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AEW INTERFERENCE REPORT
AIRBORNE PROBLEM

Prepared by:

Systems Engineering Section Staff

FR-2766

Report - R-2766

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ABSTRACT

This Project Cadillac report, AEW Interference Report A, covers the work done by the NRL Airborne Interference Group in satisfactorily reducing the interferences to the airborne portions of the AEW systems. AEW Interference Report B, listed as reference (4), covers the parallel work done for the shipboard portions of the AEW systems.

The measurement techniques and corrective devices developed by the NRL group for eliminating interferences above 100 mc/s were extended and applied to the correction of the special equipments installed in the AEW search aircraft. Investigations revealed, as predicted, that most of the radio and radar transmitters aboard the aircraft radiated strong spurious signals including harmonics, outside of their assigned frequency bands. New types of antenna networks with unusual characteristics and design factors were developed to suppress successfully these antenna radiations and provide interference-free operation of the AEW system. These new networks provide extremely flexible and useful correctives for suppressing existing and future interferences to other Naval airborne electronic systems.

It is recommended that these new networks and other corrective devices be further and extensively investigated, and that such correctives be installed as integral components of all airborne electronic systems in order to attain interference-free operation of basic equipments.

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INTRODUCTION

1. The Airborne Early Warning System (AEW) was developed by the Radiation Laboratory at the Massachusetts Institute of Technology under the code name, "Project Cadillac", for the primary purpose of extending the range of shipboard search radars to provide a greater area of coverage, thus making possible the detection of surface craft and low flying aircraft far beyond the radiation horizon of shipboard installations. This was accomplished by installing a high-powered micro-wave radar set in a carrier- based plane and controlling and presenting the search information on shipboard by means of a Block III (295-315 mc/s) radar relay link. The shipboard radar had, in effect, been placed on a mobile mast of variable height, thereby gaining flexibility and range. At 5000 feet the plane's radar searches an area of 100-mile radius, while at 20,000 feet the range is extended to a radius of 200 miles, thus covering a search area of 125,000 square miles at 20,000 feet. A functional chart of the system and its operation is included as Plate 1.

2. The secondary function of the AEW system covered the same extensions of range for the VHF communication and IFF equipments. The special VHF equipment aboard the AEW plane provided for direct communication not only between the plane and its carrier, but also between the carrier and other planes beyond the radiation horizon of the carrier by employing the AEW plane as an automatic relay station. A special IFF interrogator was installed in the AEW plane. The IFF operation could be remotely controlled from the carrier, and its information was relayed back to the carrier on the Block II link, thus IFF identification of surface and air units was possible over the same range limits as the radar search.

3. After the original AEW system, as described above, had been initiated, a second AEW program, called "Cadillac II Project", was proposed and initiated covering the following major changes:

- (a) The total CIC (Combat Information Center) functions were transferred to the AEW aircraft so that search, spotting of targets, fighter direction and dissemination of combat information took place in or from the AEW aircraft.
- (b) The radar relay was still used from plane to ship and plane to shore, but only for the purpose of supplying simultaneous information for individual use by ship and shore stations.
- (c) All controls of the aircraft equipment by ship or shore facilities were eliminated. The only links between the plane and ship-shore installations were the mutual VHF direction and relay communication ties, and the plane to ship-shore radar relay.
- (d) To provide the needed space and flight characteristics, a B-17 type aircraft was used, instead of a TBM.

4. In itself, the development of this system required many major, and innumerable minor, technical achievements so that each integral unit of the system would operate efficiently. However, use of the entire AEW system in the immediate vicinity of other operating shipboard and aircraft transmitters has shown that spurious and interfering signals, radiating at certain frequencies by these transmitters, resulted in mal-functioning and inefficient operation of the AEW. It was, therefore, of paramount importance to the entire system of AEW, and certainly to the secondary function of the system, that the VHF and IFF equipments in the AEW plane be continuously and efficiently operative. The existence of any interference with the operation of these equipments causing interruption, blocking, or excessive radio noise, constituted a serious impairment of required functions, and therefore compromised the entire AEW system.

EXISTING INTERFERENCES

5. Serious mutual interference between the VHF communications transceivers (AN/ARC-1, AN/ARC-4, AN/ARC-5) and the IFF equipments (AN/APX-1, AN/APX-2) had been reported by various fleet activities. The VHF communication band covers the range 100 to 156 mc/s (although 146 mc/s is the highest frequency used at present), while the IFF frequency band covers the range 156 to 212 mc/s. A detailed investigation of the causes of the reported interference, and development of suitable correctives to eliminate it, were undertaken by the Radio Interference Group of the Airborne Radio Division at NRL. The results of this investigation are reported in references (6) and (7), which reveal that the mutual VHF-IFF interference was almost entirely due to radiation pick-up by the antenna of these equipments. The causes for such antenna interference are:

(a) Emission of (spurious) signals on frequencies other than the fundamental by the transmitting sections of these equipments.
(b) Inadequate selectivity of the receiving sections of these equipments resulting in reception of high level adjacent channel transmissions.

It was shown that the equipments could be operated with a tolerable level of interference, provided that only the lower portion of the VHF communication band was used (below 130 mc/s). Such restricted operation, however, so compromised the tactical use of the VHF equipment that corrective measures were considered imperative.

CORRECTIVE MEASURES EMPLOYED AND RESULTS OBTAINED.

6. Attempts to correct the interference by relocating and varying the spacing of the antennas resulted in a definite but inadequte amount of correction as reported in reference (6) -- useful only as a temporary measure. Attention was therefore directed toward developing antenna network correctives which would eliminate the interference irrespective of the location of the antennas. This development, discussed in reference (7) involved the application and extension of network design equations to provide practical corrective networks in the 100-212 mc/s frequency range. Novel techniques introduced by the NRL Interference Group consisted of:

(a) An extension of the known filter design equations to permit better impedance matching in the pass band.
(b) Very careful measurement and assembly procedures for reducing to a minimum the extraneous effects due to lead lengths and for obtaining low tolerance circuit components.

7. The use of such networks with airborne VHF and IFF equipments resulted in a reduction of the mutual interference to such an extent that:

(a) The entire 156-212 mc/s operating band of the IFF equipment was not blocked, falsely interrogated, or interrupted in operation by the use of any VHF communication channel from 100 to 146 mc/s.
(b) The entire 100- 146 mc/s operating band was made available for unrestricted VHF communication use with no interference from IFF equipments.
(c) Normal VHF-IFF operating was obtained irrespective of the location of the antennas of either equipment on the plane.
(d) The average loss in sensitivity, or power output, over the entire operating band of either equipment caused by inserting these networks in the respective antenna transmission lines amounted to less than 1.0 db. The greatest loss experienced (near cut-off) was less than 2.5 db.

Earlier investigations of this problem were unsuccessful (references (8) and (9)).

SCOPE OF PROBLEM

8. With this background covering the analysis and correction of aircraft VHF-IFF interferences, the Airborne Interference Group was assigned by reference (1) the project of "design and supply" on an urgent basis of a small quantity of antenna networks for IFF and VHF equipments during the early portion of AEW program, until such time as final designs of networks would be settled and regular production started. This project also provided the authority for NRL personnel to install networks, align equipment involved, and observe operation on prototype airplanes. The problem was assigned on 4 December 1944 with the following requested completion dates:

(a) Necessary networks for one (1) airplane by 7 December 1944.
(b) Necessary networks for two (2) additional airplanes by 20 December 1944.
(c) Necessary networks for two (2) additional airplanes by 1 January 1945.

Each of the above dates was successfully met.

9. In addition to the above problem, which referred to the TBM-3W type aircraft used in the original air-to-ship AEW program, NRL was requested to provide similar services for the "Cadillac II Project" which broadened the AEW program to include an installation of AEW equipments in a B-17 type aircraft with CIC facilities aboard. This request anticipated not only the VHF-IFF interference problem, but also "problems (which) will arise involving radio interference between components of the AEW equipment and items of electrical and electronic equipment normally installed in the airplane". It was, therefore, requested by reference (2) on 7 July 1945, that the original problem be extended "to provide authority for necessary NRL personnel to (1) assist in analyzing the interference problem in the Cadillac II airplane (B-17); (2) develop, build, and install experimental corrective measures; (3) align equipment involved and; (4) observe operation of the equipment on prototype airplanes".

10. A few days later on 12 July 1945, the airborne AEW interference problem (A-7.11T-C) was incorporated into problem V2R-C by the NRL Priorities Board, together with the other AEW interference problems assigned to NRL. This was done because "proper operation of the AEW system demands trouble-free operation with all other airborne and shipboard equipments simultaneously. In order to place proper emphasis on the whole problem it was deemed advisable to include all pertinent problems under one broad problem".

INTERFERENCE SURVEY

11. The type and amounts of major interferences that existed in the TBM-3W type aircraft, used in conjunction with the AEW shipboard installations, were known at the time the first AEW interference problem was assigned. Most of the data on airborne VHF-IFF interference had been gathered and analyzed for the NRL problem reported in references (6) and (7), and mentioned in paragraph 5 above, entitled "Existing Interference". Therefore, no additional extensive survey was necessary, the problem being one of developing and supplying corrective antenna networks for these interferences. The assignment of interference clean-up on the B-17 airplane for the "Cadillac II Project", however, made necessary an extensive and complete survey of this airplane's electronic equipment. The AEW shipboard interference surveys had been completed by this time so that the same methods and techniques of measurements were used. Plate II shows a summary of the results of the aircraft survey while the details, the data, and the set-ups, are included in Appendix I. A more complete analysis of the measuring techniques is included in reference (4), (AEW Interference Report B).

12. The results of the survey on Plate II show that a serious amount of spurious radiation was emitted from the antenna of almost every transmitter tested. In the case of the ART-13 and ARC-1 communication transmitters, these radiations were closely allied to the crystal oscillator harmonics and their heterodyne frequencies. The result was a spectrum of closely spaced radiations which varied considerably in amplitude. The interference spectrum from the APX-1 and APX-2, IFF equipment, also showed a considerable amount of supurious radiation outside of the assigned frequency band. Whatever were the causes of these interferences, it was

positively known by the careful measurement methods employed that they were radiated from the antenna, and therefore were capable of suppression through the use of special antenna networks. Two important equipments, the ART-24, Radar Relay Transmitters, and APX-13, Special High-powered IFF Interrogator, which operate in the Block III frequency region were not available for survey purposes, so that essentially the chart is incomplete. However, if interferences from these equipments are reported from the B-17 AEW installation, the causes for it would be recognizable and remedial methods would be available from the technical work already performed, and which is incorporated in this report and the various references listed.

13. A very clear picture of the consequences of serious interference is shown in the photographs of Plate 3. These are photographs of the response display to an IFF interrogator (APX-2). The interrogator was set at 160 mc/s and a nearby ARC-1 transmitter was set at 144 mc/s. In sequence, Figures 1, 2, and 3 of Plate 3 show the effect on the display of (1) turning the ARC-1 transmitter completely off, (2) turning the ARC-1 transmitter on with no corrective networks installed and, (3) leaving the ARC-1 transmitter on, but with corrective networks installed in both equipments. The total blocking of the display shown in Figure 2 and the elimination of this blocking shown in Figure 3 represents the difference between disrupted and normal identification procedure. A residual level of interference can be seen in Figure 3 even after the corrective networks have been installed. This level is caused by non-antenna radiations, such as control lead and power-line pick-up, or case radiations which are capable of correction by standard methods. Careful bonding and filtering procedures must, therefore, be followed in addition to the installation of antenna networks.

14. In a like manner, the IFF transpondor operation can be completely disrupted if ARC-1 transmission blocks the transpondor circuits at any particular frequency. Such mal-functioning of identification equipment may easily result in failure of an aircraft to properly identify itself to other interrogators.

15. In addition to the B-17 survey, an investigation of case and power-line radiations was made of airborne equipments and is included as Appendix II. This work supplemented the antenna radiation surveys and showed that a considerable amount of various types of noise interference was present. The interference above 100 mc/s was caused mainly by the radiations of the oscillators in the equipment directly through the case. Reference (10) reports a study of aircraft ignition noises made aboard the CV-4 (USS RANGER). Such interference was being subjected to very intensive investigation by other Government and private groups and was, therefore, not vigorously prosecuted at NRL.

NETWORK DESIGN

16. The original networks developed for the correction of VHF-IFF interference aboard Naval aircraft were designed from basic network equations for lumped parameter circuits with an extension of the basic equations to provide for improved impedance matching within limited frequency ranges

and for sharper cut-off characteristics. Reference (7) includes a summary of the basic theory and the extension developed by the NRL Interference Group. The lumped constant networks were found to work satisfactorily at low powers (up to 10 watts continuous), and at frequencies below 250 mc/s. The networks required for the IFF equipment, however, had to withstand at least 500 watts peak power when the interrogator was operating. Calculations showed that the network components would build up voltage resonance peaks and cause a breakdown of the condensers. In addition, networks were required which would operate in the Block III band with a special IFF interrogator designed for the AEW program which would have 3000 watts peak power output. Such frequency and power requirements made it necessary to design new types of networks using distributed constants or transmission-line elements. Such network types were developed by the NRL Airborne Interference Group during the clean-up of the AEW shipboard interferences and are described in reference (4), (AEW Interference Report B). The complete development of the theory and design factors for transmission line networks is reported in reference (11). Plate 4 summarizes the theoretical equations and design factors for the specific antenna networks used in correcting the airborne AEW interferences. From the information given on Plate 4, the actual networks were designed and assembled. Plate 5 shows the experimental frequency vs. attenuation curves obtained for each network, with theoretically predicted curves also included. The very close approximation, in each case, of the experimental to the predicted values indicates the proper behavior of each lumped and distributed element comprising the entire network. Actually, the networks are closer to the theoretical values than the curves seem to show because the theoretical values shown are for an ideally assumed condition of operation.

17. The attennuation characteristics of the YL-28/ARC-1 and QH-202/APX-13 networks, shown on Plate 5 are such that normal VHF communication performance is possible up to 150 mc/s, or 4 full megacycles above the present 146 mc/s upper limit of the VHF band. In order to obtain this added performance, it was necessary to provide the unusually sharp cut-off characteristics shown for both the networks. In each case, the unusually low percentage frequency change necessary to change from pass-band to attenuation band is approximately 3%. The complicated mechanical appearance of both networks as shown in the photographs of Plates 6 and 7 belies their non-critical characteristics and ease of assembly. The measurements necessary to construct them are mostly mechanical with comparatively wide tolerances. All critical electrical measurements have been reduced to a minimum. The YL-28/ARC-1 is designed to operate with the AN/ARC-1, AN/ARC-18, or AN/ARC-24 equipments, and the QH-202/APX-13 is designed for operation with the AN/APX-1, AN/APX-2, or AN/APX-3 equipments.

18. The third network type, the Y-4(F-47/APX-13), is mechanically simple as shown in the photograph of Plate 8 and provides the desired attenuation characteristic to prevent the AN/APX-13 IFF responsor from receiving radiations from the Block III radar relay transmitter installed in the AEW aircraft. This unit was not designed to have as sharp a cut-off characteristic as the other networks mainly because such a characteristic was not necessary. Specification details and working drawings for the network are included in reference (13-b).

19. The following characteristics are common to each of the networks and serve to summarize the advantages gained by their use:

(a) Fixed pre-tuned adaptor unit which requires no installation adjustments or maintenance.
(b) Highly efficient electrical characteristics as shown by the extremely low insertion loss in the pass-band (less than 1.0 db everywhere) and high rejection ratios in the attenuation band, (greater than 60 db.).
(c) Ability to withstand high power operation, involving up to 100 watts continuous or 500 watts peak, with adequate reserve power handling capacity.
(d) Ease of production and installation by relatively non-skilled personnel.
(e) Durable and stable units obtained by eliminating adjustments of the elements, and by eliminating fragile components from the design considerations.

INSTALLATION

20. The first installation of interference correctives for the AEW plane took place aboard a TBM-3W at Bedford Field, Massachusetts, on 7 December 1944. A set of the lumped-constant type of low-pass and high-pass networks developed and built by the NRL Airborne Interference Group and described in reference (7) was installed in the antenna transmission lines of the AN/ARC-1, AN/ARC-18 (relay communication) and AN/APX-1, and AN/APX-13 equipments. The installation was reported as highly successful, resulting in an estimated 90% elimination of the mutual interference of these equipments. The residual interference was considered as caused by (1) extraneous interference sources and paths, and (2) deficiencies in the networks. Subsequent installations were made by the NRL group on 20 December 1944 and 1 January 1945. The last set of correctives was not personally installed by the NRL Interference Group, but was shipped to the proper location where they were easily installed by relatively inexperienced personnel. The results of each installation were individually successful.

21. The development of the transmission-line networks to handle greater powers and provide better frequency characteristics further reduced the amount of interference and eliminated cause (2) above. These transmission line networks were used exclusively for the "Cadillac II AEW Program" (aboard the B-17) since this program was considered more permanent than the original AEW. The first Cadillac II installation was made on 20 November 1945 and, the results of the test were reported as very satisfactory. Slight modifications were made in the mechanical assembly of one of the networks to comply with the space available in the B-17 aircraft.

CONCLUSIONS

22. Based on the results of the studies reported herein, it is concluded that:

(a) Practically every airborne transmitter surveyed for spurious frequency emission, radiates signals from its antenna outside of the frequency band assigned to that transmitter. These signals are both harmonics of the fundamental frequency and spurious emissions unrelated to the fundamental. (See Plate 2)

(b) The new types of antenna networks described in paragraphs 16 through 19, and installed aboard the AEW aircraft, successfully and efficiently eliminate the spurious emissions and provide interference-free operation of the AEW equipment aboard the aircraft (see paragraph 7).

(c) Other airborne electronic systems would undoubtedly experience similar interference from spurious transmitter radiations.

