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INTRODUCTION

The attenuation of electro-statically and electro-magnetically shielded rooms in the "E," "R," "I," and "T" Buildings was measured so that corrective measurements, if of a simple remedial nature, could be taken if the attenuation was found to be low. If remedial measures could not be taken, the shortcomings of the rooms would be known. Also, the men making the measurements could "oversee" construction and correct errors at the time.

SUMMARY AND CONCLUSIONS

The work was performed by measuring the attenuation at spot frequencies over the range of from 150 kilocycles to 1280 megacycles with suitable equipment mounted in small rubber-tired trucks. The attenuation was determined by "before and after" shielding and/or "door open and door closed" measurements after installation of copper shielding. In general, attenuation in the frequency range of approximately 10 to 150 mc., was good and was of the order expected. At frequencies in the range of 150 mc. to 1280 mc., the attenuation curve was more erratic; that is, at certain frequencies a severe loss of attenuation was noted, while at others, the attenuation was very good. This was mainly due to poor or faulty seals around doors and pass windows. These poor seals existed in the "T," "E," and "I" Buildings because the doors were fitted improperly and somewhat inferior material was used. By experience from these difficulties, both causes were corrected in the "R" Building, which resulted in the improvement of the very high frequency (v.h.f.) range in this building. In some specific cases, however, the results were about the same. For the range of frequencies below approximately 10 mc., the attenuation, in almost all cases, gradually decreased as the frequency decreased and reached a minimum at .3 to 1.0 mc. This loss of attenuation was attributed to multiple grounding caused by moisture in the insulating timbers and will gradually decrease as the wood dries out.

EXPERIMENTAL WORK AND DATA

The procedure, as originally outlined, consisted of transmitting from the site of the shielded room and receiving at some other convenient location. The reason for this was to reduce, as much as possible, the amount of radiated signal. The method of measurement was to determine the field strength of the transmitted signal before and after installation of copper shielding. It was assumed that the reciprocity theorem would hold; therefore, making no difference whether the signal was propagated into or out of the shielded room. However, it was decided to check the theorem in this case by reversing the two equipments and repeating the measurement. This was done at several sites when making the "first run" measurement. The two readings did not agree, as was later found.
after making "second run" measurements; the error being as much as 20 to 30 db., or more, depending on frequency and the particular site. Transmitting from the shielded room caused this error. The presence of sheet copper above the top loaded antenna lowered the radiation resistance to the extent that considerably less power was radiated, giving a greater indicated attenuation.

The following procedure used to minimize these errors was followed only in the "R" Building. Transmission over the range of 150 kc. to 40 mc. was accomplished by radiating from a long wire outside antenna (approximately 400' overall), suspended between the cupola of the "E" Building and the top of the West stack. Radiation over the range of 40 mc. to 300 mc. was accomplished with the same equipment, but the transmitting truck was outside the building and measurements were made before and after shielding. Propagation at frequencies of 300 to 1280 mc. was, with one exception, made inside the building, line of sight, by the "open and closed door" method since the door dimensions are greater than one-half wavelength at 300 mc. Measurements of Room R-166 were for the complete range "before and after" shielding. The v.h.f. range was propagated through solid sheet copper and walls and the reception was at the site of the shielded rooms. The receiving and transmitting equipment consisted of filtered and regulated a.c. input. The filtering and thorough grounding was essential and the lengths of the ground leads were critical. This was another reason for receiving in the shielded rooms where the same ground conditions could be maintained for both sets of readings. When receiving on frequencies from 20 to 1280 mc. inside the shielded rooms or at the site of the shielded rooms, the loop (or dipole) was oriented for maximum pick-up (extraneous maximum pick-up ignored) and that reading was recorded. For frequencies less than 20 mc., the antenna was maintained at the same fixed position in both cases.

The receiving and transmitting equipment was conveyed in separate rubber-tired trucks which could be pushed from room to room. The distance of propagation was between 15 to 100 feet, or more.

The equipment on the receiving truck was as follows:

1. A Radio Noise and Field Strength Meter (Communications Company Model 186). Range of 150 kc. to 20 mc. (continuous except in the range of 455 kc., the i. f. frequency). Antenna was a 20" vertical rod.

2. A Radio Noise and Field Strength Meter (Measurements Corporation Model 58). Range of 20 mc. to 150 mc. Pick-up device was a 9" loop or a half-wave dipole.

3. A Radio Receiver AN/APR-4, modified for field strength measurements. Tuning units used with this receiver were TN-17, TN-18, and TN-19. Frequency coverage was 150 mc. to 1280 mc. The antenna was a resonant dipole fed with RG-8U coaxial cable balanced to the dipole by means of a "bazooka." The antenna was mounted on a 3' x 3' aluminum ground plane.
4. A general purpose receiver (Hammarlund HQ-129).

5. A Sola constant voltage transformer and one Cornell-Dubilier type IF-18 low frequency line filter.

The equipment on the transmitting truck was as follows:

1. A Rollins Company power type signal generator (approximately 20 watts output). For mobile use, a short vertical rod loaded to resonance at the operating frequency was used for the radiator. A 400-foot single-wire antenna operated against ground, again loaded to operate at the specified frequencies, was used for "fixed" transmissions into the "R" Building.

