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IMPROVEMENT OF INTERFERENCE CHARACTERISTICS OF THE MODEL TDZ TRANSMITTER

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NRL REPORT R-3349

IMPROVEMENT OF INTERFERENCE CHARACTERISTICS OF THE MODEL TDZ TRANSMITTER

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August 31, 1948

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ABSTRACT

Methods have been devised to reduce conducted and radiated interference from the Model TDZ transmitter to as low a level as is practicable. Interference reduction was accomplished by applying noise-suppression networks to transmitter relay solenoids, and by the use of shielded keying leads and a Navy Type 53522 power-line filter. A modification kit has been developed for field installation embodying the required circuitry for application to the relay solenoids. By means of the methods described, all forms of interference from the Model TDZ transmitter have been reduced to satisfactory levels with the exception of radiated c-w signal interference; it proved impossible to lessen this latter form of disturbance without extensive changes in the transmitter design.

PROBLEM STATUS

This is the final report on the problem. Unless otherwise advised by the Bureau, the Laboratory will consider this problem closed one month from the mailing date of this report.

AUTHORIZATION

NRL Problem R01-17D. This investigation was initiated by BuShips conf. ltr. Section 911, S67-1-(9), Serial 2680A, of 22 September 1947, to NRL, and is an extension of a phase of certain earlier work undertaken in accordance with BuShips conf. ltr. Serial No. 529, Section 911, of 24 October 1945, to NRL.

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IMPROVEMENT OF INTERFERENCE CHARACTERISTICS OF THE MODEL TDZ TRANSMITTER

INTRODUCTION

Considerable emphasis is being placed by this Laboratory on the study and analysis of 225- to 400-megacycle Navy communication systems. This report relates to one phase of the subject and concerns the interference characteristics of the Model TDZ transmitter, one of the important terminal units of these communication systems. Previous work at this Laboratory on a single model of this transmitter indicated that the interference level was generally high at frequencies between 0.15 and 400 megacycles, and tentative means were devised for lessening the disturbance.[1]

This previous interference investigation, made on one of the first units of the Model TDZ equipment manufactured, indicated that appreciable conducted and radiated noise interference was present during keying, channel-dialing and automatic channel-shifting operations, and also whenever the carrier was "on," whether keyed or not keyed. Both conducted and radiated c-w signal interference were also present at the crystal oscillation frequency and at many of its harmonic frequencies.

Operation of the keying or channel-dialing mechanisms produced an impulse or "click" type of noise. A random interference was observed during channel shifting, and also while the transmitter was operated under locked-key condition, as when voice intelligence was being transmitted.

The impulse noise associated with keying and dialing processes was the result of inductive surges caused by sudden interruptions of current in relay solenoids. These surges produced arcs at switching points and caused shock oscillation of associated circuitry. Channel-shifting noise was caused by sparking at the autotuning motor brushes. Random noise with the carrier "on" was largely "hash" from the high-voltage thyratrons in the transmitter power supply. Continuous signal interference was a product of oscillator and frequency multiplication stages. Choice of transmitter

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[1] A. R. Rumble, NRL conf. Ltr. Report, C-S67/L5(1210-ARR), Serial C-1210-181/46, of 13 July 1946, to BuShips.

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channel frequency had no effect on amplitude or frequency distribution of conducted or radiated noise. It did, however, affect the frequencies of the radiated and conducted c-w signal interference, but had only a secondary effect on amplitudes.

While the intensity of the various forms of noise had a definite bearing upon the disturbing effect, duration and recurrence rate of the interference were also significant. Keying interference was present whenever, and as long as mcw transmission was employed. Dialing noise lasted for 3 to 4 seconds; channel-shifting noise for about 30 seconds. Dialing or channel-shifting noise was experienced only when the transmitter output frequency was changed from one channel to another. Radiated c-w signal interference was experienced as long as the carrier was present.