(d) The techniques and corrective devices reported herein can be applied to effect a successful correction of such interferences to other airborne electronic systems.

(e) The special antenna networks developed for correcting interferences to the AEW system equipments provided: (See paragraph 19.)

1. A fixed, pre-tuned corrective, employed as a single external attachment
2. Highly efficient electrical characteristics, i.e., low insertion-loss and high attenuation.
3. High frequency, wide band application
4. High power handling capacities
5. Durability and stability
6. Ease of production and installation
7. No required installation adjustments or maintenance.

RECOMMENDATIONS

23. **It is recommended that:**

(a) The techniques and devices employed by the NRL Airborne Interference Group for successfully correcting interferences to the airborne AEW system be applied to the correction of interferences which are compromising the performance of other electronic systems.

(b) The type of networks that have been developed be incorporated as an integral part of the antenna coupling networks of all radio and radar transmitters, in order to reduce to a minimum the harmonic and spurious radiations from such transmitters. This would eliminate at the source a great percentage of the radio interferences now present in Naval electronic equipments.

(c) Further research be undertaken to explore the theory and application of such networks, and other interference correction devices, particularly for purposes of attaining interference-free operation of basic electronic equipments.

ACKNOWLEDGMENTS

The scope of the AEW Interference Correction problem increased so rapidly and to such an extent that the available personnel in the Radio Interference Group of the Airborne Radio Division were far too few to prosecute it effectively and quickly. Therefore, the Office of Chief Coordinator and Consultant for Electronics, through Dr. B. Salzburg as special co-ordinator for the AEW problem, recruited personnel from each radio division of the Laboratory to work cooperatively on the project, under the active supervision of Dr. M. K. Goldstein. The accompanying chart, included as TABLE I, shows some of the personnel and their groupings. It is impossible to list all the other persons who actively aided in the prosecution of this problem, such as:

(a) Personnel at the Chesapeake Bay Annex of NRL
(b) " " " Radio Materiel School at NRL
(c) " aboard the CV-4 (USS RANGER) at SanDiego Navy Yard.
(d) " from the Airborne Co-ordinating Group and Electronic Field Service Group.

This, and other AEW Interference Reports, is intended to represent the efforts and contributions of all the scientific and non-scientific personnel associated with the problem.

REFERENCES

(1) BuAer conf. ltr. to NRL AER-E-3165-JHW, F42-1/85 dated 4 December 1944. Request for assignment of Problem No. A-7.11T-C.

(2) BuAer conf. ltr. to NRL AER-E-3165-EPMcD, F42-1/85 dated 7 July 1945. Request for extension of Problem No. A-7.11T-C.

(3) NRL conf. ltr. C-F42-1/85, Ser. 701-2747/45, dated 12 July 1945 to Sec. (Rad. Prob. Priorities Board) from Chf. Con. and Coord. requesting assignment of Problem No. V2R-C.

(4) NRL conf. report R-2767 dated 29 March 1946 entitled "AEW Interference Report B, Shipboard Problem".

(5) NRL conf. report R-2768, entitled "AEW Interference Report C, Studies of Mast Structure Corona Effects".

(6) NRL conf. ltr. F42-1/85(312), Ser. 310-730, dated 15 August 1944, covering antenna spacing and frequency separation experiments on VHF-IFF equipments on Problem A7.08T-C.

(7) NRL conf. report R-2769, entitled "Antenna Network Correctives for VHF-IFF Interference". Final report on Problem A7.08T-C.

(8) ARL Test Report No. 168 dated 26 November 1942. Filters for the elimination of mutual interference between the SCR-695 (IFF) and SCR-522 (VHF).

(9) ARL Engineering Report No. 329 dated 6 October 1942. Study of interference between IFF -- equipments and other radio equipments installed in the same airplane.

(10) NRL conf. ltr. F-42-1/85(312:PVN:OLW) Ser. 310-144/45 Interim Report on Problems S1012.1R-C covering ignition interferences.

(11) NRL Report 2770 of (in process). covering the development work on transmission line networks by the Airborne Interference Group.

(12) Bell System Technical Journal Monograph No. B-1003 "Filters and Transformers Using Co-Axial and Balanced Transmission Lines" by W. P. Mason and R.A. Sykes.

(13) NRL conf. ltrs. to Bu Aer covering specifications from NRL built filter networks:

   (a) NRL conf. ltr. F42-1/85(312), Ser. 310-17/45 dated 12 February 1945 covering VHF-IFF Interference Correctives for Project Cadillac - Interim Report on Problem No. A-7.11T-C.

   (b) NRL conf. ltr. F-42-1/85(312:AB) Ser. 310-96/45 dated 11 May 1945 covering IFF - Block III Interference Correctives for Project Cadillac - Second Interim Report on Problem A-7.11T-C.

APPENDIX I

7 August 1945

Memorandum to: Dr. M. K. Goldstein

From: H. W. Chitty

SUBJECT: B-17 Interference Survey

1. This interference survey was conducted in order that interaction with one type of equipment on another in the B-17 could be observed. The test is not conducted as a system test but rather as a preliminary survey. Interference so far as this test is concerned referes to spurious frequencies radiated by the transmitting antenna systems.

2. The various equipments which are located in the B-17 AEW plane are as follows:

	Transmitting Equipment		Antenna
ART-13	2-18 Mc. L.F.	Communications	Straight Wire
ARC-1	100-156 Mc. UHF	"	Co-AX
APX-1AM	157-187 Mc. A. Band) 194-212 Mc. G. Band) I.F.F. 172-182 Mc. RDO)		Co-AX
*APX-13	157-187 Mc.	Interrogator I.F.F.	Co-AX
*ART-22	285-315 Mc.	Radar Link	
APN-1	420-460 Mc.	Altimeter	Co-AX
*APS-20	3000 Mc.	Radar Search	

Receiving Equipment

ARN-7	(1) 100-200 kc.) (2) 200-410 kc.) (3) 410-850 kc.) Radio Compass (4) 850-1750 kc.)		Loop Co-AX

Note: The ARN-7 was not available for this test, a substitute was made which has the same frequency range with the exception of the low frequency range of 100-200 kc. This equipment is the BC-4336.

APN-4	(1) 1950 kc.) (2) 1850 kc.) Loran (3) 1750 kc.)		Co-AX
R23A-ARC-5	.19-.55 Mc/s.)		
R26-ARC-5	3-6 Mc/s.)	Communications	Straight Wire
R27-ARC-5	6-9 Mc/s.)		
ARC-1	100-156 Mc/s.	UHF Communications	Co-AX
*APX-13	157-187 Mc/s.	I.F.F. Responsor	Co-AX
APX-1AM	157-187 Mc/s.) 194-212 Mc/s.) 172-182 Mc/s.)	I.F.F. Responsor	Co-AX

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ARW-35	60-65 Mc/s	Radio Control, ten channel system, channels start at 200 cycles and are spaced approximately 200 cycles apart.	Co-AX
ARN-8	72-78 Mc/s.	Marker Beacon	Co-AX
ARR-2A	234-258 Mc/s.	ZBX Navigation	Co-AX
*ARN-5A	(1) 332.6 Mc/s.) (2) 333.8 Mc/s.) (3) 335.0 Mc/s.)	Inst. Landing	
APN-1	420-460 Mc/s.	Altimeter	Co-AX
*AIA-2A	Inter Communication System		
*ARD-4	VHF Direction Finder		
*BC-348	Army Low-Frequency Receiver		

3. The above mentioned equipment was mounted on two benches specially constructed as follows. Copper sheeting was placed on both benches and seams soldered, heavy braid was used in bonding the benches together in several different points. A raised frame-work was constructed above the bench at a height of approximately five feet, over the top of this frame-work was laid a roof constructed of 1/16" aluminum sheet. This aluminum sheet served as a ground plane for mounting various antennas, an effort was made to keep each antenna directly overhead of its respective equipment. The distance between antennas averaged about 20 inches. A sketch showing the location of the equipment on the benches is shown in Plates 1 and 2.

4. D.C. power was furnished to the equipment by Mallory recto-starters. A separate supply being used for each bench. The supply line from the recto-starter to the bench and along the bench was entirely shielded, individual junction boxes were provided for each equipment and these boxes were also completely shielded.

5. After satisfactory operation of the various equipments had been ascertained, surveys of each transmitter were made. The surveys of the transmitters can be seen in Tables 1 through 3.

6. After the surveys had been completed it was possible to predict what equipment would be interfered with and on what frequencies. Experimental tests were made to provide a double check on both interference and the equipment which was interfered with. This was done in the following manner. With a particular transmitter operating, each piece of equipment was operated separately and tuned over its respective band and interference noted. The following is an outline of the interference encountered.

* Equipment not available.

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Interference Outline

(1) ART -13 (ATC) 2-18 Mc/s. 10 pre-set channels.

1.	3000 kc.	6.	15000 kc.
2.	5000 kc.	7.	18000 kc.
3.	7200 kc.	8.	Not Operated
4.	9000 kc.	9.	Not Operated
5.	12000 kc.	10.	Not Operated

7. The oscillator in the ART-13 is either between 1000 and 1250 or 1250 and 1500 kc. depending upon position of tuning mechanism.

(a) BC4336 Radio Compass

The BC4336 was interfered with on each of the ART-13 preset channels. However it was not the fundamental signal but that of the oscillator which interfered with the BC4336. The interference was of such a nature as to make the compass in-operative at a tuned frequency which would be the same as the oscillator in the ART-13.

(b) APN-4 Loran (Navigation)

ART-13	APN-4		
CHANNEL #	#1	#2	#3
1.	1950 kc.	1850 kc.	1750 kc.
2.	Strong	Strong	Strong
3.	None	None	None
4.	None	None	None
5.	None	None	None
6.	None	Weak	None
7.	None	None	None

Keying the transmitter causes the traces on the APN-4 indicator to jump approximately 1/2". Readings would be impossible to take while transmitting with the ART-13.

(c) Fluxgate Compass -- The fluxgate compass did not give any indications that it was being interfered with while the ART-13 was being operated.

(d) APX-Responsor -- Interference was obtained when the ART-13 was operated on channels 2 to 7 throughout the tuning range of the APX receiver. There was no interference when the ART-13 was tuned to Channel 1.

(e) ARN-8 Beacon Receiver -- Interference on the ARN-8 receiver was noted on all channels in the form of bad key-clicks. However, when the ART-13 was tuned to channels 5 and 6, the interference was of such intensity so as to operate the indicator lamp on the ARN-8.

(f) ARR-2 Homing Receiver (2BX) -- The receiver tone changes greatly

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when the ART-13 is keyed. The interference is great enough so as to cause the receiver to be in-operative.

(g) APN-1 -- No interference was found in the APN-1 as caused by the ART-13.

(h) ARC-1 -- 100 - 156 Mc/s. V.H.F. Communications -- No interference was found in this equipment.

(i) ARW-35 60-65 Mc/s. Radio Control -- No interference was found in this equipment.

(2) APX-I.F.F. . 172 Mc/s. (Interrogator)

This equipment has a range 157-187 Mc/s on "A" band. A frequency of 172 Mc/s was chosen as representative.

(a) BC-4336 -- No interference found in this equipment.
(b) APN-4 -- No interference found in this equipment.
(c) Fluxgate Compass -- No interference noted in this equipment.
(d) ARN-8 -- Slight interference but of not great enough intensity to key indicator lamp.
(e) ARR-2 -- No interference in this equipment.
(f) APN-1 -- " " " " "
(g) ARW-35 - " " " " "
(h) ARC-1 -- " " " " "

(3) The ARC-1 transmitter-receiver was set up to operate on six channels.

Channel	Crystal Frequency (Kc)	Output Frequency (Mc/s)
1	5910	116.1
2	6370	124.38
3	6470	126.18
4	6610	128.7
5	7350	142.02
6	7580	146.16

Interference survey was made on the following equipments to determine the amount of interference radiated by the ARC-1.

(a) ARC-5 Receivers R-23, R-26 and R-27 -- Strong interference from the ARC-1 transmitter operating on all channels was heard when the receivers were tuned to the frequency of the crystal oscillator in the transmitter. When the receivers were not tuned to this frequency only key-click interference was noticed and this was not serious.

(b) ARR-2 Homing Receiver 234 to 258 Mc/s. -- There was no interference from the ARC-1 transmitter with this receiver.

(c) APN-4 Loran Receiver 1750 Kc., 1850 Kc. and 1950 Kc -- The ARC-1 transmitter did not interfere with the operation of the Loran receiver.

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(d) ARN-8 Beacon Receiver (75 Mc/s.) -- The receiver was interfered with by the ARC-1 transmitter when the transmitter was operated on channels one through four. The interference was sufficiently strong to trigger the indicator light.

(e) APX-2 I.F.F. Responsor -- The APX-2 receiver was tuned through its range of 157 Mc/s to 187 Mc/s. while the ARC-1 transmitter was operated on each of its channels and the following interference was noted.

Channel	
1, 3 and 4	Medium Interference
2	Very little interference
5 and 6	Very strong interference

This interference was measured by noting the effect on the receiver output as viewed on a servoscope while tuned to receive an emergency reply. Small interference merely increased the noise along the sweep. Medium interference slightly lowered the base line and partially blocked the pulse. Strong interference lowered the whole base line completely obliterating the pulse.

(f) APN-1 Radio Altimeter (420 to 460 Mc/s.) -- No interference found in this equipment.

(g) Flux-Gate Compass -- No interference found in this equipment.

(h) SCR-269G Radio Compass (250 Kc to 1750 Kc) -- No interference found in this equipment.

(i) R146A-ARW-35 Receiver (60-65 Mc/s.) -- No interference found in this equipment.

8. A Survey Chart has been constructed which shows the survey of the B-17 transmitters available and also the effect on various receiving equipment in the B-17.

(4) APN-1 -- Radio Altimeter 420-460 Mc/s. -- The operation of the APN-1 did not interfere with any other equipment.

TABLE I

SPURIOUS FREQUENCY SURVEY ART - 13

ART-13 Freq. Mc/s.	Signal Freq. Mc/s.	Trap Freq. Mc/s.	Rel. Signal Strength	ART-13 Freq. Mc/s.	Signal Freq. Mc/s.	Trap Freq. Mc/s.	Rel. Signal-Strength
3	45.5	----	M	12	79	----	
3	46.6	----	M	12	83	83	M
3	48.5	----	M	12	86	86	W
3	50.0	----	M	12	106	106	M
3	61.0	----	W	12	118	118	M
3	73.0	----	W	12	125	125	M
3	80.0	----	W	12	130	130	S
5	87	87	M	12	138	138	W
5	91	91	S	12	142	142	M
5	100	100	W	12	150	150	M
5	112	112	M	12	153	153	S
5	117	117	M	12	163	163	S
5	121	121	M	12	187	187	M
5	127	127	M	12	210	210	M
5	132	132	S	15	80	80	W
5	152	152	W	15	88	88	M
5	155	155	M	15	94	94	W
5	160	160	S	15	103	103	M
5	191	191	M	15	147	147	M
5	197	197	W	15	153	153	M
5	202	202	W	15	161	161	S
7.2	79	----	S	15	190	190	W
7.2	81	----		15	203	203	M
7.2	87	87	M	18	87	87	S
7.2	89	89	W	18	93	93	S
7.2	91	91	M	18	100	100	S
7.2	120	120	W	18	105	105	S
7.2	150	150	W	18	116	116	W
7.2	155	155	W	18	120	120	W
7.2	162	162	M	18	123	123	S
7.2	197	197	W	18	130	130	S
9.0	80	----	S	18	140	140	S
9.0	89	89	M	18	147	147	M
9.0	115	115	W	18	153	153	S
9.0	130	130	W	18	157	157	S
9.0	133	133	M	18	160	160	M
9.0	150	150	M	18	164	164	S
9.0	158	158	M	18	170	170	W
				18	175	175	W
				18	183	183	M
				18	195	195	S
				18	200	200	S
				18	206	206	S
				18	265	265	W
				18	308	308	W

APPENDIX I (cont'd)

TABLE II

SPURIOUS FREQUENCY SURVEY ARC-1

Trans. Freq. Mc/s.	Signal Freq. Mc/s.	Trap Freq. Mc/s	Relative Signal Strength
116.1	116.1	116.1	S
116.1	228	228	S
128.7	108	108	M
128.7	122	122	M
128.7	128.7	128.7	S
128.7	136	136	M
128.7	192	192	S
128.7	232	232	M
128.7	252	252	S
128.7	125	125	S
146.16	145	145	S
146.16	152	152	W
146.16	160	160	W
146.16	225	225	S
146.16	270	270	S
146.16	285	285	M
146.16	295	295	S
146.16	305	305	M
146.16	445	445	W

TABLE III

SPURIOUS FREQUENCY SURVEY APX-2A

Trans. Freq. Mc/s.	Signal Freq. Mc/s.	Trap Freq. Mc/s	Relative Signal Strength	
172	105	105	W	
172	128	128	W	
172	147	147	M	
172	170	170	S	fo
172	235	235	S	
172	350	350	S	2 fo
172	522	522	S	3 fo
172	690	690	M	4 fo
172	850	850	M	5 fo