2. A special constructed medium high frequency (m.h.f.) transmitter. The range being from 36 to 80 mc, and from 75 to 320 mc., using type HY-75A vacuum tubes. The antenna for the former range was a resonant vertical and the antenna for the latter range was a broad band stub. Both antennas were interchangeable on the aluminum ground plane.

3. Radio Transmitter AN/APT-5A covering the very high frequency (v.h.f.) range of from 300 to 1280 mc. The single antenna was of broad band construction known as type AT-49A/APT-5. One frequency meter TS-175/U, covering the range of 85 to 1000 mc, and one frequency meter BC-221AJ, covering the range of 125 kc. to 20 mc. (It was desired to maintain transmitting frequencies to within 2 per cent for the two sets of readings.)

4. Sola constant voltage transformer.

Telephone communications equipment (i.e., handset and ringer), when used, was kept at a distance of approximately 15 feet from each operating position to minimize r. f. coupling between transmitter and receiver. Coupling was noticed at lower frequencies (up to 10 mc.) when the equipment was placed within the reach of the operator.

The attached curves show in graphical form the shielding efficiency of shielded rooms in the "E," "I," and "R" Buildings. The logarithmic ordinate is shown as the frequency in megacycles, while the abscissa is plotted linearly in decibels as the attenuation. The attenuation is derived from the expression \[ \text{db.} = 20 \log E_1/E_2. \] Thus, shielding efficiency is greater with increasing db. In some cases, a greater signal strength was noted after shielding than before the installation of copper. This was probably due to the uncontrolled effects of ground resistance (or length of ground path), difference of antenna radiation resistance (both transmitter and receiver), standing waves, resonant effects, mechanical and electrical construction differences between the first and second measurements, and because of low attenuation indicated a gain instead of a loss. On some curves, a broken
line is used to indicate that the signal was unreadable between the extremities of the broken line. Figure 1 shows the curve for the "I" Building and represents the average of six sets of readings. Measurements were taken through doors, floors and pass windows. Since some of these measurements were made while transmitting from the room, the data were replotted by using minimum values of each frequency. This is shown as Figure 2. Considerable leakage existed around the two doors (due to poor seals) and the loss of attenuation above 100 mc, was quite severe. (Since readings were taken, the seals were made light-tight, which should result in considerable improvement.) The loss below approximately 10 mc was, no doubt, due to moisture content in the furring strips, which resulted in multiple grounding. With time, this condition should improve. This general trend is typical of almost all the shielded rooms, as seen in Figures 4, 5, 6, 7, 8, 9, and 10.

Figure 3 is the average reading with the deletion of several "out-of-line" readings.

Figure 11 shows the attenuation for two different types of outside antennas. The fixed (or long wire) antenna transmitting over the range of 280 kc to 40 mc, and portable (or loaded vertical type) antenna located outside Room R-116. From this same site, all higher frequency transmissions were made. Note in Figure 11 that in the vicinity of 900 mc, the loss of attenuation was due to leakage around the door knob which was caused by absence of a section of weather stripping.

The measurements shown in Figure 12 for Room R-116 in the "R" Building were obtained from "before and after" readings. Somewhat different conditions existed between the first and second sets of readings. The length of ground lead on the Sola transformer and the Type IF-18 line filter was approximately 20 per cent longer due to presence of laboratory furniture over ground pipe. This may have caused the peculiarities in the curve at the low frequency end and the sharp increase at 20 mc, where a 9" loop and the Measurements Corporation Model 58 were used.

Figures 13 and 14 represent the amount of signal (or noise) entering the room through an open door. As the frequency approaches the approximate quarter-wave dimension of the door (length and width), the ambient signal increases approximately 35 db.

There are some constructional variations between the shielded rooms. The walls and ceilings of all shielded rooms are constructed of sheet copper .020" thick. All rooms except two (in the "T" Building) have the floor shielded with silver-plated copper screen of size 1/4 mesh; the two exceptions having solid copper .020" thick. All fluorescent lamps are outside the room, light entering through 1/4 mesh silver-plated copper screens. The lamps are individually filtered with a General Electric fluorescent filter, type 599635 (2 amperes). Anemastats in the "E," "I," and "T" Buildings are insulated from
NOTE: NO SIGNALS WERE RECEIVED ON 280 & 340 KG FOR THE SECOND SET OF MEASUREMENTS. ALSO NO SIGNALS WERE DETECTIBLE FROM LOCAL BROADCAST STATIONS FOR THE SECOND MEASUREMENT.

