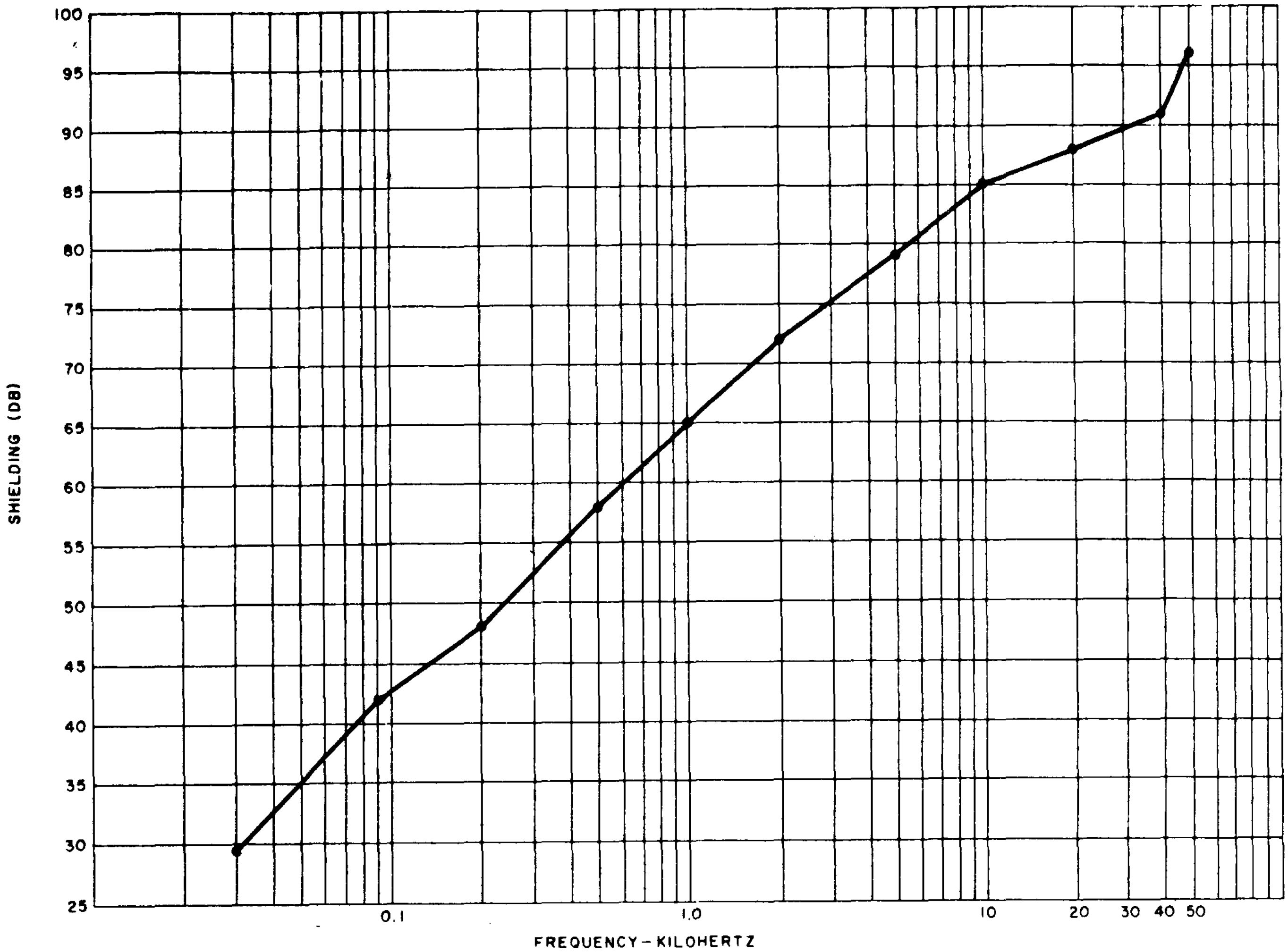

Fig. 5—Regular Copper Shield Spectrum Run

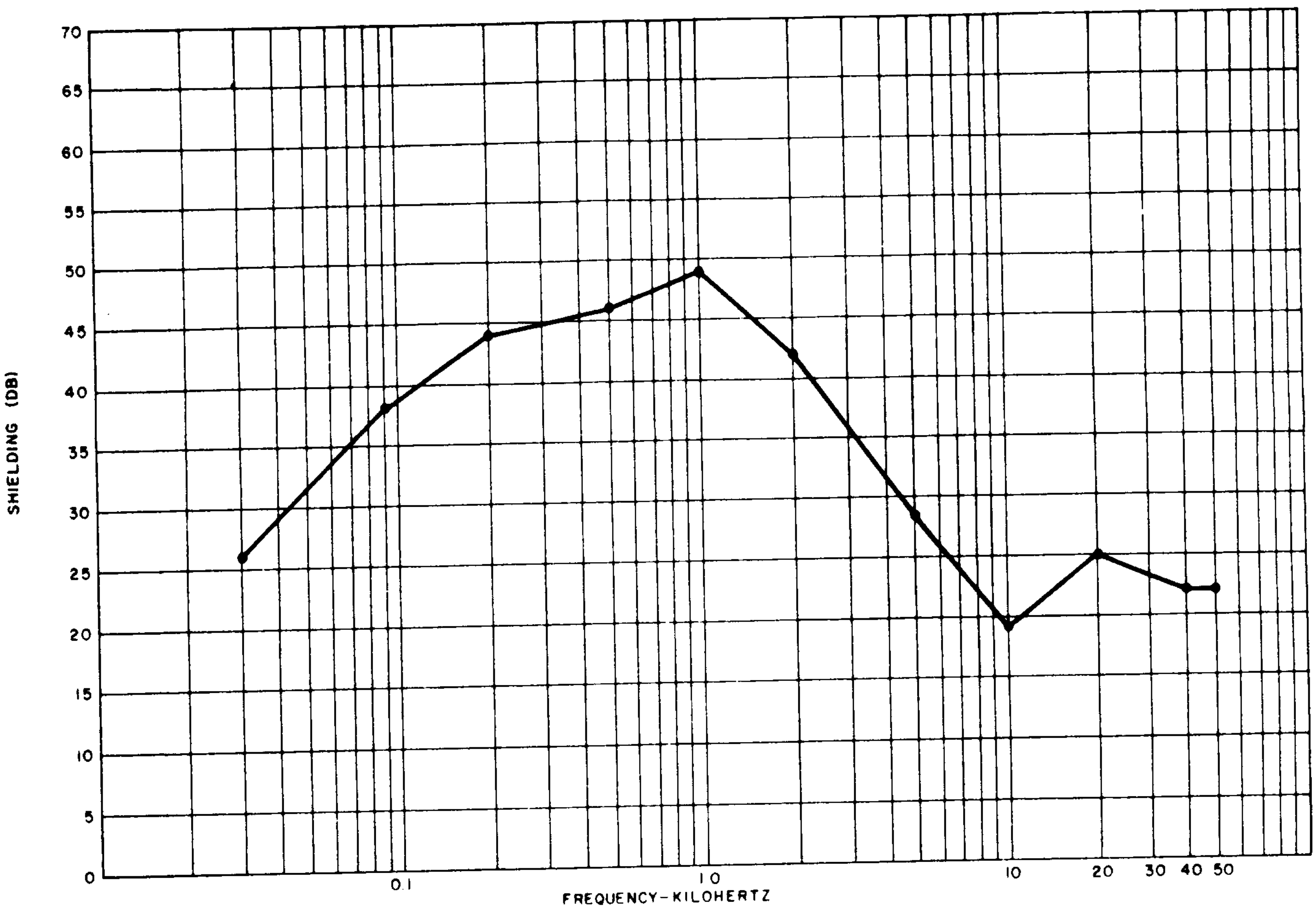

Fig. 6—Irregular Copper Shield Spectrum Run

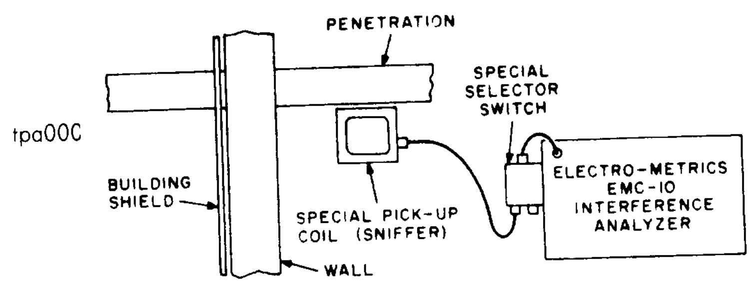

Fig. 7—Use of One Sniffer to Determine Magnitude of Penetration Influence

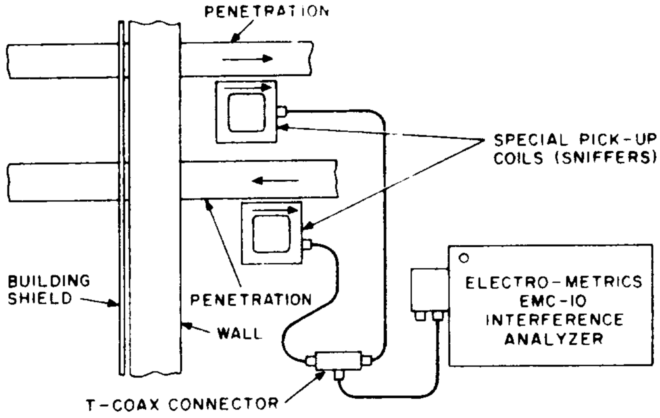

Fig. 8—Use of Two Sniffers to Determine Relative Polarities of Penetration Currents