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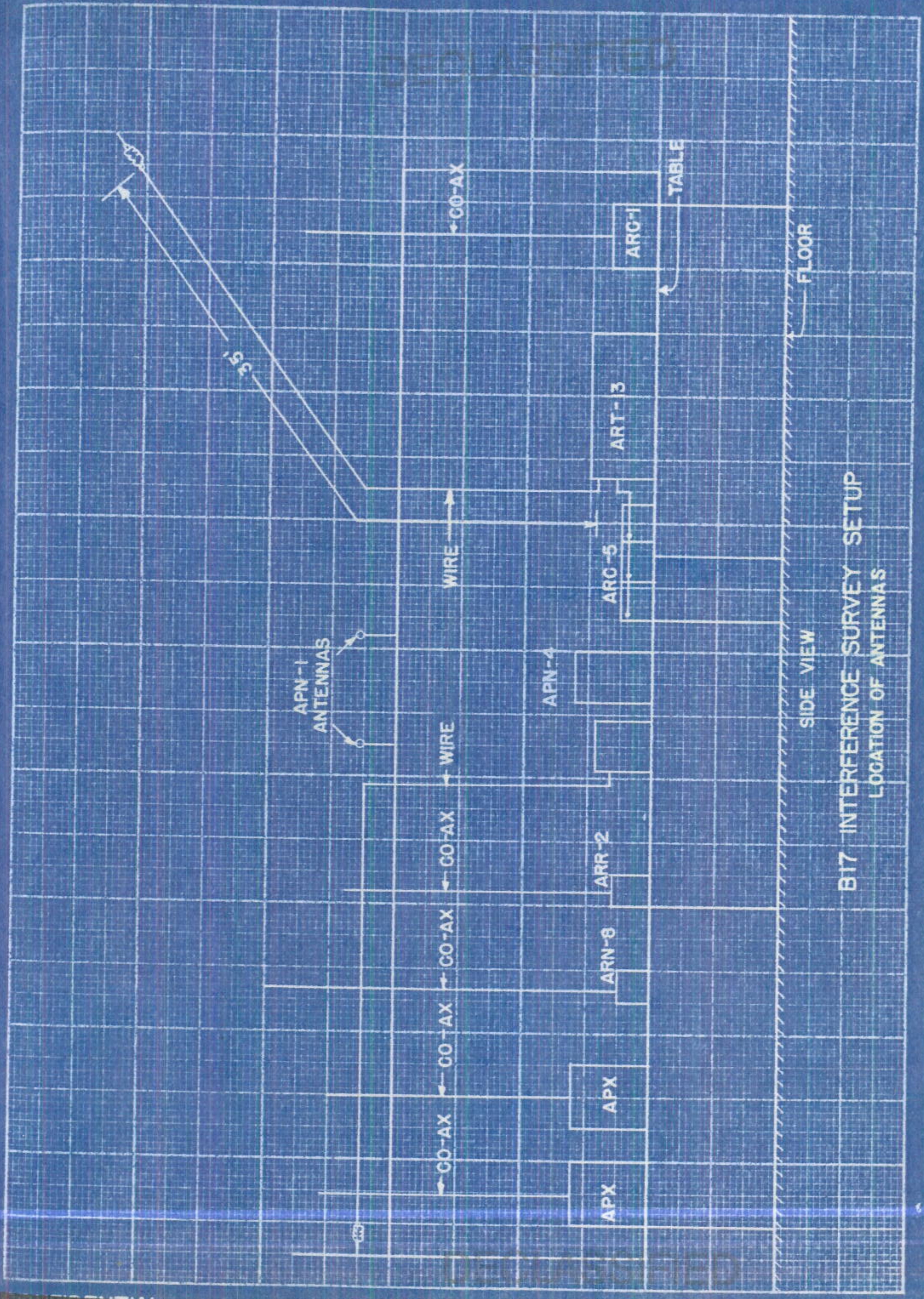
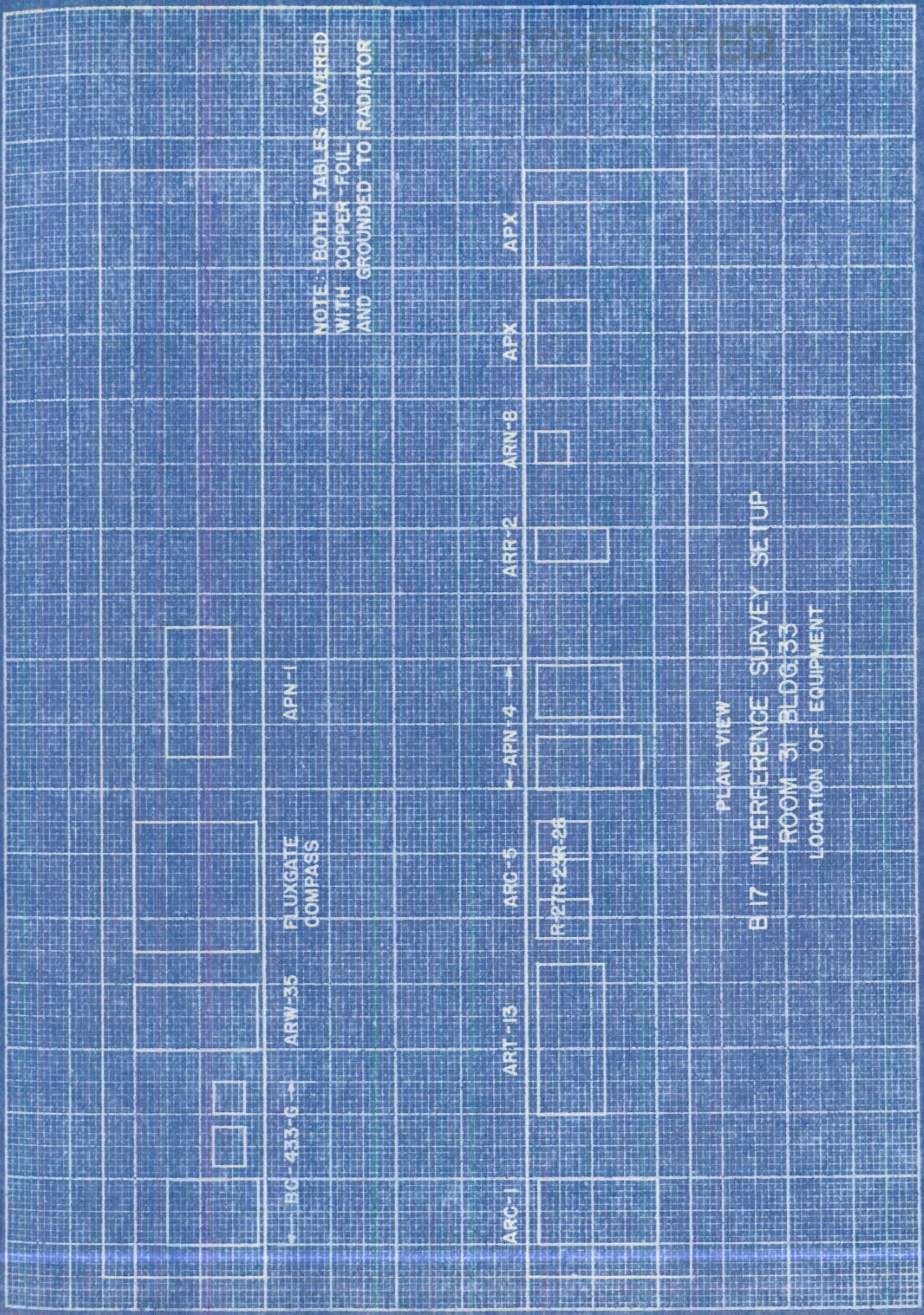


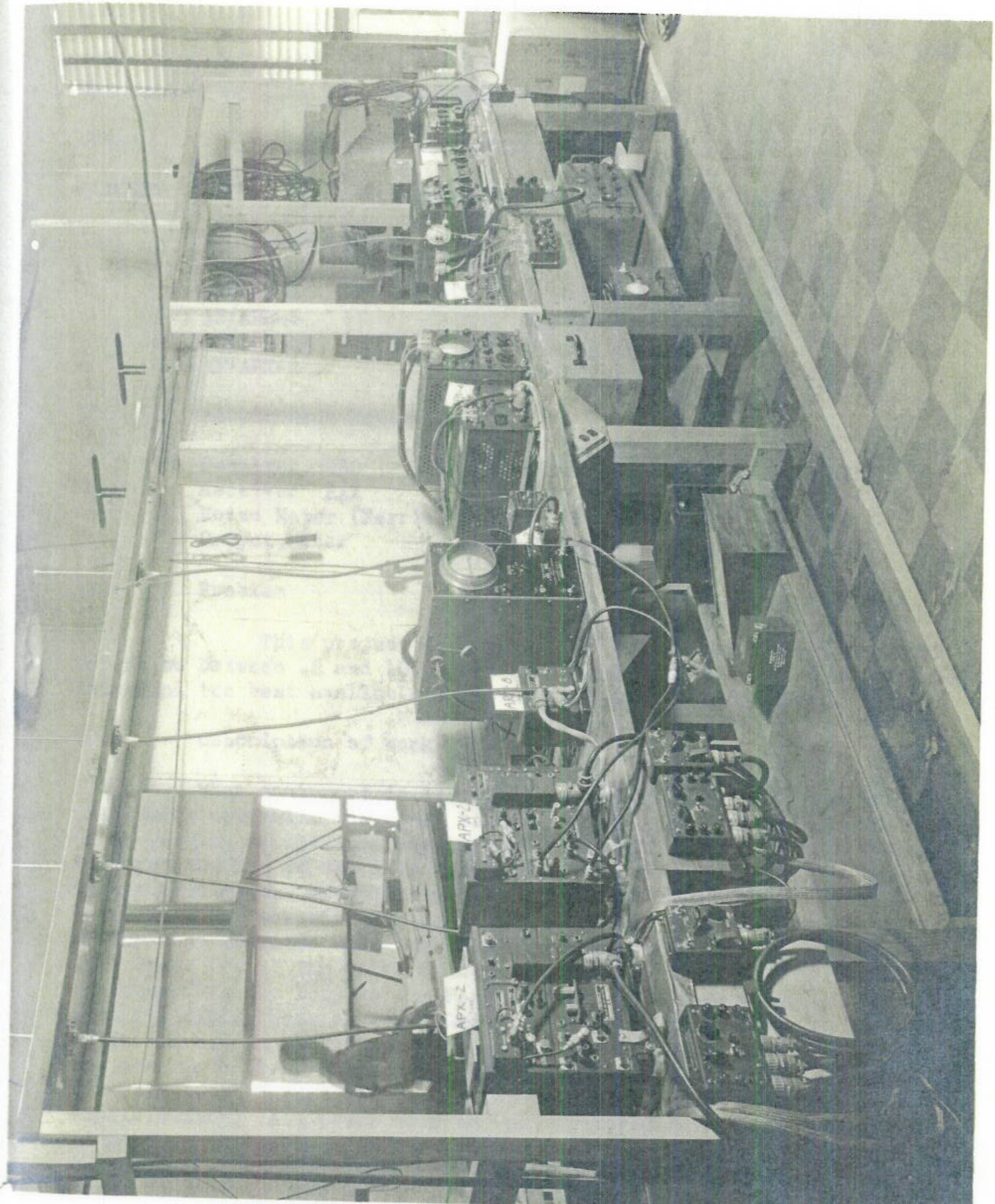
SIDE VIEW

B17 INTERFERENCE SURVEY SETUP

LOCATION OF ANTENNAS



 R-2766 PLATE 2



TEST EQUIPMENT LAYOUT

APPENDIX I

APPENDIX II

7 August 1945

Memorandum to: Dr. M. K. Goldstein

From: Lt. J. M. Corbin

SUBJECT: Interference, Power Line and Case Radiations.

I. Equipment Tested

AN/ARC-1	Receiver Component
AN/ARC-5	MHF Receiver
AN/ARR-2A	Homing Receiver
AN/APX-1	Receiver Component

II. Measurement Equipment

Receiver RDO	38 to 1000 Mc.	Serial 703
Receiver RAX	0.2 to 27 Mc.	Serial 262
Noise Meter (Ferris)	0.16 to 20 Mc.	Serial 195
Output Meter	General Radio	type 583-A

III. Problem

This project is a survey of the above airborne equipment for noise between .2 and 1000 Mc/s which radiates from the cases and power lines, and the best available solution to eliminate this noise.

IV. Description of Work

When equipment is installed in a plane, the proximity of the units will determine the final balance of the plane as well as the ease of operation, maintenance and installation. If there is no electrical interference due to the close proximity of the equipment, the ideal set-up has been made. With this procedure in mind measurements of noise radiating from the airborne equipment were made by obtaining the output of the test receiver when its antenna was placed in a loop around the unit under test. The connections made are shown in Plate 7. Instead of connecting the loop to the Ferris meter, that instrument was used with its dipole antenna installed one foot from the center of the aircraft radio. In all cases where exact location of noise radiations was desired a probe antenna was used. The output meter was connected directly to the audio output of the test receiver with full gain amplification. All power sources were filtered and the test was run within a shielded space. During each test run the base noise level of the test equipment was found to vary from one unit to another with peaks ranging as high as 150 milliwatts. When there was a large variation in base level registered within the over-lapping frequency

[redacted]

Memo to Dr. M. K. Goldstein 7 August 1945

bands the results of the most sensitive measurement were used. In this way noise radiations of small value could be picked up which would otherwise be lost in the base level noise.

The RDO was further modified so that measurements of the pure R.F. noise voltage could be made. This was done by wiring a microammeter in the plate circuit of the 2nd detector so that the audio frequency modulation would not affect the amplitude of the radio frequency noise voltage. It was found, however, that the audio output voltage was proportional to the RF voltage output in the measurements of noise radiations.

In the majority of the tests the survey was conducted and then attempts were made to reduce the noise level of the radiations from the case and power lines. The acceptable level of reduction was the noise level of the testing equipment. In all cases dynamotor hash could be substantially reduced. However, it is believed that to reduce oscillator radiations it will be necessary to redesign part of the internal circuit or install filters in all leads that pass between junction and control boxes.

V. Narrative

All surveys showed that dynamotor hash could be measured over the entire band and that at certain frequencies the noise saturated the test receiver. Oscillator radiations could be detected emanating from the power lines, cases and control cables with the noise signals strongest when open wire cable was used. All charts show the difference between the test receiver noise level and the noise signal received. To clarify the results obtained:--

The VHF receiver AN/ARC-1 radiated strong oscillator squeals and dynamotor hash from 5 to 30 Mc/s. However above 40 Mc/s the receiver was quiet except for hash around 70 megacycles.

To eliminate the dynamotor noise, capacitors were installed from each brush to ground. Other tests showed that grounding each crystal holder and installing an RF tight cover over the front panel eliminated noise from the case. By filtering each lead running from the unit to the controls with an RF choke and capacitor, power line radiations could be reduced. Results of the survey are shown in Plate I.

The MHF units of the AN/ARC-5 gave off strong signals at different frequencies depending on the unit which was used. Each of the receivers had a dynamotor constructed by a separate manufacturer which resulted in variations in noise and variations in corrective measures. The corrective measures applied reduced the dynamotor noise until it disappeared in the noise level of the test set. This base level was not reached in the reduction of the oscillator radiations.

Memo to Dr. M. K. Goldstein 7 August 1945

A plot of the difference between the noise level of the receiver and the noise radiations, as well as a plot of the results of corrective measures are shown on Plates 2, 3, and 4. The figures showing the decibel reductions were obtained by using the noise of the test receiver as the base level and obtaining the ratio of milliwatt and microamp output before and after installing corrective measures. (See addenda for further information concerning test equipment.)

The Homing receiver AN/ARR-2A was found to have strong signals emanating from the local oscillator which is tunable from .74 to 1.03 Mc/s. There was also strong dynamotor hash which was reduced by properly grounding the dynamotor and by providing adequate metal to metal contact throughout the case. Plate 5 shows the survey results with decibel values of noise reduction. In order not to disturb any of the internal electrical circuits and because of the time limitations the open wire connections between the unit and the control box were not filtered but were shielded. The final figures of noise reduction are based on this fact.

The receiver component of the AN/APX-1 was surveyed for case and power line radiations by grounding out the antenna connections so that no spurious interference could be radiated from the transmitter section. With adequate grounding of the case and with open wire circuits between the unit and the control box, readings of noise radiations were obtained and plotted. By placement of capacitors throughout the equipment the dynamotor hash was reduced to the noise level of the test receiver. Leakage of the .3 Mc/s quench oscillator causes interference for which no satisfactory method of elimination could be found.

VI Conclusions:

The following procedure should be followed on each unit tested in order to reduce noise radiating from the case and power lines.

AN/ARC-1

1. Ground negative line of 24 volt power at brush holder in dynamotor.
2. Connect .01 mfd capacitors from each of the high voltage brushes and the positive low voltage brush to ground.
3. Ground all crystal holders.
4. Assemble R.F. tight cover over front panel.
5. All connecting wires leading from main unit to junction and control boxes should be filtered to block oscillator fundamental and harmonic frequencies.

AN/ARC-5

1. Connect .25 mfd capacitor across input power leads inside receiver rack.
2. Place grounding connections (springs coil 5/8" long by a diameter from .1875 to .218 inches) on the three pins beneath each dynamotor.

APPENDIX II (cont'd)

Memo to Dr. M. K. Goldstein 7 August 1945

AN/ARC-5 (cont'd)

3. Connect one .01 mfd capacitor across pins 1 and 6 of each of the terminals J18, J19 and J20 leading from receiver rack to unit.
4. Connect .01 mfd mica capacitor between high voltage brushes of dynamotors, Series 693A and 35X009B.
5. Connect .01 mfd mica capacitor between low voltage brushes of dynamotors series 6936.
6. Shield cable between control box and unit and well ground both ends of shield separately from AN/connectors.
7. Scrape paint from all metal mating surfaces of case.
8. Tighten all screws on base, cover and sides.

AN/ARR-2A

1. Connect 1.0 mfd or 0.5 mfd capacitor between 24 volt positive input terminal and ground.
2. Connect .01 mfd mica capacitor between the high voltage brushes of the dynamotor.
3. Place grounding connector (coil springs 5/8" long by a diameter from .1875 to .218 inches) on the three pins beneath each dynamotor.
4. Scrape all paint from the mating surfaces so there will be good metal to metal contact throughout the case.
5. Install spring contacts beneath cover so that there is good pressure contact at the mating surfaces.
6. Shield the cable between the control box and unit, grounding both ends separately from the AN connector.