BUILDING
ROOM: 3101
AVERAGE ATTENUATION
Nov. 16, 1948

FIGURE 1
E BUILDING
ROOM #113
AVERAGE ATTENUATION
SEPT. 13, 1948
FIGURE 7

ATTENUATION, DB.
F.C. STATION CHECK

<table>
<thead>
<tr>
<th>STATION</th>
<th>FIRST</th>
<th>SECOND</th>
<th>RADIO</th>
<th>DB</th>
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<tbody>
<tr>
<td>WLW</td>
<td>180</td>
<td>1000</td>
<td>250</td>
<td>124.25</td>
</tr>
<tr>
<td>WPFB</td>
<td>910</td>
<td>175</td>
<td>250</td>
<td>125</td>
</tr>
<tr>
<td>WHIO</td>
<td>1270</td>
<td>200</td>
<td>350</td>
<td>128</td>
</tr>
<tr>
<td>WING</td>
<td>1410</td>
<td>450</td>
<td>450</td>
<td>120.4</td>
</tr>
</tbody>
</table>

FREQUENCY, Mc.

ATTENUATION, DB. -14-
**Figure 9**

**R. Building**

Room #107 (magnetic)

Jan. 19, 1923

[Graph showing frequency and attenuation with various lines indicating signal strength and frequency points such as WING, WHIO, WPFB, and WLW, with notes like "no signal at this freq." and a grid for frequency and attenuation in dB.]
SIGNAL LEAKAGE THROUGH OPEN DOOR
FROM BUILDING ROOM 107
TRANSMITTING ROOM 107, RECEIVING
IN CORRIDOR, DOOR DIMENSIONS 31" X 83"
NOV 23, 1948

FIGURE 13
the shielding and are also covered with 1/4 mesh silver-plated copper screen. However, the anemastats in the "R" Building have no screen covers and are grounded to the copper at entry. To prevent the anemastats from grounding the copper, a section of insulating material was inserted in the duct just above the port. Shielding is accomplished by the insertion of copper screen soldered in the duct. The services entering nearly all rooms pierce a common point (as practical as possible). These service pipes were filtered by grounding the pipes to the copper shield at several points within the room. One-inch copper braid was the grounding conductor. The threshold door seals in the "E," "I," and "T" Buildings are of the spring-loaded type and gave considerable trouble in use. Grounding was incomplete and difficult to maintain. Grounding along the single edge of weather stripping was also unsatisfactory. The inadequacies of these shielded doors were corrected in the design for the "R" Building. Two sealing edges of spring bronze strip were employed at 90° to each other in place of the single edge and interlocking-type threshold seals on the floor. A similar, but narrower, interlocking seal was used on the top edge of the door.

Magnetically shielded rooms were constructed of galvanized iron sheets thoroughly soldered, but uninsulated from ground. All electrical equipments were bonded with 1/4 x 1" copper bar and grounded. A.C. power entering the room was filtered by means of a 2-wire, Tobe, 100 ampere filter (2 each, type 1180 Tobe filterettes) with a nameplate frequency rating of 0.15 to 400 mc. The unit was placed in the distribution panel feeding the room. Rooms requiring stabilized voltage were regulated by means of a Sola constant voltage transformer, Catalogue No.'s. 30808, 30809, 30M814, or of a similar style. Telephone lines, when used, enter in conduit and terminate in a copper-lined box. The telephone is placed in the box when not in use.

REFERENCES

"Methods of Controlling Radio Interference" by C. V. Aggers. (Electrical Engineering, Volume 59, April, 1940, pp. 193 to 199, Discussion pp. 199 to 201.)


"Radio Transmission Measurements" by R. Bowm, C. R. Englund and H. T. Friis. (Institute of Radio Engineering Proceedings, Volume 11, #2, April, 1923, pp. 115 to 152.)
Aircraft Electricity (N. J. Clark and H. E. Corbett).

Bonding and Shielding of Aircraft, 1942, Chapter 5 (Ronald).


"Radio Noise Filters Applied to Aircraft" by C. W. Frick and S. W. Zimmerman (Electrical Engineering, Volume 62, September, 1943, pp. 590 to 595).

"Field Strength of Motorcar Ignition Between 40 and 450 Megacycles" by R. W. George (Institute of Radio Engineering Proceedings, Volume 28, No. 9, September, 1940, pp. 409 to 412).


"High Frequency Measurements" by A. Hund (McGraw, 1933).


"A Study of the Characteristics of Noise" by V. D. Landon (Institute of Radio Engineering Proceedings, Volume 24, No. 11, November, 1936, pp. 1514 to 1521).

"Ignition Shielding Design" by J. J. Maschuch (Aeronautic Digest, Volume 41, November, 1942, pp. 227 to 228).

"Screening at V. H. F." and "Efficiency of Metallic Surfaces" by B. Roston (Wireless Engineer, July, 1948).
"The Impedance Concept and Its Application to Problems of Reflection, Refraction, Shielding and Power Absorption" by S. A. Schelkunoff (Bell System Techniques, Volume 17, January, 1938, pp. 17 to 48).

"Formulas for the Skin Effect" by H. A. Wheeler (Institute of Radio Engineering Proceedings, Volume 30, No. 9, September, 1942, pp. 412 to 424).

"Skin Effect Formulas" by J. R. Whinnery (Electronics, Volume 15, February, 1942, pp. 44 to 48).


"Techniques of Radio Design" by Zepler and Wiley, Chapter 8, pp. 183, "The Principles of Screening."

JSS/eat