Maximum values noted for conducted and radiated noise and c-w signal interference levels at frequencies between 0.15 and 400 megacycles are listed in Table I.

TABLE I

Maximum Values of Noise Produced by an Early Model TDZ Equipment

Condition	Conducted Interference* (μv)	Radiated Interference** (μv/m)
Keying	100,000	2,500
Channel dialing	10,000	1,200
Channel shifting	10,000	3,500
Noise with carrier "on"	20,000	none
C-w signal interference with carrier "on" at carrier frequency	58,000	30,000

* Measured between the 115-volt power line and ground at transmitter terminal No. 32.

** Measured with noise-meter antenna 3 feet from front of transmitter.

Following this work noise-reduction remedies were evolved and reported.[2] These remedies were:

(a) Use of a power-line filter, similar to the Tobe Type 1166 Filterette.

(b) Complete shielding of the key and associated circuitry.

[2] A. R. Rumble, NRL conf. ltr. Report, C-S67/L5(1210-ARR), Serial C-1210-217/46, of 30 September 1946, to BuShips.

(c) Application of a resistance-capacitance type of noise-filter, of 82 ohms and 1 microfarad, to principal noise-producing relay solenoids.

(d) Use of a low-pass inductance-capacitance type of filter for each channel-shifting motor.

Incorporation of these noise-suppression devices in this model TDZ unit produced approximately a 60-decibel reduction both in conducted and in radiated noise. With due allowance for the probable measurement error, this reduction brought the conducted and radiated noise levels near usual Navy requirements of 5 microvolts and 5 microvolts-per-meter, respectively. However, conducted c-w signal interference levels as high as 500 microvolts were still experienced at some frequencies. This may have resulted in part from the induction of radio-frequency signals into the power-line cable by radiation from the transmitter cabinet.

Measurements also indicated that the radiated c-w signal interference was of the order of 30,000 microvolts-per-meter maximum, as shown in Table I. At the time, it was evident that reduction of c-w signal radiation from the Model TDZ transmitter would require extensive additional shielding measures, and that the nature of any modifications likely to produce the desired result was so complex as to be impractical. Furthermore, c-w signal interference is not broad-band in nature, as is noise interference, and is therefore ordinarily not so objectionable as noise. For these reasons no effort toward reduction of c-w signal interference level was suggested.

A later study, which is the subject of this report, undertook to determine:

(a) Whether the noise conditions noted in the previous work were typical of the model of transmitter in question.

(b) Whether keying interference could be reduced to a satisfactory level without resorting to shielding the key, as had appeared necessary from earlier work.

(c) Whether a modification kit could be designed that would be effective in any Model TDZ equipment and that would be of such a nature as to allow ready installation in the transmitter by naval service personnel.

(d) Whether the application of the noise-suppression devices would impair the operation of the equipment.

INVESTIGATION OF RECENTLY MANUFACTURED MODEL TDZ EQUIPMENTS

Before attempting the final development of noise-suppression devices for general use in Model TDZ equipments, measurements of the noise interference in units of more recent manufacture were undertaken. This was believed desirable in view of the possibility that newer units might be more free of interference than was the model tested earlier. Furthermore, to insure that the data obtained would be more nearly representative of equipment, it was deemed advisable to make noise measurements on at least two recent transmitters.

[redacted]

Equipments, Serial Nos. 1184 and 1187, were selected for this study. These units were placed in a shielded room on a ground plane bonded to the wall of the enclosure. To approximate an actual shipboard installation, a Remote Channel Selector, Type 23445, and a Radiophone Unit, Type 23211-A, were mounted near each transmitter, and were connected to the transmitter under test through 30 feet of appropriate MHFA cable, bonded to the ground plane at intervals of about 3 feet. This was considered to be representative of cable exposure in a compartment of a ship. The transmitter output load was a 100-foot length of 50-ohm attenuating cable, most of which was located outside the shielded room. Transmitter keying was accomplished by an automatic cam-actuated telegraph key. The incoming power line to the shielded room was well filtered from all external sources of interference. No interference voltage could be measured on the incoming line over the frequency spectrum under consideration, using standard Navy noise meters. A Navy Type 47959 choke coil was used in each side of the transmitter power-supply line to facilitate measurement of conducted noise by providing partial isolation between the transmitter and the bypass capacitors of the incoming power-line filter. The constants of this choke coil were such that it presented an impedance of 60 ohms at 0.15 Mc, 200 ohms at 15 Mc, and 80 ohms at 150 Mc. The impedance data at frequencies above 150 Mc are not available.