AN/APX-1

1. Connect .01 mfd mica capacitor from contact B of switch S-502 to chassis.
2. Connect 1.0 mfd 400 v. capacitor from pin #17 of J509 to ground.
3. Connect 1.0 mfd 400 v. capacitor from pin #6 of J509 to ground.
4. Connect a .01 mfd mica capacitor from pin #15 of J509 to ground.
5. Connect a .01 mfd mica capacitor across 28 v. terminals of sweep motor B-501.
6. Connect shorter ground wire 1/2" from negative terminal of sweep motor to motor frame.
7. Connect short ground wires to all destructor holders.
8. Scrape paint from all metal mating surfaces of case
9. Scrape paint and place copper wire screen across louvres on oscillator side of cabinet.
10. Scrape paint and place copper wire screen between upper and lower section of APX-1.
11. Connect capacitors from pin 7 to pin 1 of J101 to give a capacitance of 1.28 mfd.
12. Connect a .01 mfd mica capacitor from pin #2 of J102 to ground.
13. Connect a .01 mfd mica capacitor from pin #3 of J102 to ground.
14. Connect a .01 mfd mica capacitor across 28 v. terminal of dynamotor.

APPENDIX II (Cont'd)

Memo to Dr. M. K. Goldstein 7 August 1945

References: MISCELLANEOUS INTERFERENCE SURVEY

(a) Pratt & Whitney R-2800 Engine Bulletin #113 of 14 January 1944 and supplement #1 of 4 December 1944.

(b) NRL - Interference Effects Caused by Ignition Systems Letter C-F42-1/85 (312: PVN:OLW) of 13 July 1945.

(c) NAS Patuxent River report NA 83/F42-1/85 on project TED #PTR-31508-1 of 6 December 1944 concerning Ignition Interference tests on Wright R-1820 engine.

(d) NAS Patuxent River report NA 83/F42-1/85 on project TED #PTR-31586-2 of 3 March 1945 concerning Ignition Interference tests on Wright R-2600 engine

(e) NAMC Philadelphia report ARRL 265-45 on project TED #NAM 31292.0 of 28 March 1945, concerning Ignition Interference tests on F6F-5 aircraft.

(f) Uncompleted projects issued by BuAer on NAMC Philadelphia TED numbers NAMC 31299.1, 31299.2, 31299.3 covering ignition interference of flight deck equipment such as tractors, jeeps, etc. and TED #NAMC 31298 and 31298.1 covering plane starter induction vibrator.

Purpose:

To determine ignition noise levels present in Block III frequency band (295-315 mc/s) and ignition noise present in receiving equipment of aircraft associated with Project Cadillac.

Investigation:

Research as to previous surveys disclosed that references (a) thru (f) cover the subject question regarding interference encountered and methods of elimination.

Conclusion:

Due to the short time involved and due to the fact that it would be a duplication of previous effort, no survey of gasoline engine ignition systems was conducted.

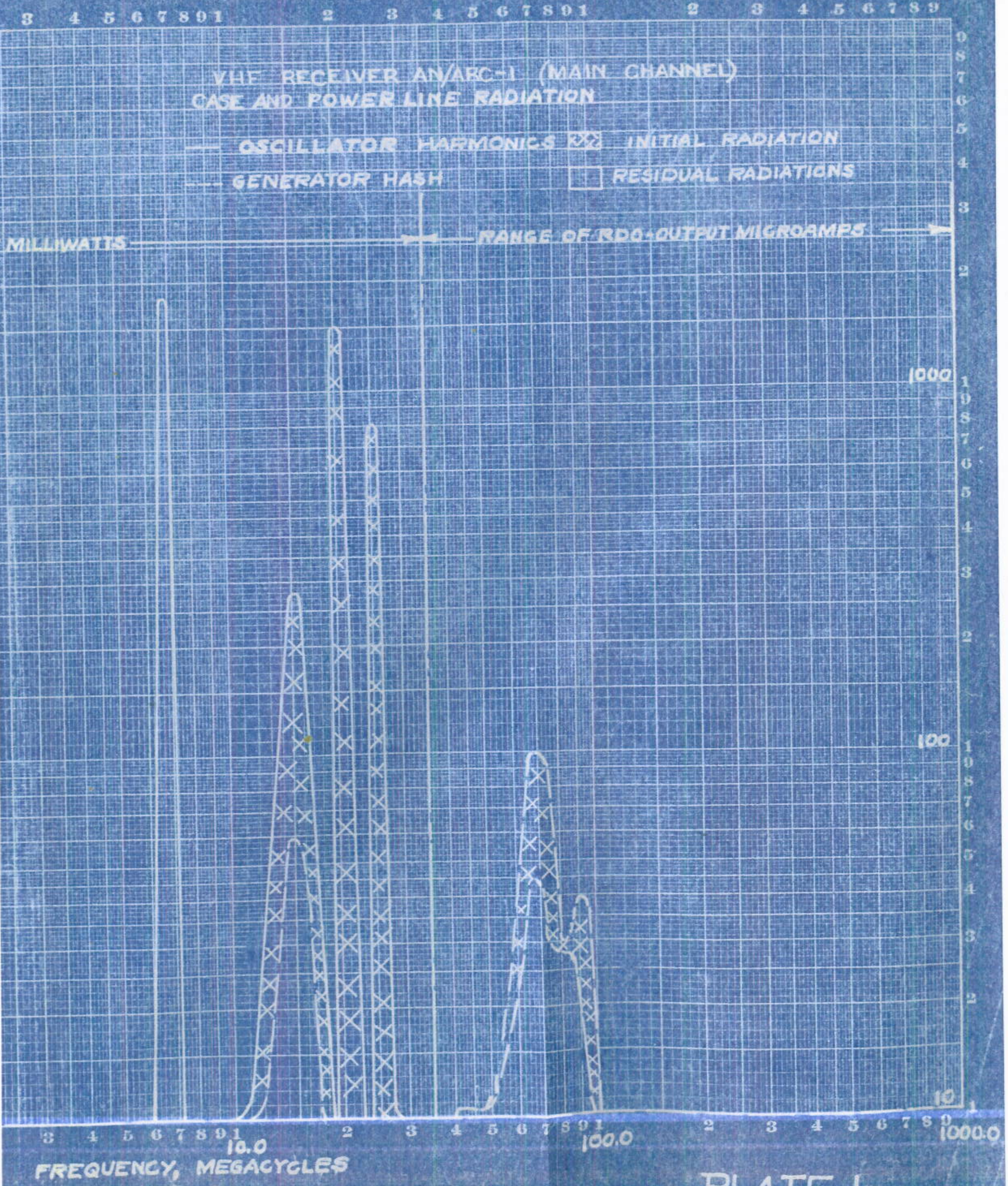
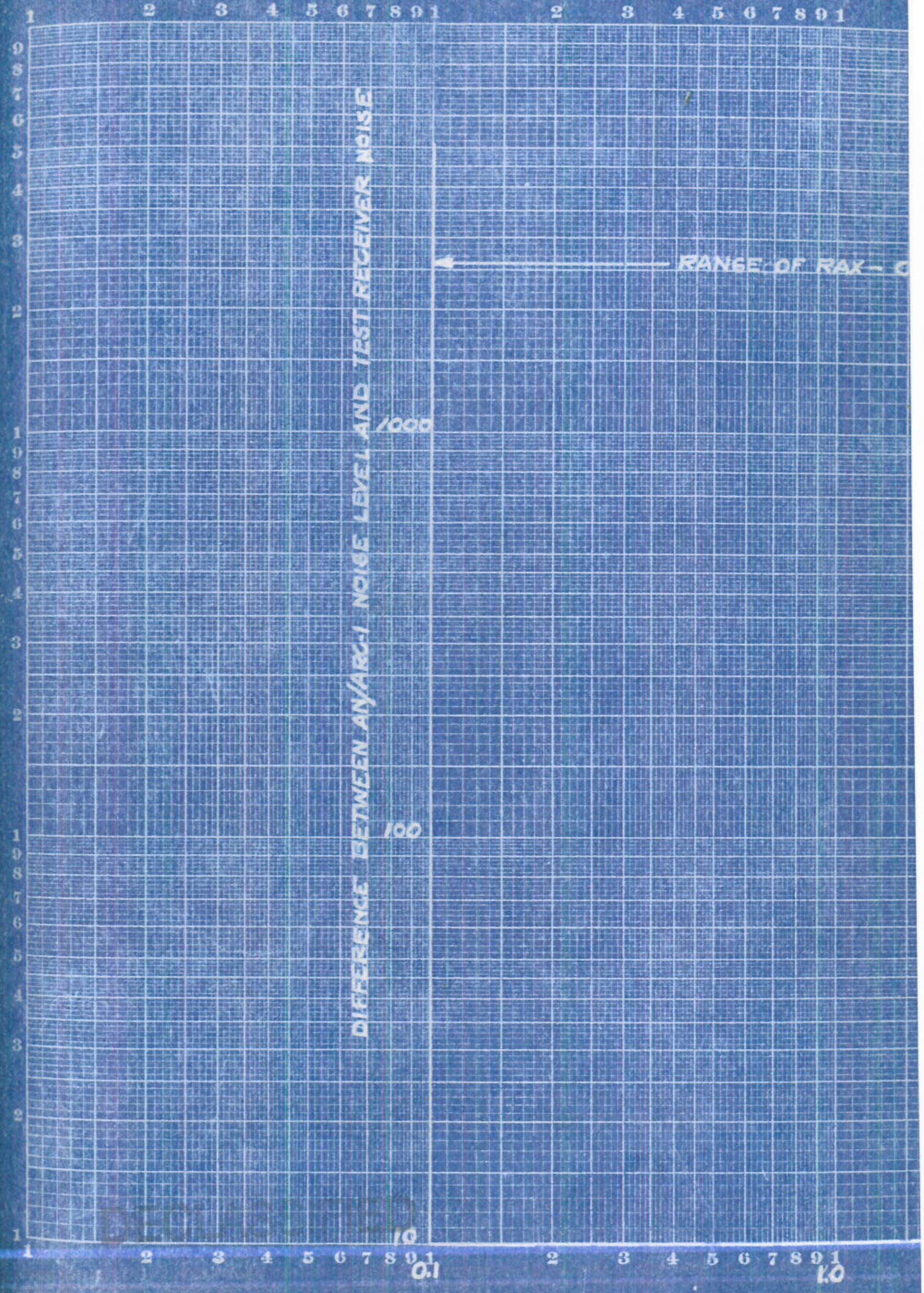

VHF RECEIVER AN/ARC-1 (MAIN CHANNEL)
CASE AND POWER LINE RADIATION
OSCILLATOR HARMONICS
INITIAL RADIATION
GENERATOR HASH
RESIDUAL RADIATIONS
MILLIWATTS
RANGE OF RDO-OUTPUT MICROAMPS
1000
100
10
10.0
100.0
1000.0
FREQUENCY, MEGACYCLES

PLATE I



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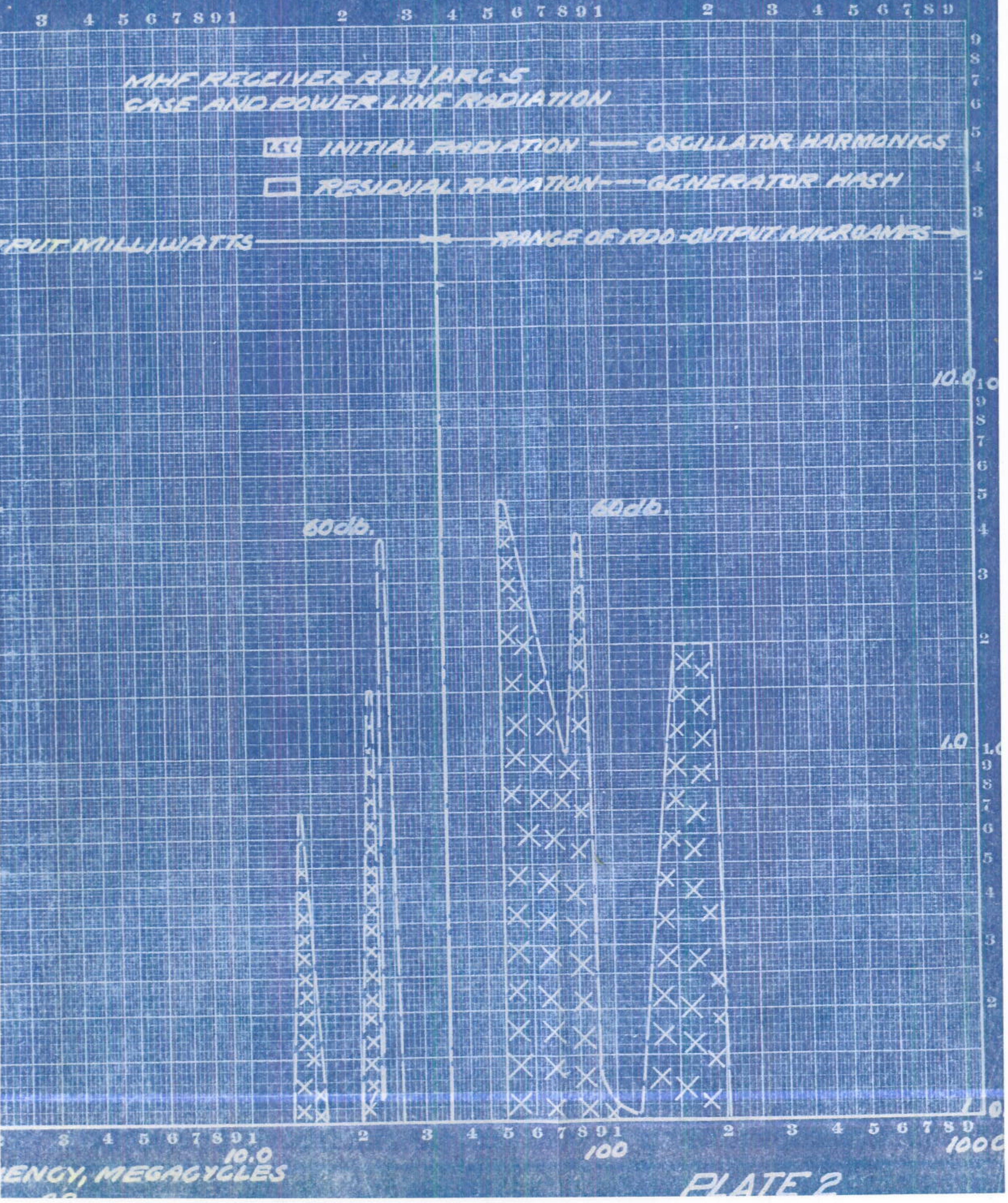
MHF RECEIVER R23/ARC-5
CASE AND POWER LINE RADIATION
INITIAL RADIATION —— OSCILLATOR HARMONICS
RESIDUAL RADIATION --- GENERATOR HASH
PUT MILLIWATTS
RANGE OF RDO-OUTPUT MICROAMPS
60db.
60db.
10.0
1.0
10.0
100
1000
ENCY, MEGACYCLES

PLATE 2

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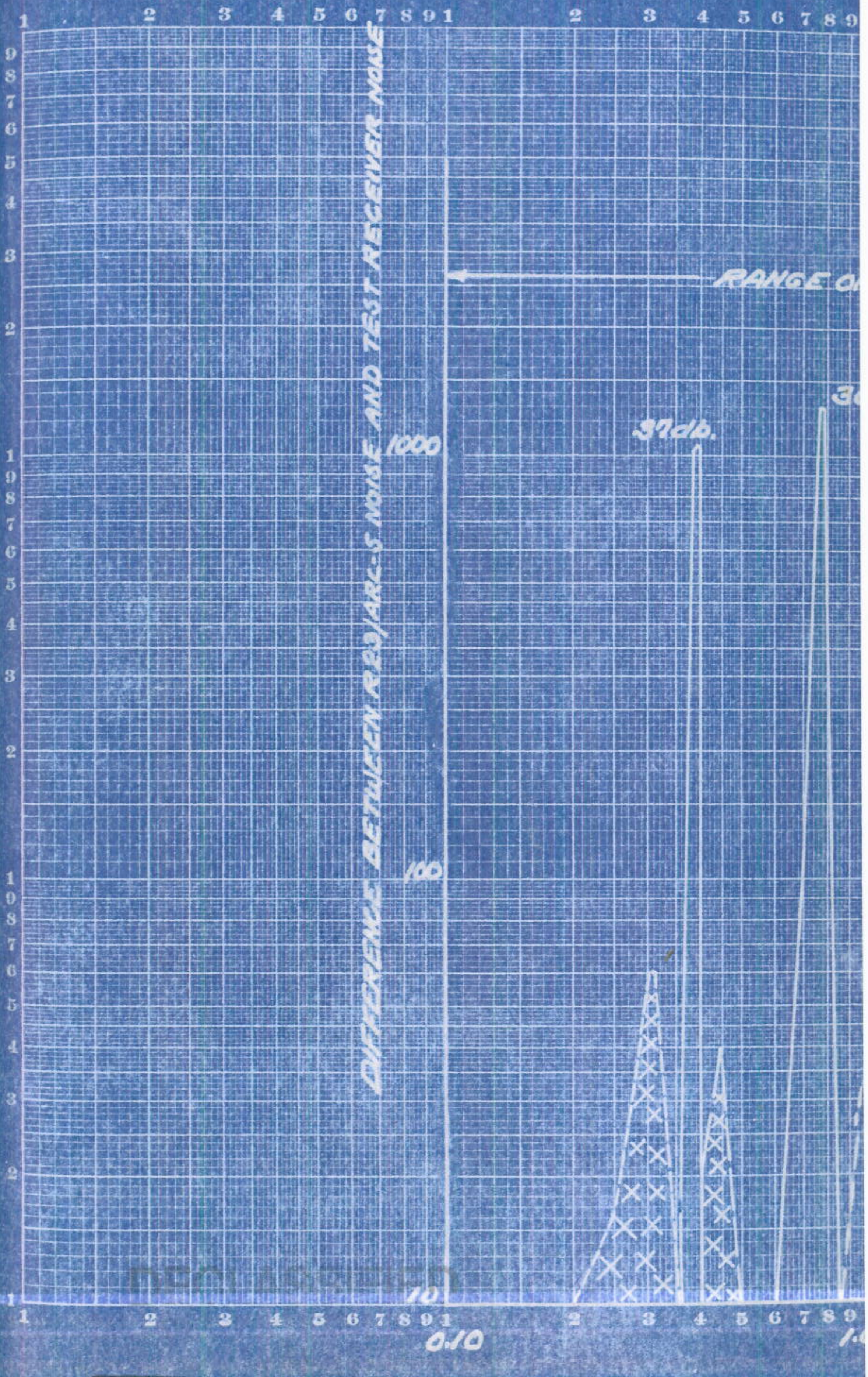