TABLE A

NOMINAL FREQUENCY	ACTUAL FREQUENCY
30 Hz	30 Hz ± 2 Hz
90 Hz	90 Hz ± 2 Hz
200 Hz	210 Hz ± 2 Hz
500 Hz	510 Hz ± 2 Hz
1 kHz	990 Hz ± 2 Hz
2 kHz	2,010 Hz ± 3 Hz
5 kHz	5,010 Hz ± 3 Hz
10 kHz	9,990 Hz ± 3 Hz
20 kHz	20,010 Hz ± 5 Hz
40 kHz	39,990 Hz ± 5 Hz
50 kHz	49,990 Hz ± 5 Hz

TABLE B—EXAMPLE OF RECORDED INFORMATION FOR SIGNAL SOURCE EQUIPMENT

FREQ		AMPLIFIER OUTPUT IMPEDANCE	DECODE CAPACITOR BOX SETTING	VOLTMETER DB SCALE
NOM FREQ	ACTUAL FREQ			
30 Hz	30 Hz	4 ohms	Short	+6.0
90 Hz	90 Hz	4 ohms	Short	+7.5
200 Hz	210 Hz	4 ohms	Short	+5.5
500 Hz	510 Hz	8 ohms	Short	+3.0
1 kHz	990 Hz	8 ohms	16.0 mF	+0.0
2 kHz	2,010 Hz	16 ohms	6.8 mF	−1.5
5 kHz	5,010 Hz	16 ohms	1.1 mF	−2.0
10 kHz	9,990 Hz	16 ohms	1.0 mF	−2.5
20 kHz	20,010 Hz	16 ohms	0.6 mF	−3.5
40 kHz	39,990 Hz	16 ohms	0.09 mF	−1.0
50 kHz	49,990 Hz	16 ohms	0.08 mF	−1.0

TABLE C — EXAMPLE OF OUTSIDE MAGNETIC FIELD REFERENCES

FREQ		EMC 10 TEST SET READINGS			
NOM FREQ	ACTUAL FREQ	Z PLANE	X PLANE	Y PLANE	COMBINED REF QUANT
30 Hz	30 Hz	+12	+4	+8	+14
90 Hz	90 Hz	+25	+13	+17	+26
200 Hz	210 Hz	+32	+19	+34	+37
500 Hz	510 Hz	+38	+23	+28	+39
1 kHz	999 Hz	+42	+27	+32	+43
2 kHz	2,010 Hz	+47	+32	+40	+48
5 kHz	5,010 Hz	+55	+44	+48	+56
10 kHz	9,990 Hz	+61	+45	+53	+62
20 kHz	20,010 Hz	+61	+44	+51	+62
40 kHz	39,990 Hz	+69	+49	+60	+70
50 kHz	49,990 Hz	+65	+49	+54	+66

TABLE D

DIFFERENCE IN TWO QUANTITIES	COMBINING TERM
0	3.0
1	2.5
2	2.0
3	2.0
4	1.5
5	1.0
6	1.0
7	1.0
8	0.5
9	0.5
10 or greater	0.5

TABLE E

RECORD OF 10 kHz SHIELDING MEASUREMENTS

SHIELDING MEASUREMENTS RECORD SHEET

DATE ________
SITE ________
INITIALS ________

LOCATION			FREQ		REF FIELD (DB)	PICKUP LOOP PLANES									TOTAL SHIELD (DB)
						Z PLANE			X PLANE			Y PLANE			
FLOOR	N-S	E-W	NOM FREQ	ACTUAL FREQ		AMB	MEAS	SHIELD (DB)	AMB	MEAS	SHIELD (DB)	AMB	MEAS	SHIELD (DB)	
1	C	1	10 kHz	9,990 Hz	+62	−42	−26	88	−40	−23	85	−40	−23	85	81
1	B	3	10 kHz	9,990 Hz	+62	*	−20	82	*	−15	77	*	−10	72	71
1	A	3	10 kHz	9,990 Hz	+62	−50	−20	82	−45	−2	64	−45	−1	63	60
1	1/2A	3	10 kHz	9,990 Hz	+62	−50	−15	77	−45	+15	47	−45	+10	52	46
1	1/2A	1 1/2	10 kHz	9,990 Hz	+62	*	−22	84	*	+5	57	*	+4	58	54
1	1/2A	4	10 kHz	9,990 Hz	+62	*	−16	78	*	+28	34	*	+27	35	31
1	1/2A	5	10 kHz	9,990 Hz	+62	*	+46	16	*	+45	17	*	+44	18	16
1	1/2A	6	10 kHz	9,990 Hz	+62	*	+15	47	*	+15	47	*	+15	47	42
1	1/2A	7	10 kHz	9,990 Hz	+62	−35	−1	63	−32	−5	67	−35	−2	64	60