Three noise-measuring equipments were used to survey the frequency spectrum between 0.15 and 400 megacycles:

Navy Model OF-2	(0.15 - 15 Mc)
Measurements Model 58	(15. - 100 Mc)
Navy Model OCV	(100. - 400 Mc)

For the purpose of this investigation these instruments were operated so as to indicate "peak" noise. Conducted interference was measured from one side of the power line to ground at the transmitter supply-line terminals. Radiated interference was measured with the noise-meter antenna centered 3 feet in front of the transmitter.

Although interference data were observed using both of the units, Serial Nos. 1184 and 1187, the results obtained from the two equipments were so nearly identical that only single sets of data rather than data for the two units have been furnished. Measured values of noise conducted into the power line are presented in Figure 1. Conducted c-w signal interference data are found in Table II. Radiated noise measurements are shown in Figure 2. Radiated c-w signal interference levels were not measured, since no remedial measures for this form of disturbance were contemplated.

It may be observed from the data in Figures 1 and 2 and in Table II that during normal operation the Model TDZ equipment noise output was considerably in excess of permissible values. The results were in reasonably close agreement with those noted in the examination of one of the first units manufactured. Thus it may be assumed that the noise condition is typical of that found in various units now in use in the Naval Service.

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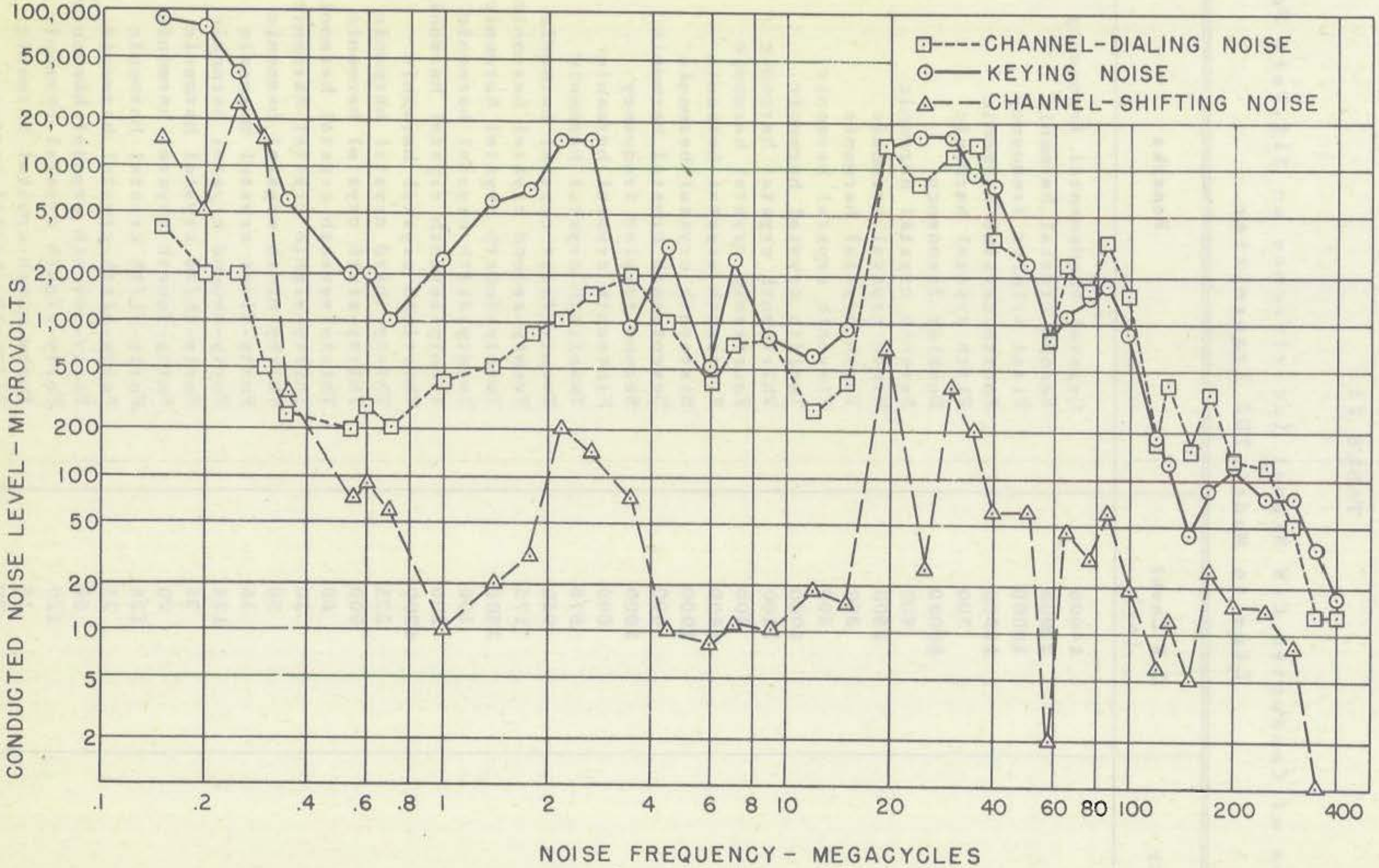