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CONFIDENTIAL

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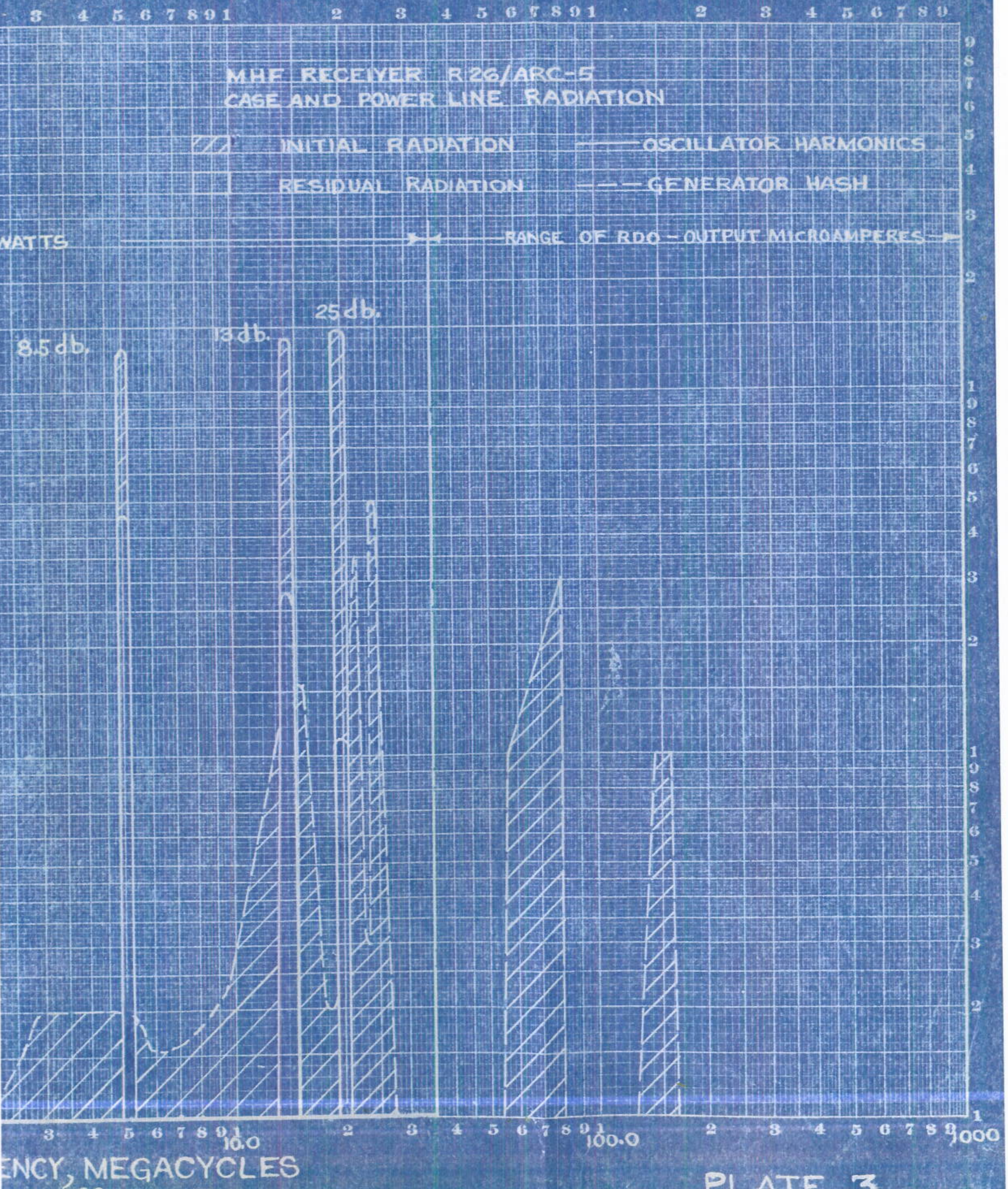
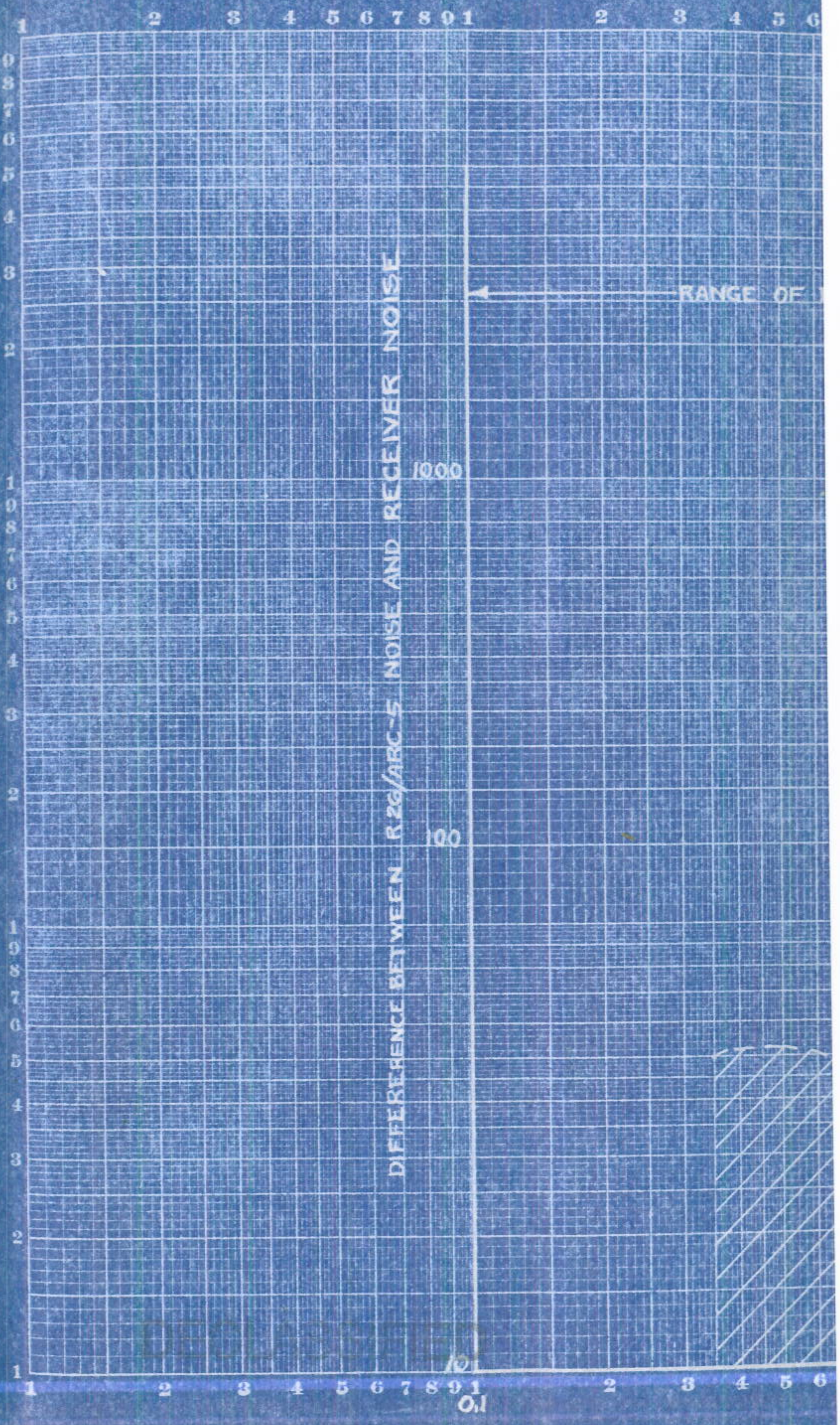

MHF RECEIVER R 26/ARC-5
CASE AND POWER LINE RADIATION
INITIAL RADIATION
RESIDUAL RADIATION
OSCILLATOR HARMONICS
GENERATOR HASH
WATTS
RANGE OF RDO - OUTPUT MICROAMPERES
8.5 db.
13 db.
25 db.
10.0
100.0
1000
ENCY, MEGACYCLES

PLATE 3


DIFFERENCE BETWEEN R 26/ARC-5 NOISE AND RECEIVER NOISE
1000
100
10
0.1
RANGE OF

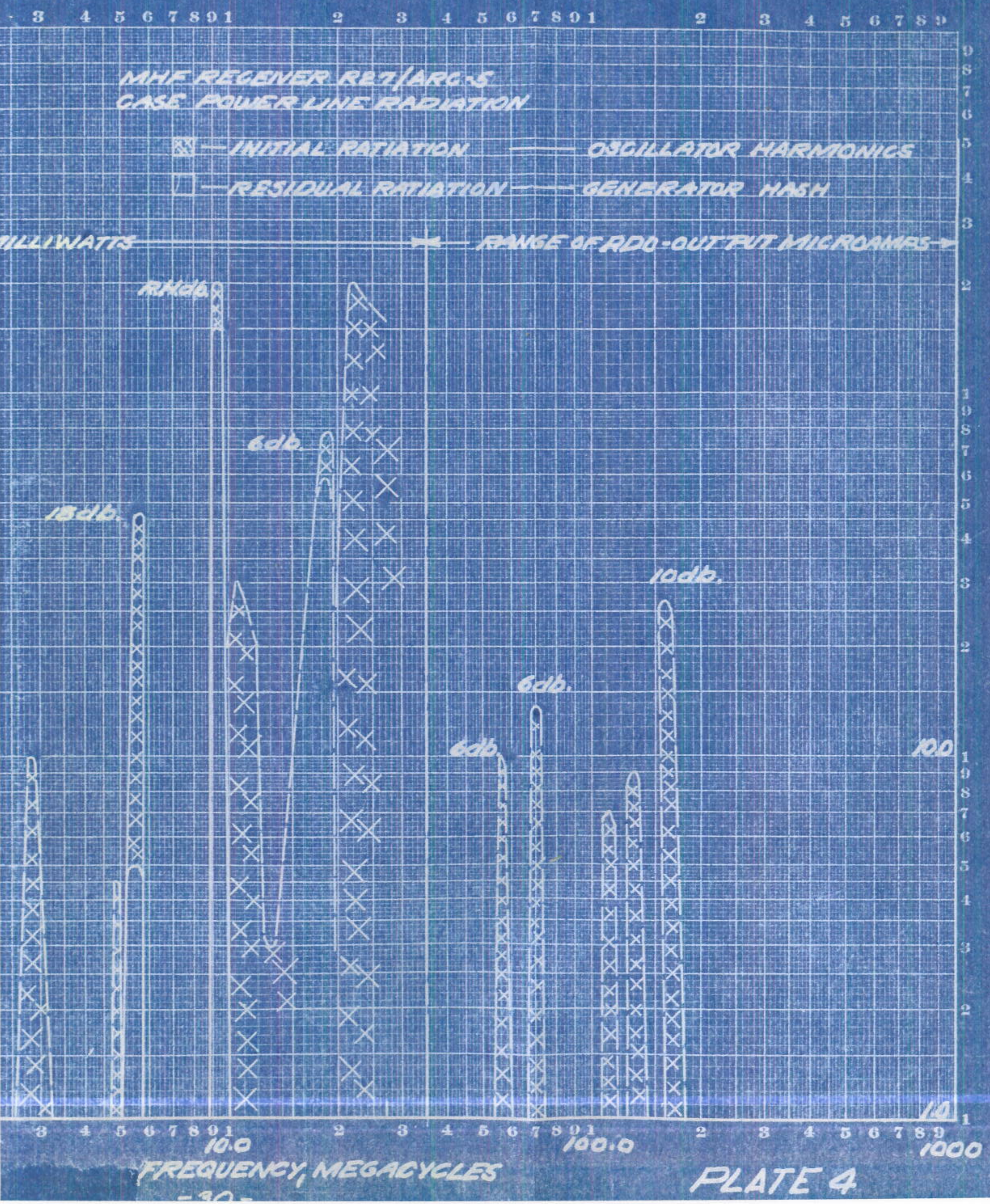
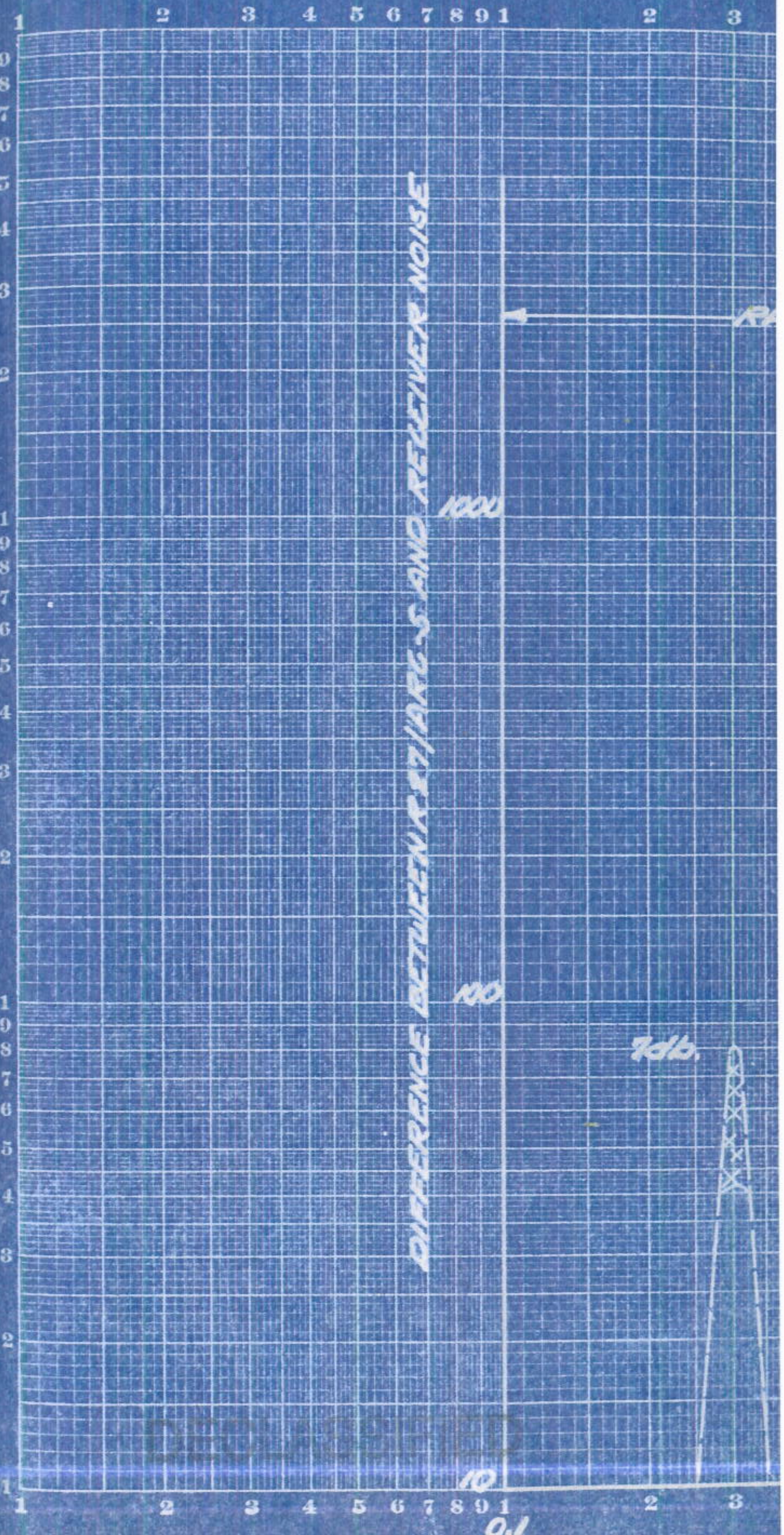

MHF RECEIVER R27/ARC-5
CASE POWER LINE RADIATION
INITIAL RATIATION
RESIDUAL RATIATION
OSCILLATOR HARMONICS
GENERATOR HASH
ILLIWATTS
RANGE OF RDO-OUTPUT MICROAMPS
18db.
6db.
6db.
6db.
10db.
10.0
100.0
1000
10.0
1.0
FREQUENCY, MEGACYCLES

PLATE 4


DIFFERENCE BETWEEN R 27/ARC-5 AND RECEIVER NOISE
1000
100
10
0.1
7db.