*Ambient noise less than 50 dB.

TABLE F—REGULAR COPPER SHIELD SPECTRUM TEST DATA

SHIELDING MEASUREMENTS
RECORD SHEET

DATE
SITE
INITIALS

LOCATION			FREQ		REF FIELD (DB)	PICKUP LOOP PLANES									TOTAL SHIELD (DB)
						Z PLANE			X PLANE			Y PLANE			
FLOOR	N-S	E-W	NOM FREQ	ACTUAL FREQ		AMB	MEAS	SHIELD (DB)	AMB	MEAS	SHIELD (DB)	AMB	MEAS	SHIELD (DB)	
1	C	1	30 Hz	30 Hz	+14	−29	−20	34	−28	−20	34	−28	−20	34	29
1	C	1	90 Hz	90 Hz	+26	−29	−21	47	−27	−21	47	−27	−20	46	42
1	C	1	200 Hz	210 Hz	+37	−35	−21	58	−35	−21	58	−34	−12	49	48
1	C	1	500 Hz	510 Hz	+39	−35	−26	65	−35	−26	65	−35	−21	60	58
1	C	1	1 kHz	990 Hz	+43	−36	−25	68	−37	−28	71	−35	−28	71	65
1	C	1	2 kHz	2,010 Hz	+49	−36	−25	74	−36	−30	79	−36	−28	77	72
1	C	1	5 kHz	5,010 Hz	+56	−39	−24	80	−38	−34	90	−39	−33	89	79
1	C	1	10 kHz	9,990 Hz	+62	−39	−28	90	−39	−38	>100	−39	−25	87	85
1	C	1	20 kHz	20,010 Hz	+62	−38	−26	88	−38	−38	>100	−38	−38	>100	88
1	C	1	40 kHz	39,990 Hz	+71	−45	−26	97	−45	−24	95	−45	−24	95	91
1	C	1	50 kHz	49,990 Hz	+66	−45	−36	102	−45	−36	102	−45	−32	98	96

TABLE G—IRREGULAR COPPER SHIELD SPECTRUM TEST DATA

SHIELDING MEASUREMENTS
RECORD SHEET

DATE
SITE
INITIALS

LOCATION			FREQ		REF FIELD (DB)	PICKUP LOOP PLANES									TOTAL SHIELD (DB)
						Z PLANE			X PLANE			Y PLANE			
FLOOR	N-S	E-W	NOM FREQ	ACTUAL FREQ		AMB	MEAS	SHIELD (DB)	AMB	MEAS	SHIELD (DB)	AMB	MEAS	SHIELD (DB)	
1	F	1	30 Hz	30 Hz	+14	−20	−15	29	−21	−15	29	−22	−25	39	26
1	F	1	90 Hz	70 Hz	+26	−22	−12	38	−22	−20	46	−22	−30	56	38
1	F	1	200 Hz	210 Hz	+37	−22	−10	47	−23	−10	47	−24	−21	58	44
1	F	1	500 Hz	510 Hz	+39	−25	−9	48	−26	−11	50	−27	−22	61	46
1	F	1	1 kHz	990 Hz	+43	−27	−8	51	−27	−11	54	−27	−22	65	49
1	F	1	2 kHz	2,010 Hz	+49	−27	−9	58	−24	+6	43	−25	−8	57	42
1	F	1	5 kHz	5,010 Hz	+56	−25	+10	46	−25	+28	28	−28	0	56	28
1	F	1	10 kHz	9,990 Hz	+62	−25	+38	24	−27	+38	24	−28	+38	24	19
1	F	1	20 kHz	20,010 Hz	+62	−34	+10	52	−34	+36	26	−35	+8	54	25
1	F	1	40 kHz	39,990 Hz	+71	−34	+47	24	−35	+45	26	−36	+10	61	22
1	F	1	50 kHz	49,990 Hz	+66	−40	+39	27	−38	+42	24	−37	+26	40	22