Figure 1 - Conducted Noise on the 115-Volt Supply Line to Model TDZ Transmitter

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TABLE II

Values of Conducted C-W Signal Interference on 115-Volt Power Line to Model TDZ Transmitter

Frequency (Mc)	C-W Level (μv)	Remarks
5.574	14000	Crystal Fundamental frequency
11.15	22000	Second crystal harmonic
16.72	10000	First tripler frequency
22.30	18000	Fourth crystal harmonic
27.87	700	Fifth crystal harmonic
33.44	60000	Doubler frequency
39.02	400	Seventh crystal harmonic
50.17	2500	Ninth crystal harmonic
55.75	300	Tenth crystal harmonic
61.31	500	Eleventh crystal harmonic
66.89	6000	Twelfth crystal harmonic
72.46	1100	Thirteenth crystal harmonic
78.04	400	Fourteenth crystal harmonic
83.61	1800	Fifteenth crystal harmonic
89.18	1900	Sixteenth crystal harmonic
94.76	600	Seventeenth crystal harmonic
100.33	2000	Second tripler frequency
105.90	600	Ninteenth crystal harmonic
111.48	575	Twentieth crystal harmonic
117.05	950	Twenty-first crystal harmonic
122.63	175	Twenty-second crystal harmonic
133.78	1400	Twenty-fourth crystal harmonic
139.35	100	Twenty-fifth crystal harmonic
150.50	200	Twenty-seventh crystal harmonic
167.22	6200	Thirtieth crystal harmonic
183.94	225	Thirty-third crystal harmonic
200.66	900	Thirty-sixth crystal harmonic
206.24	60	Thirty-seventh crystal harmonic
211.81	10	Thirty-eighth crystal harmonic
217.39	50	Thirty-ninth crystal harmonic
228.53	16	Forty-first crystal harmonic
234.11	125	Forty-second crystal harmonic
239.68	25	Forty-third crystal harmonic
245.26	20	Forty-fourth crystal harmonic
250.83	125	Forty-fifth crystal harmonic
256.40	25	Forty-sixth crystal harmonic
261.98	50	Forty-seventh crystal harmonic
267.55	120	Forty-eighth crystal harmonic
273.13	15	Forty-ninth crystal harmonic
278.70	30	Fiftieth crystal harmonic