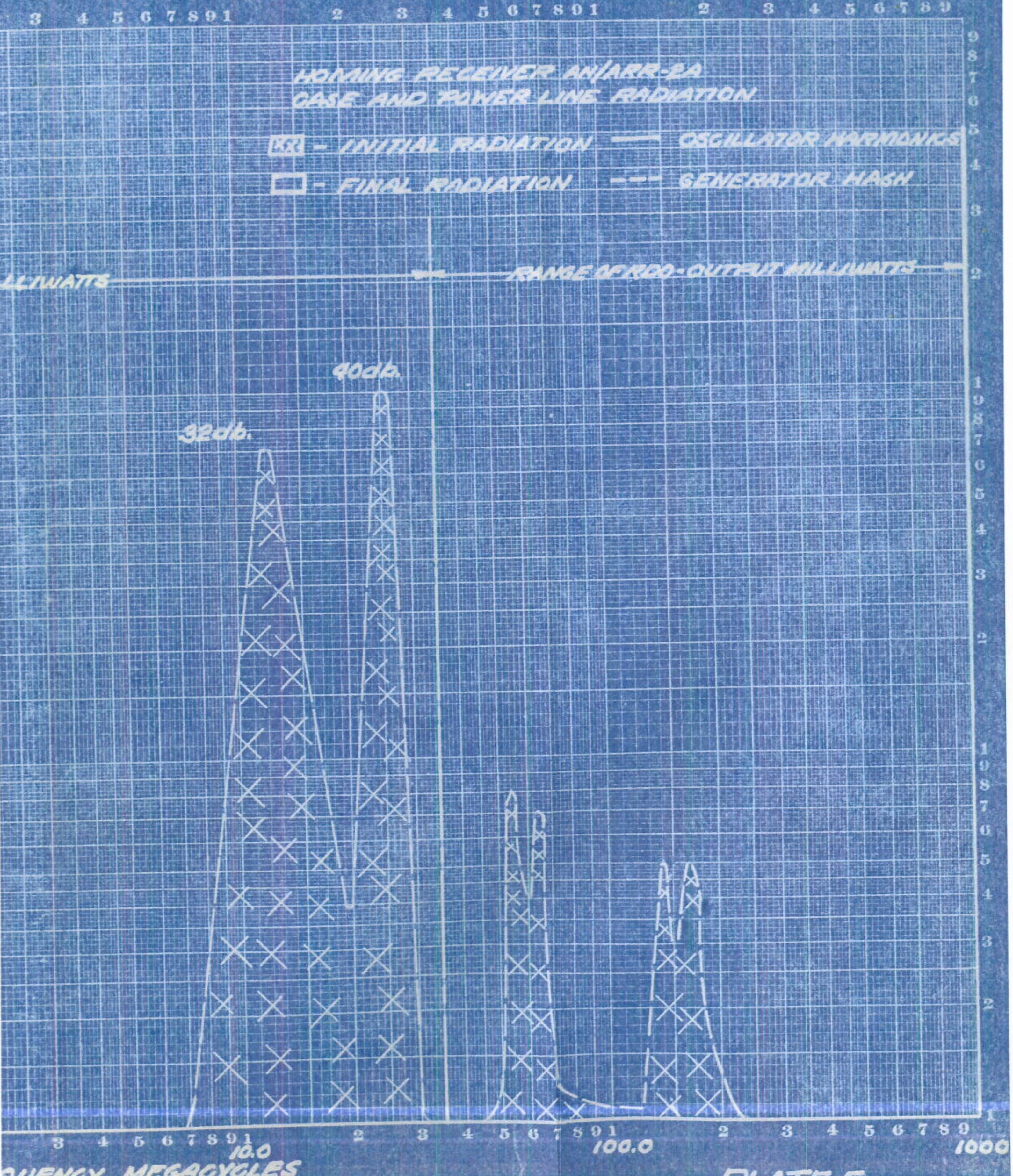
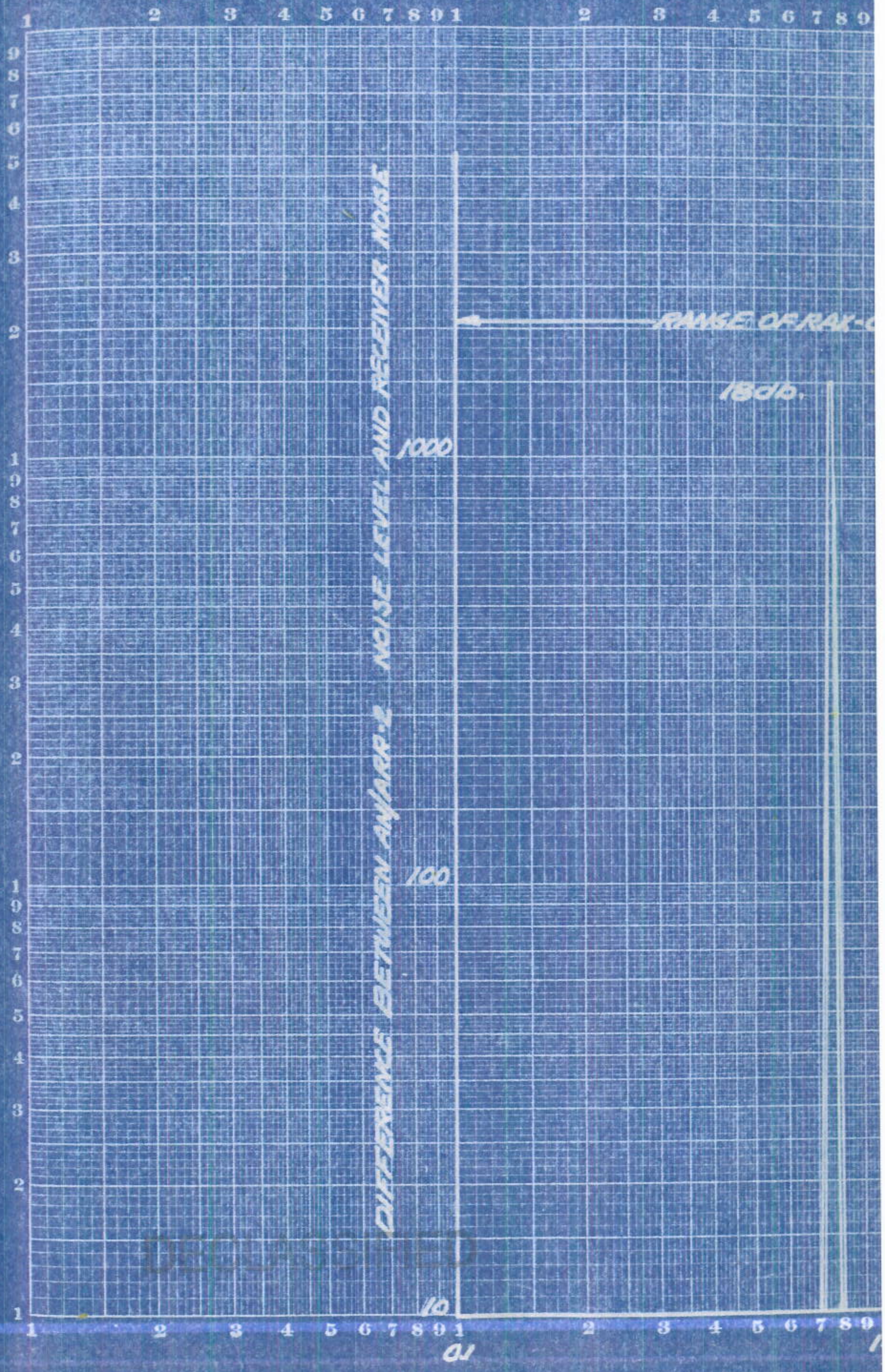

HOMING RECEIVER AN/ARR-2A
CASE AND POWER LINE RADIATION
- INITIAL RADIATION
- FINAL RADIATION
OSCILLATOR HARMONICS
GENERATOR HASH
LLIWATTS
RANGE OF RDO-OUTPUT MILLIWATTS
40db.
32db.
10.0
100.0
1000
QUENCY, MEGACYCLES

PLATE 5


DIFFERENCE BETWEEN AN/ARR-2 NOISE LEVEL AND RECEIVER NOISE
1000
100
10
RANGE OF RAK-
18db.
.01

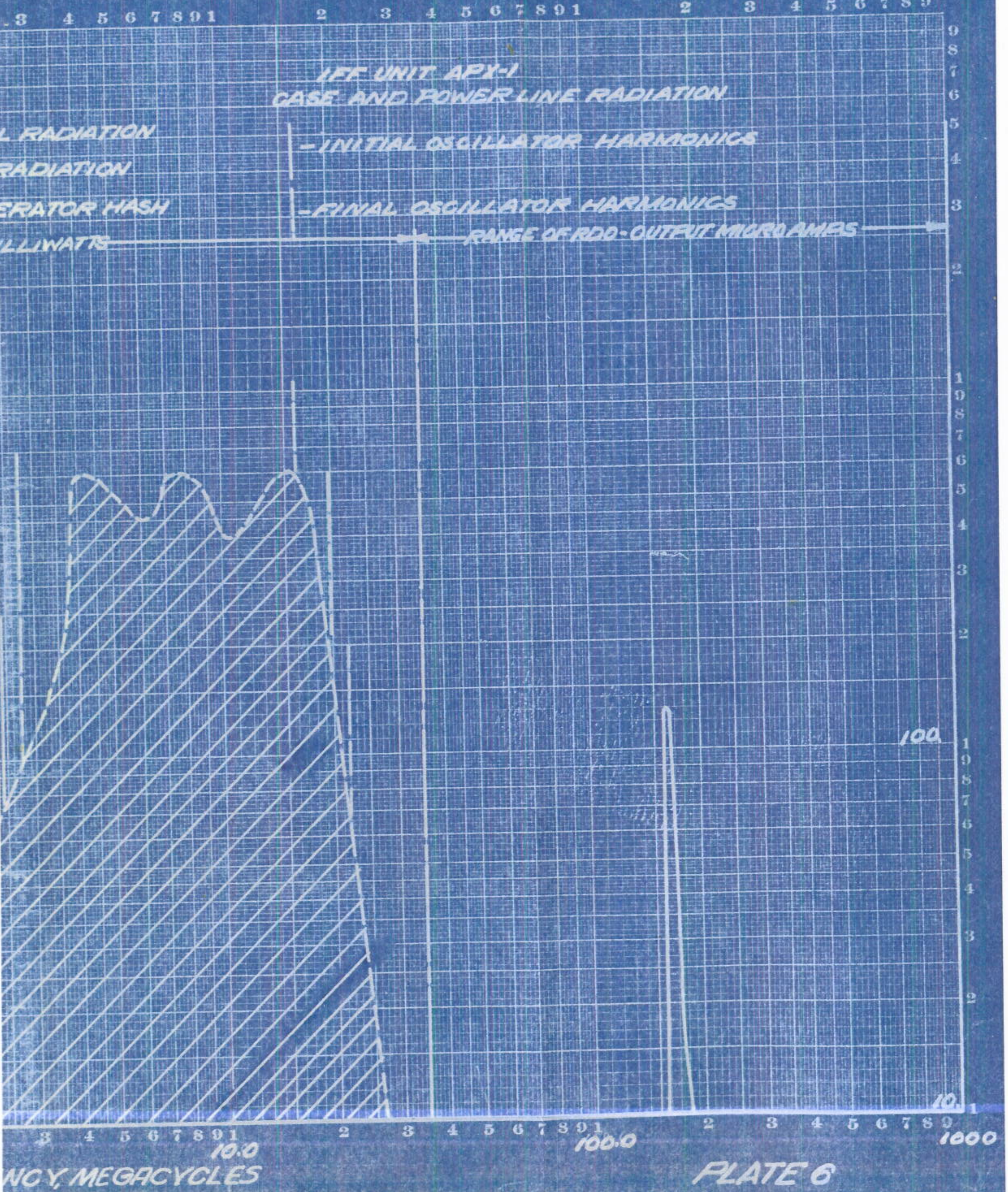
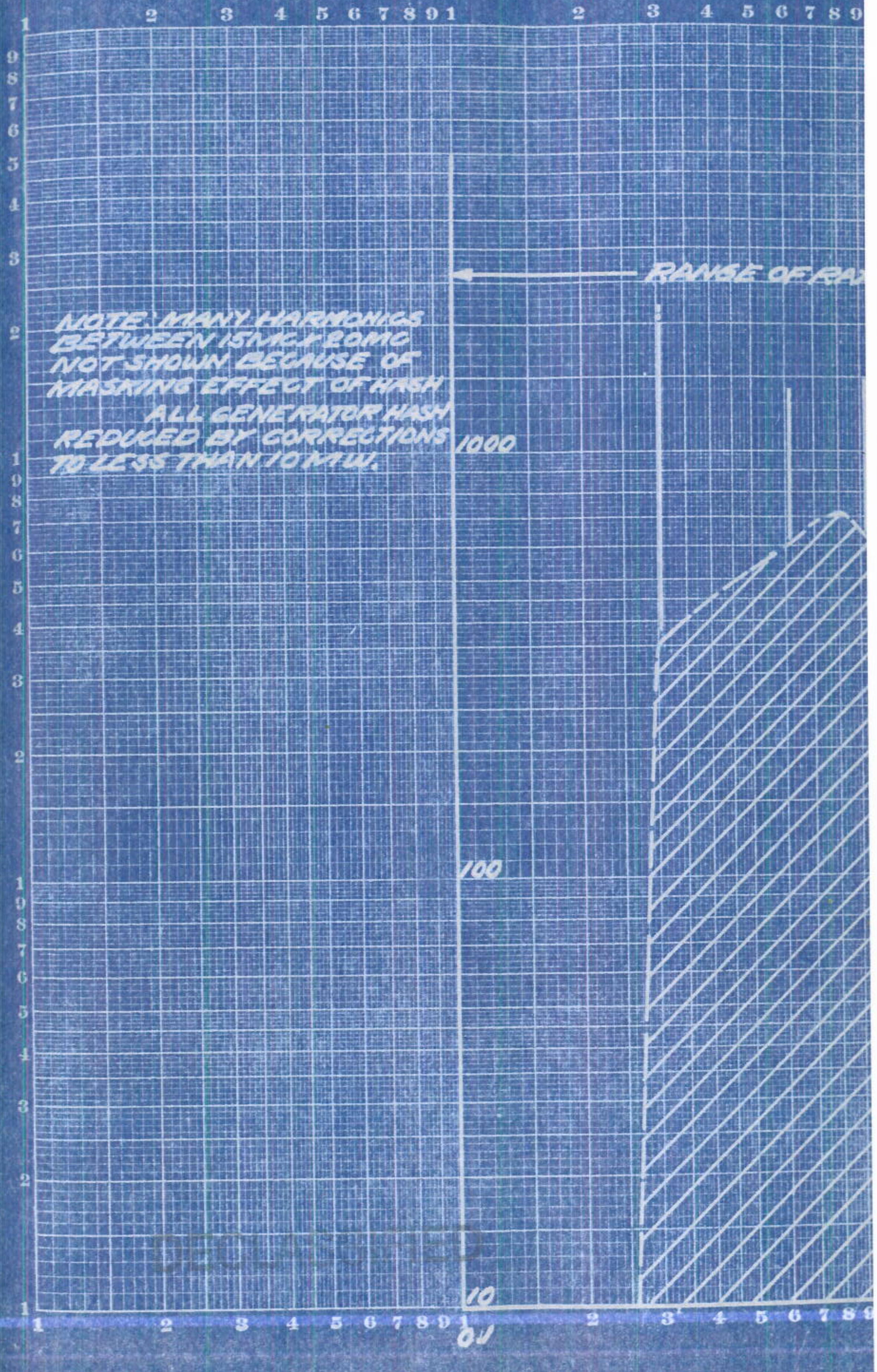

IFF UNIT APX-1
CASE AND POWER LINE RADIATION
L RADIATION
RADIATION
ERATOR HASH
LLIWATTS
- INITIAL OSCILLATOR HARMONICS
- FINAL OSCILLATOR HARMONICS
RANGE OF RDO-OUTPUT MICROAMPS
100
10
10.0
100.0
1000
NCY, MEGACYCLES

PLATE 6



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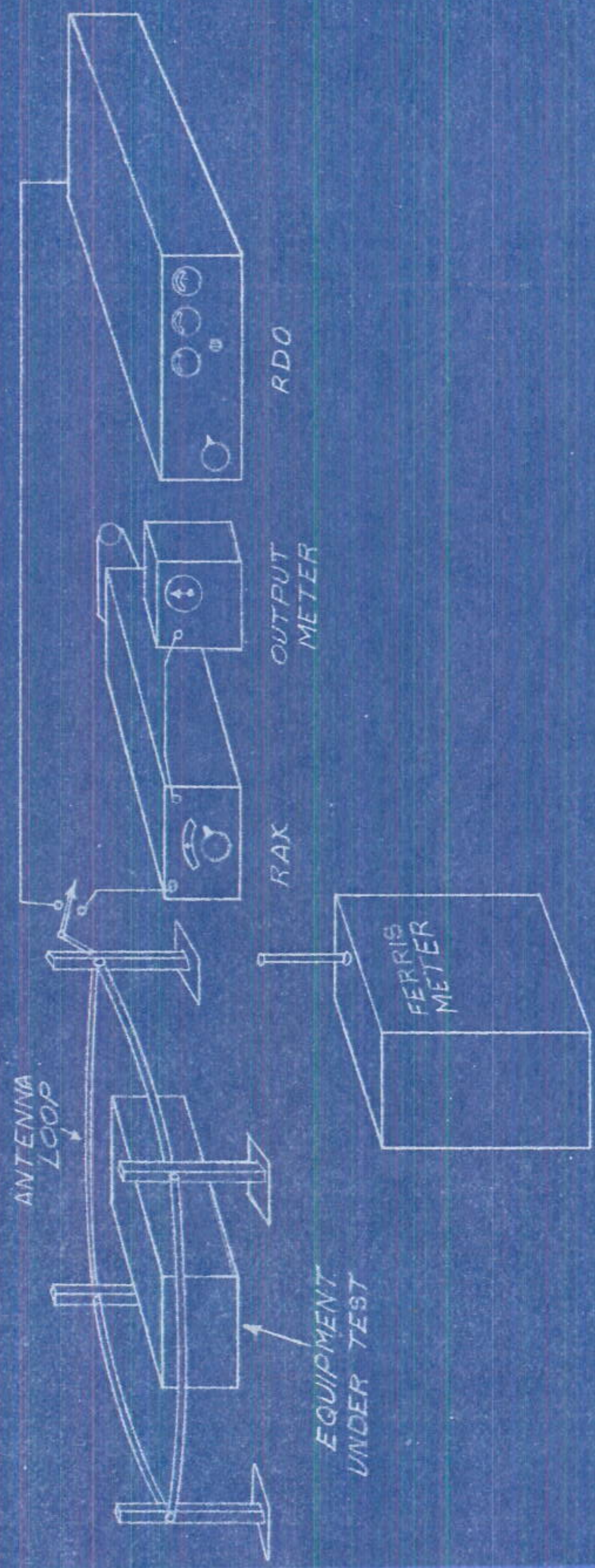

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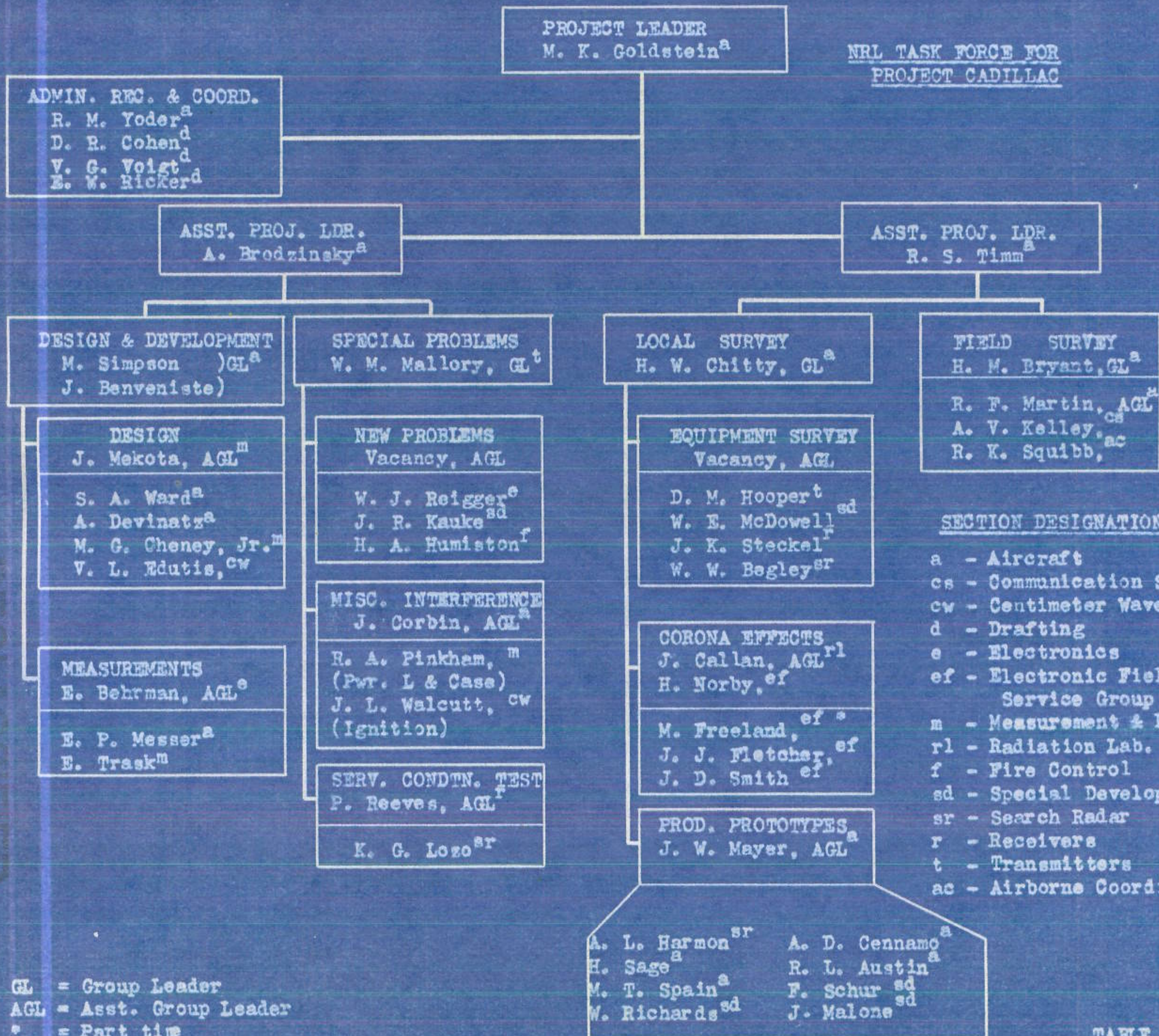
NRL TASK FORCE FOR PROJECT CADILLAC

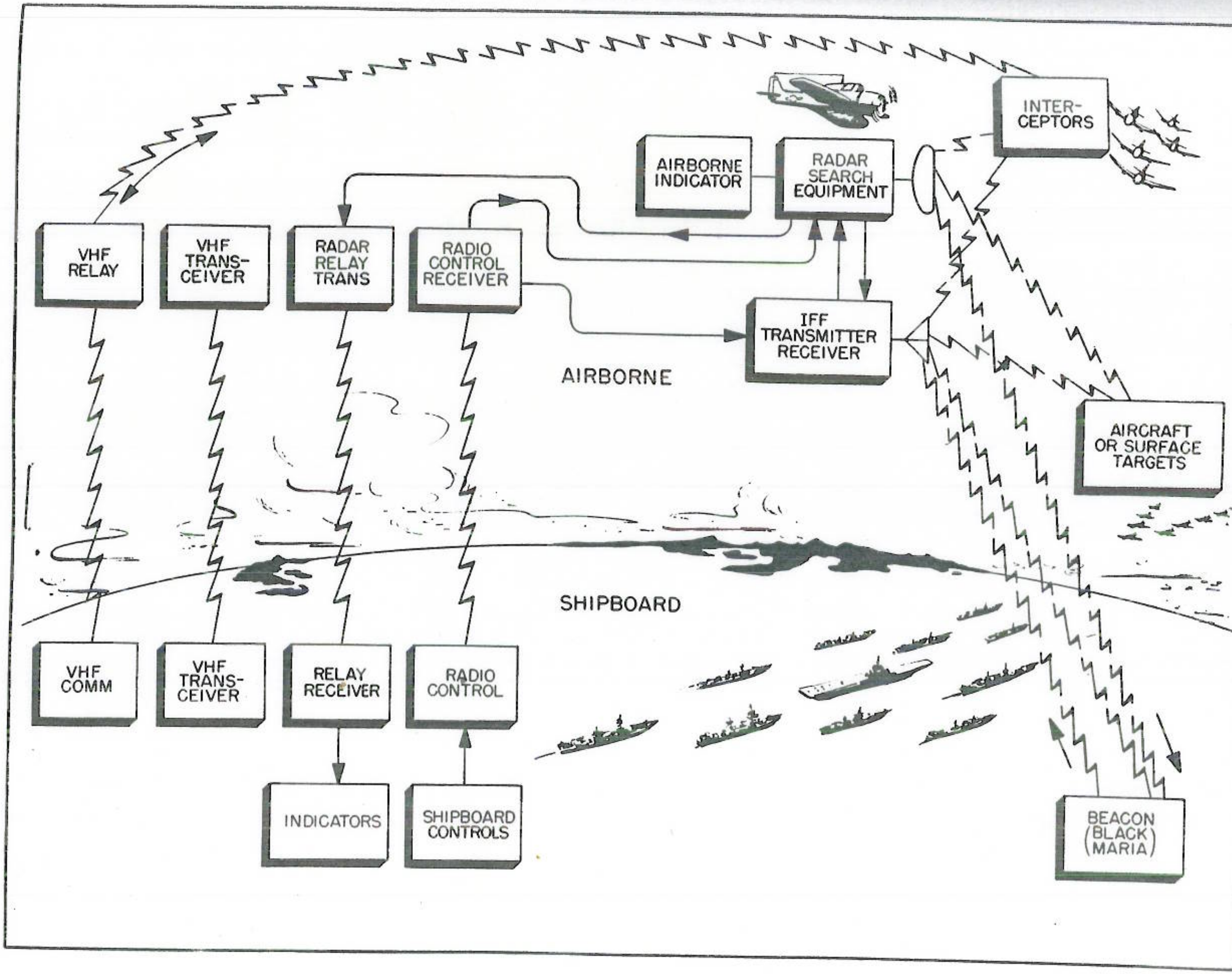


SECTION DESIGNATIONS

- a - Aircraft
- cs - Communication Security
- cw - Centimeter Wave
- d - Drafting
- e - Electronics
- ef - Electronic Field Service Group
- m - Measurement & DF
- rl - Radiation Lab.
- f - Fire Control
- sd - Special Development
- sr - Search Radar
- r - Receivers
- t - Transmitters
- ac - Airborne Coordinating Group

GL = Group Leader
AGL = Asst. Group Leader
* = Part time

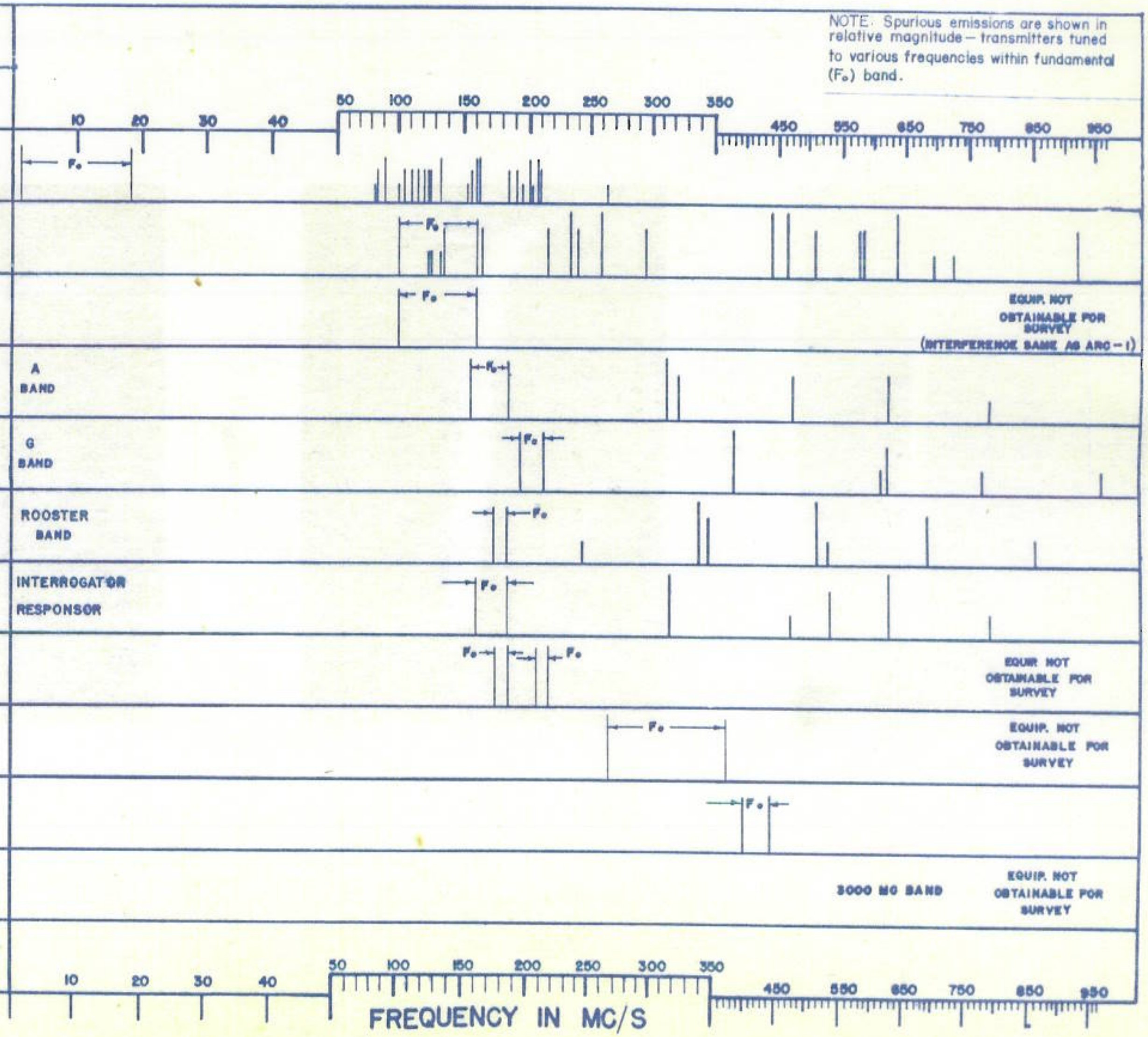
TABLE I



FUNCTIONAL BLOCK DIAGRAM OF THE COMPLETE AEW SYSTEM

CADILLAC 2 INTERFERENCE SURVEY

TRANSMITTER		
MODEL	TYPE	POWER
ART-13	COMM	2-30 W
ARC-1	COMM	12 W
ARC-28	COMM	12 W
APX-1	IFF TRANS	5 W
APX-1	IFF TRANS	5W
APX-1	IFF TRANS	5 W
APX-2	IFF INT	300W PEAK
APX-13	IFF INT	3000 W PEAK
ART-22/24	RADAR LINK	
APN-1	ALT	
APS-20	SEARCH RADAR	1 MEG W



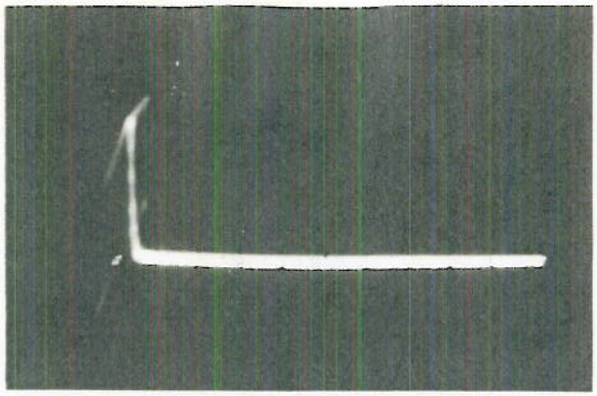
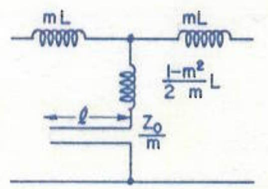
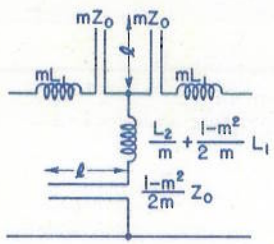
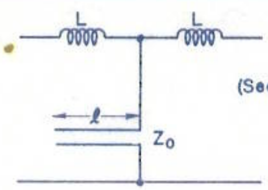


FIGURE 1

FIGURE 2

FIGURE 3

REDUCTION OF INTERFERENCE ON APX-2, IFF EQUIPMENT
FIG. 1 NO INTERFERENCE PRESENT
FIG. 2 INTERFERENCE PRESENT - NO NETWORK INSTALLED
FIG. 3 INTERFERENCE PRESENT - NETWORK INSTALLED

NETWORK TYPE	CIRCUIT (ONE SECTION)	GENERAL EQUATIONS	DESIGN FACTORS
YL-28/ARC-1 Low pass for VHF communication equipments. AN/ARC-1 AN/ARC-18 AN/ARC-28	 $y = \frac{Z_0}{\omega_0 L}$ $f_0 = \frac{3 \times 10^{10}}{4 \ell}$	$\frac{Z_{0\pi}}{Z_0} = \frac{2 \cot\theta - (1-m^2)\frac{f}{f_0}\frac{1}{y}}{\sqrt{2\frac{f}{f_0} y \cot\theta - 1}}$ $\theta = \frac{\pi}{2}\frac{f}{f_0}$ $\cosh\alpha = \left\lvert \frac{2y - (1+m^2)\frac{f}{f_0}\tan\theta}{2y - (1-m^2)\frac{f}{f_0}\tan\theta} \right\rvert$	$y = .08$, $m = 0.3$, $Z_0 = 7.5$ ohms — 6 sections $f_0 = 500$ mc/s $y = .04$, $m = 0.35$, $Z_0 = 17.5$ ohms — 1 section $f_0 = 950$ mc/s
QH-202/APX-13 High pass for identification equipments. APX-1 APX-13	 $y_1 = \frac{Z_0}{\omega_0 L_1}$ $y_2 = \frac{Z_0}{\omega_0 L_2}$ $f_0 = \frac{3 \times 10^{10}}{4 \ell}$	$\frac{Z_{0\pi}}{Z_0} = \frac{\left[2\frac{f}{f_0}\frac{1}{y_2} - (1-m^2)(\frac{f}{f_0}\frac{1}{y_1} - \cot\theta)\right]\left[\frac{f}{f_0}\frac{1}{y_1} - \cot\theta\right]}{\sqrt{\left[\frac{f}{f_0}\frac{1}{y_1} - \cot\theta\right]\left[\cot\theta - \frac{f}{f_0}(\frac{1}{y_1} - \frac{2}{y_2})\right]}}$ $\theta = \frac{\pi}{2}\frac{f}{f_0}$ $\cosh\alpha = \left\lvert \frac{\left[\frac{f}{f_0}\frac{1}{y_1} - \cot\theta\right]\left[1+m^2\right] + \frac{f}{f_0}\frac{2}{y_2}}{\left[\frac{f}{f_0}\frac{1}{y_1} - \cot\theta\right]\left[1-m^2\right] + \frac{f}{f_0}\frac{2}{y_2}} \right\rvert$	$Z_0 = 50$ ohms $y_1 = 1$ $y_2 = 0.5$ $m = \begin{cases} 0.4 - 3 \text{ sections} \\ 0.58 - 3 \text{ sections} \end{cases}$ $f_0 = \frac{f_c}{0.339} = 442$ mc/s
F-47/APX-13 (Y-4) Low pass for identification equipments. APX-13	 (See note) $y = \frac{Z_0}{\omega_0 L}$ $f_0 = \frac{3 \times 10^{10}}{4 \ell}$	$\frac{Z_{0\pi}}{Z_0} = \frac{2 \cot\theta}{\sqrt{2y\frac{f_0}{f}\cot\theta - 1}}$ $\theta = \frac{\pi}{2}\frac{f}{f_0}$ (see note) $\cosh\alpha = \left\lvert 1 - \frac{1}{y}\frac{f}{f_0}\tan\theta \right\rvert$	$\frac{Z_{0\pi}}{Z_0} = .8$ $f_0 = 200$ mc/s (see note) $y = 1.7$ NOTE: The circuit, equations and design factors for the Y-4 type network are only approximate since the actual network was found to have a high mutual inductance between adjacent coils, a condition not presently accounted for by the equations.