[redacted]

TABLE II (Continued)

Frequency (Mc)	C-W Level (μv)	Remarks
284.27	10	Fifty-first crystal harmonic
289.85	20	Fifty-second crystal harmonic
295.42	60	Fifty-third crystal harmonic
301.00	21000	Transmitter output frequency
306.57	60	Fifty-fifth crystal harmonic
312.14	12	Fifty-sixth crystal harmonic
317.72	50	Fifty-seventh crystal harmonic
323.29	23	Fifty-eighth crystal harmonic
328.87	25	Fifty-ninth crystal harmonic
334.44	500	Sixtieth crystal harmonic
345.59	25	Sixty-second crystal harmonic
351.16	160	Sixty-third crystal harmonic
367.88	1000	Sixty-sixth crystal harmonic
373.46	35	Sixty-seventh crystal harmonic
379.03	20	Sixty-eighth crystal harmonic
384.61	200	Sixty-ninth crystal harmonic
390.18	27	Seventieth crystal harmonic
401.33	55	Seventy-second crystal harmonic

NOTE: C-w signals were measured from one side of the power-supply line to ground.

At frequencies below 200 Mc, only the signals in excess of 100 μv are included in the above tabulation. Over the frequency range from 200 to 400 Mc, signals in excess of 10 μv are included.

CONFIRMATION OF PREVIOUSLY RECOMMENDED NOISE-SUPPRESSION MEASURES

After it had become reasonably clear that similar noise conditions prevailed in various Model TDZ equipments, the unit bearing Serial No. 1187 was provided with the interference suppression means found effective during the course of the earlier work in order to establish more firmly the adequacy of such measures. These methods have already been covered herein in outline form and more completely in the earlier report. In this case, however, one modification was made in the previously used arrangements; namely, substitution of a Navy Type 53522 power-line filter for the Tobe Filterettes. These two filters were identical save for the improved shielding characteristics of the first mentioned unit. Measurements of conducted interference made after installation of the suppression devices revealed that this filter reduced conducted noise and c-w signal interference to a level which could not be detected by the noise-measuring instruments, even when no filtering arrangements were employed in the power leads of the channel-shifting motors. This was an important finding since elimination of the motor filters materially reduced the additional circuitry required within the transmitter for

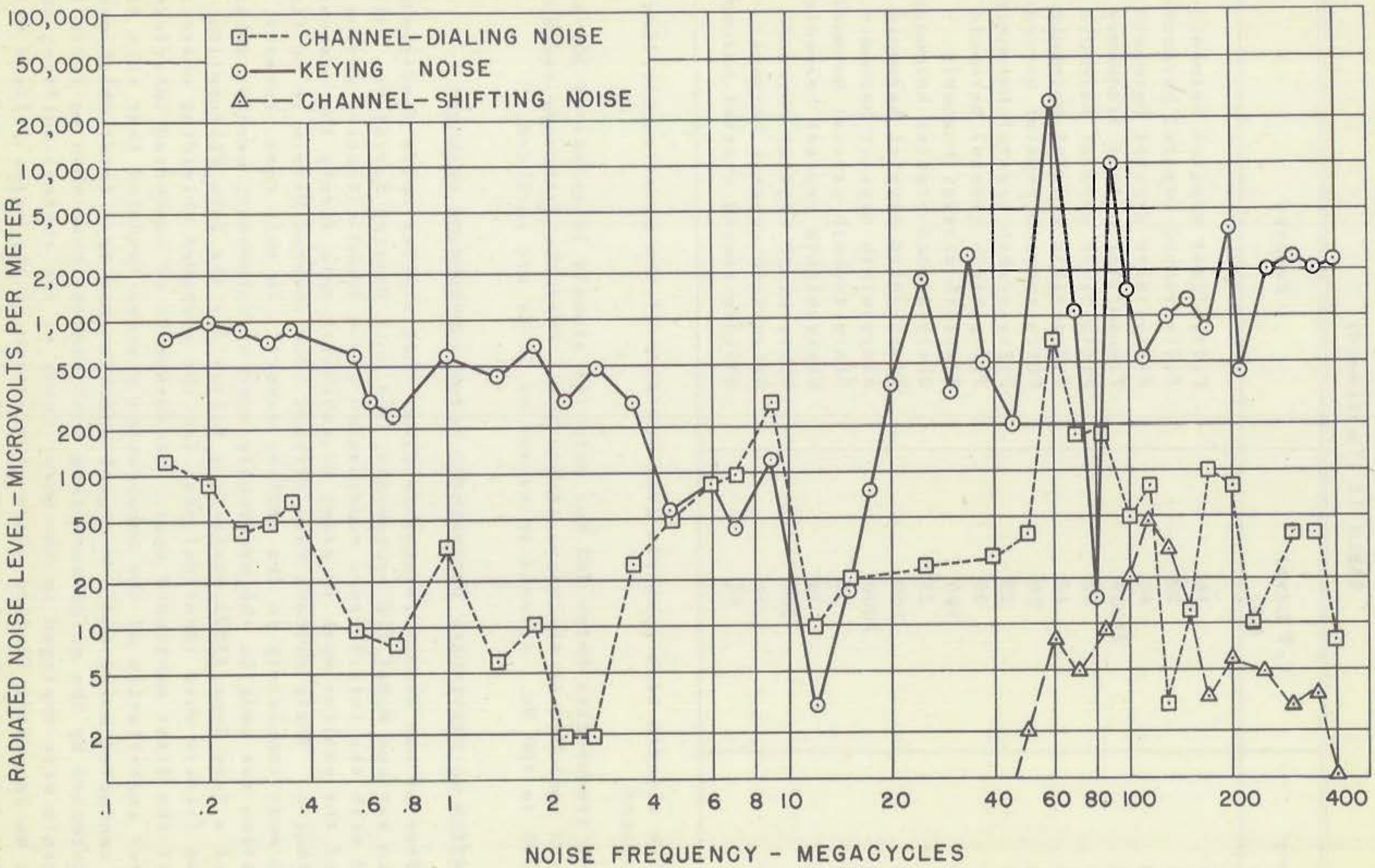

Figure 2 - Radiated Noise from Model TDZ Transmitter

interference suppression. Measurements of radiated noise indicated that disturbance of this nature was still satisfactorily low.

SIZE REDUCTION OF SUPPRESSOR COMPONENTS

After determining that the suppressor circuits were effective in two Model TDZ equipments made at widely different stages or production, consideration was given to the possibility of reducing the size of suppressor circuit components before evolving a design for a modification kit for the transmitter. This was desirable since the available space within the Model TDZ transmitter for installation of the suppressor devices was severely limited. By studying each suppressor separately it was determined that an economy of size could be effected without sacrificing noise-reduction characteristics. In the main this was accomplished by decreasing the value of certain capacitors. Several resistance elements were also changed to improve the noise-suppression characteristics. The finally adopted values of capacitors and resistors for each suppressor network, together with the relay designations with which these circuits are associated are presented in Table III.

TABLE III

Values of Relay Noise-Suppressor Circuit Components

Relay Symbol	Relay Function	Resistance (ohms)	Capacitance (μf.)
K102	Carrier Delay	82	1.0
K104	Carrier Control	47	0.10
K106	Keying	82	1.0
K112	Channel Impulse	47	0.25
K113	Channel Clearance	82	0.10
K114	Channel Timing	82	0.10
K115	Channel Preparation	47	0.25
K116	Channel Stepper	82	2.0