THEORETICAL EQUATIONS AND DESIGN FACTORS for AIRBORNE AEW CORRECTIVE NETWORKS

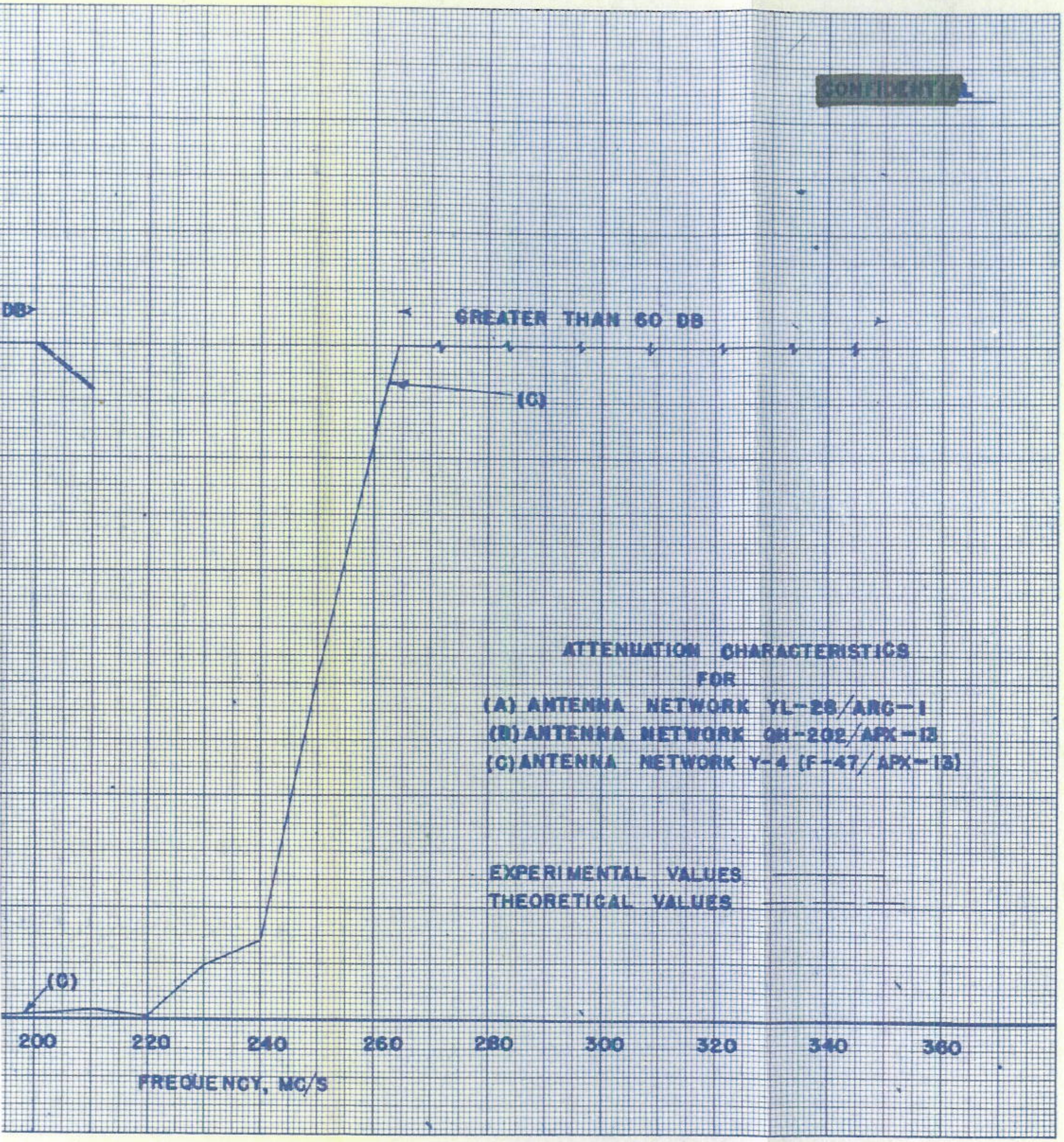


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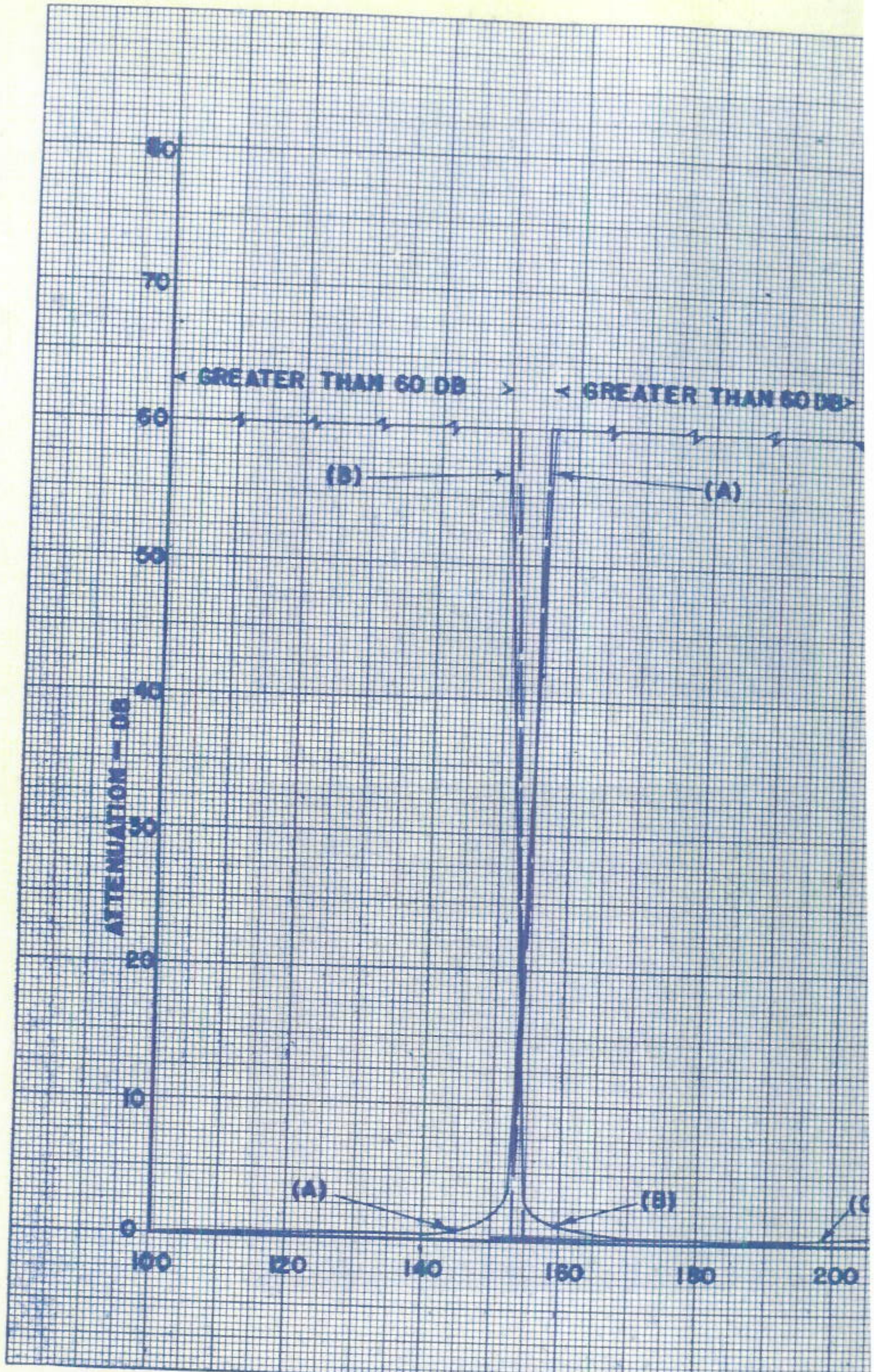
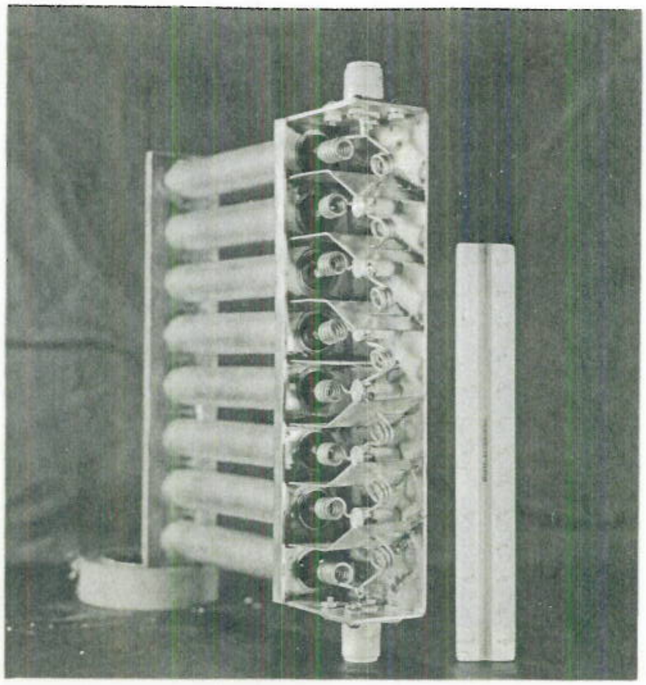
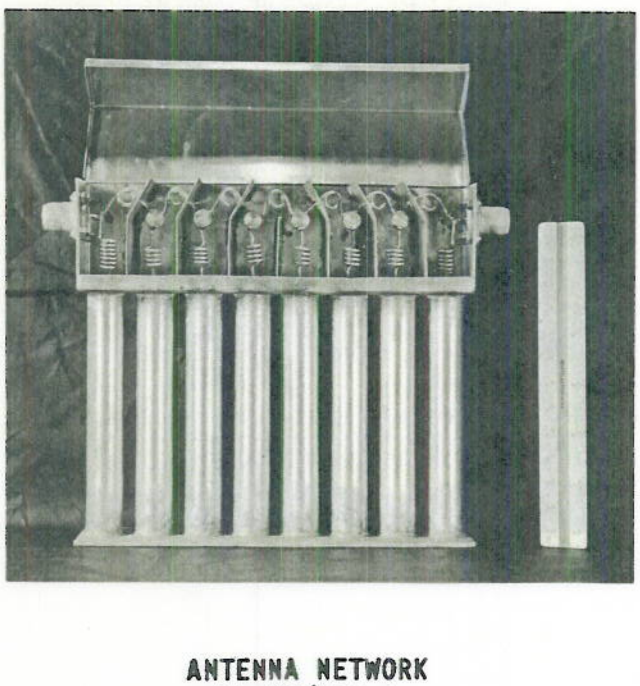
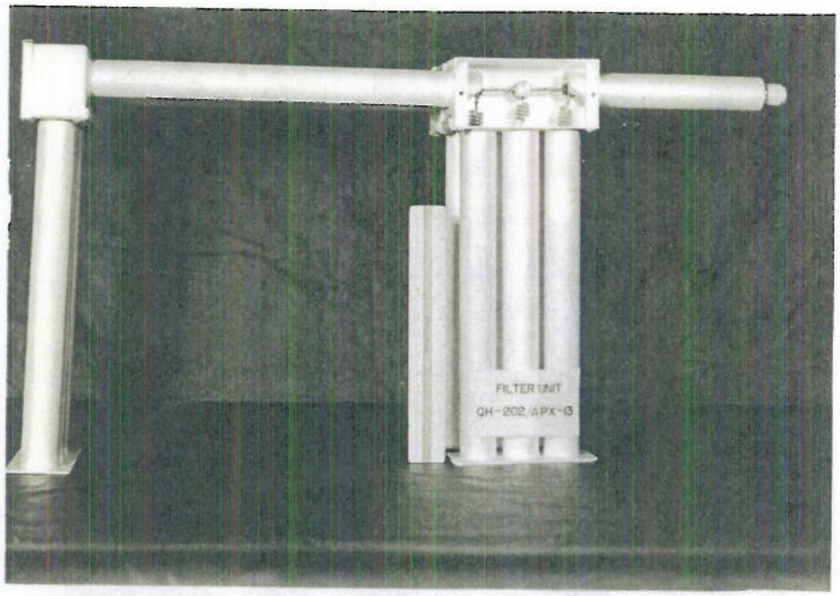
PLATE 5


80
70
60
50
40
30
20
10
0
ATTENUATION — DB
< GREATER THAN 60 DB >
< GREATER THAN 60 DB>
(B)
(A)
(A)
(B)
100
120
140
160
180
200



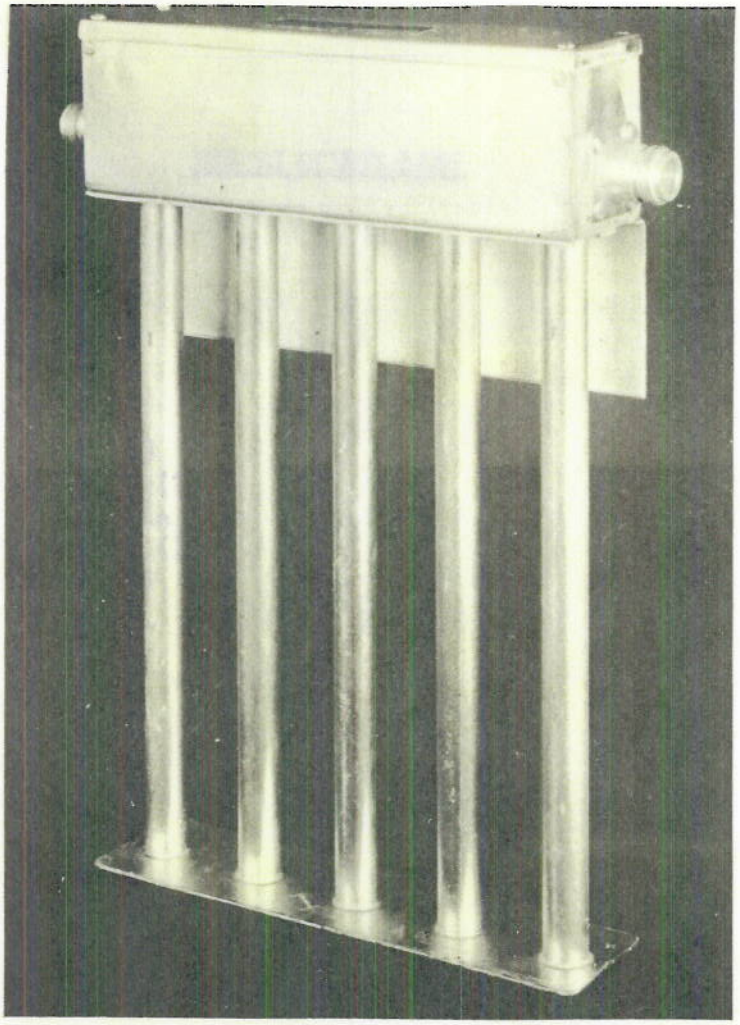


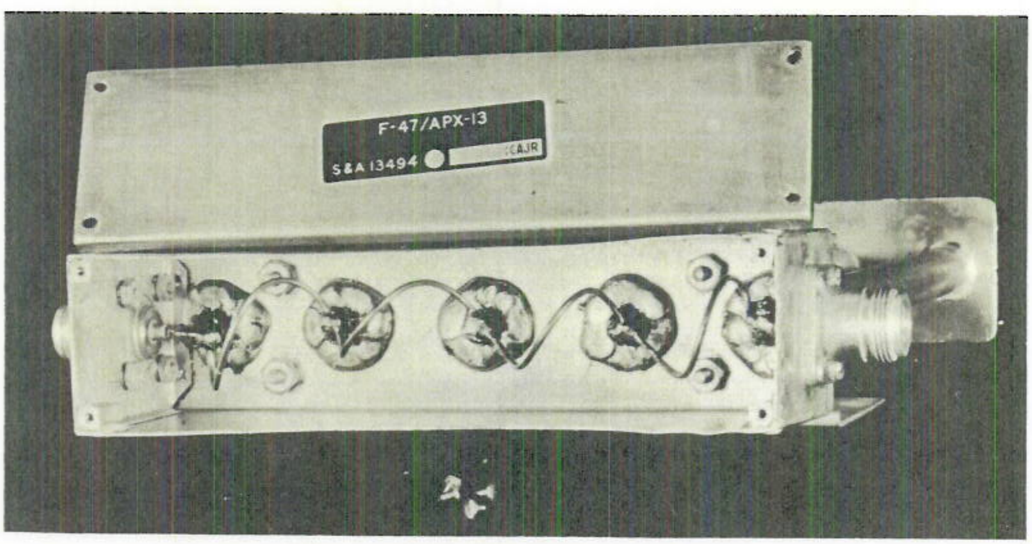
ANTENNA NETWORK
YL-28/ARC-1



ANTENNA NETWORK
QH-202/APX-13

DECLASSIFIED





ANTENNA NETWORK
Y-4(F-47/APX-13)

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