[redacted]

measure a given noise. The discrepancies are due to the varying and impulsive nature of noise, and to the different bandwidths and time constants of the instruments. In the case of conducted noise measurements, the different input impedances of the instruments also contribute; and for radiated noise measurements, variations in the surroundings cause considerable differences in the indications. Consequently measured noise levels should not be considered as absolute levels. Differences between the indications of different noise meters for the same noise are sometimes as high as 20 db. Thus, in the foregoing graphs, abrupt changes may be observed in the values of interference at 15 and at 100 Mc where measuring instruments were exchanged. However, comparative measurements may be made with reasonable accuracy, provided they are made with the same instrument and under the same conditions. Examples of this are measurements made before and after the installation of a given filter or shield.

SEARCH FOR POSSIBLE ADVERSE EFFECTS OF SUPPRESSOR CIRCUITS

The transmitter was keyed at speeds up to 75 words per minute during m-c-w transmission to determine whether keying was impaired by application of the noise suppression devices. At speeds up to 50 w.p.m. separate dots were easily recognized and there was no discernible difference between operation with or without the suppressors in place. At keying speeds of 75 words per minute clipping of dots became apparent but the keying characteristics were not influenced by the noise suppressors. Operation of the channel-dialing and automatic-tuning circuits was also unaffected by the modifications, and the transmitter gave no evidence of malperformance. It is apparent, therefore, that operation of the Model TDZ transmitter was nowise affected by inclusion of noise suppression measures.

MODIFICATION KIT DEVELOPMENT

By use of the various experimental observations already described herein, together with a study of the interior of the Model TDZ transmitter, it became apparent that the suppressor circuit components could be placed on a prewired assembly and supplied as a modification kit to be installed by operating personnel in the field. Thus noise suppression can be accomplished in the transmitter with a minimum interruption to transmitter service. A suppressor assembly has therefore been designed to be bolted to the underside of the Model TDZ transmitter relay sub-assembly chassis.[4] It consists of an aluminum-alloy bracket supporting eight capacitors and eight composition resistors, as shown in Figure 3. Plans call for factory wiring of the modification assembly so that only 13 soldered connections need be made at the time of installation. The noise-suppression assembly is to be used in conjunction with properly shielded keying leads and a standard Navy Type 53522

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[4] R. S. Werner, NRL Conf. ltr. Report, C-3910-56/48, of 9 June 1948, to BuShips.

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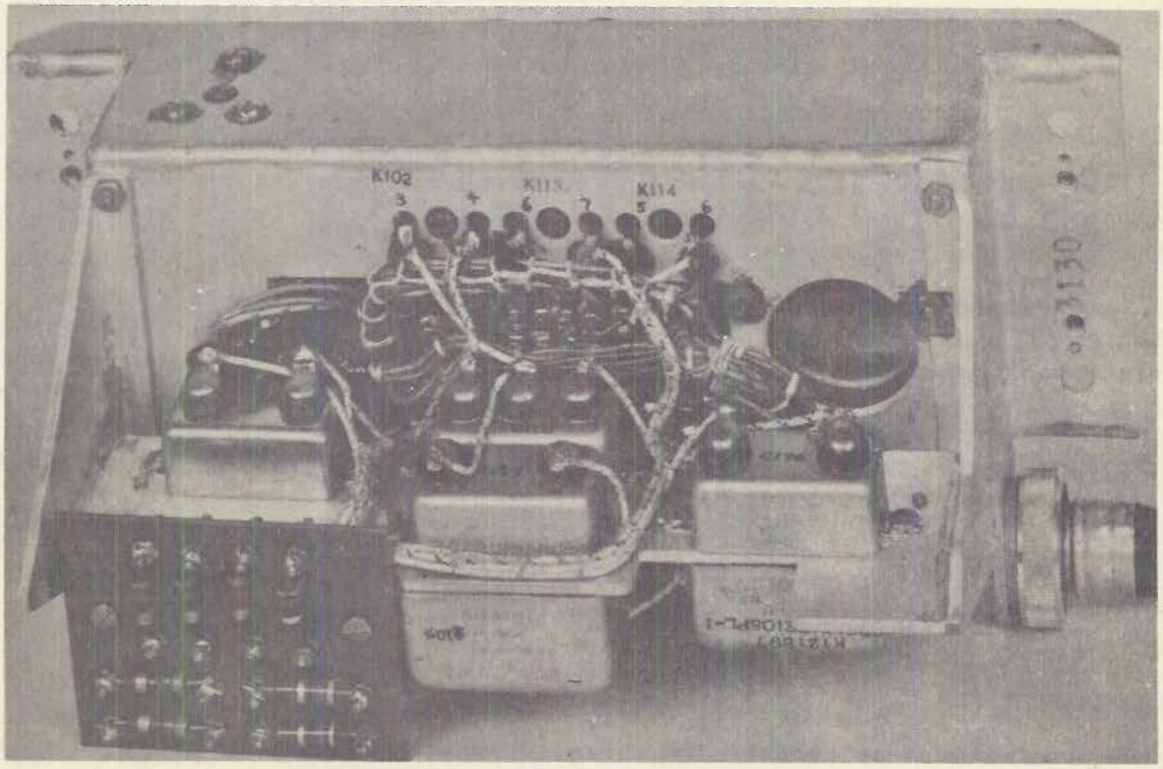

Figure 3 - Noise Suppressor Assembly Mounted on Relay Sub-Assembly Chassis of Model TDZ Transmitter

power-line filter. The filter is standard equipment for a Model TDZ transmitter installation[5] and its omission would result in a high level of conducted interference in the power line.

GENERAL COMMENT

The present trend in Navy communication equipment is toward automatic channel-shifting features, and experience with the Model TDZ transmitter indicates that serious noise interference may be expected in any apparatus embodying automatic control devices of the nature employed in this equipment. In the case of future uhf communication transmitters based on the crystal-oscillator, frequency-multiplier principle, especially where a high-order of frequency multiplication is used, such as in Model TDZ equipment, serious radiated c-w signal interference is to be anticipated in conventional designs of apparatus.

Interference of this nature cannot ordinarily be corrected by modifications to a finished equipment. Only by recognition of the problem at the beginning of the design of a new equipment, and by the inclusion of necessary shielding features augmented by other appropriate measures for the particular

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[5] BuShips "Radio Installation Bulletin," Volume 9, No. 214, 19 November 1947.

equipment in question, is there much promise of obtaining the required low level of c-w signal interference.

CONCLUSIONS

It is evident that automatically operated equipments similar to the Model TDZ transmitter can cause high noise-interference levels unless suitable noise-suppression features are included.

The interference characteristics of the Model TDZ transmitter are materially improved by the installation of a resistance-capacitance type of noise-suppression circuit across each of certain transmitter relay solenoids, by use of shielded keying leads and by placing a Navy Type 53522 filter in the power-supply line. Through these measures, conducted interference of all forms on the power line is reduced to negligible proportions, and radiated noise, is held to a satisfactorily low level.

The level of radiated c-w signal interference, however, remains comparatively high, but no remedy for this undesirable condition is apparent without extensive redesign of the transmitter.

RECOMMENDATIONS

It is recommended that the noise suppression kit referred to in this report be applied to the various Model TDZ transmitters now in use in the Naval Service and that shielded keying leads be used with these equipments. In the event that a Navy Type 53522 power-line filter has not been included in any Model TDZ transmitter shipboard installation, it is recommended that such a filter be provided.

It is further recommended that steps be taken to insure that satisfactory interference characteristics are provided in new designs of equipment to be furnished to the Navy, especially in automatically-operated equipments similar to the Model TDZ transmitter. Similarly, it is recommended that in new designs of uhf transmitters where a high order of frequency multiplication is employed, it shall be required of the manufacturer that adequate design features be embodied to prevent radiated c-w signals from reaching serious proportions.

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