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RADIO REPORT NO. 1464.

AN INVESTIGATION OF THE SUSCEPTIBILITY OF SHIPS RECEIVERS AND AUTO-ALARM EQUIPMENT (500 KC/S) TO INTERFERENCE FROM LONG AND MEDIUM WAVE BROADCAST TRANSMISSIONS.

Case No. 2940

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SUMMARY

Severe interference to ships' reception in the frequency band 485 to 515 kc/s used for distress calls, has been experienced in some coastal areas from high power broadcasting transmissions. Interference in the distress band is a most serious matter and the work described is part of a programme to minimise the trouble. The selectivity of several ships' receivers of different types has been measured with each receiver alone and also when preceded by a 485-515 kc/s filter. Measurements have also been made of the performance of auto-alarm equipments, used for the automatic reception of distress signals.

In general, it has been found that ships' receivers with only one RF amplifier preceding a reacting detector (total of two tuned circuits) have inadequate selectivity and the use of the 485-515 kc/s filter is essential if interference from powerful broadcast stations is to be avoided. Receivers with two RF stages preceding a reacting detector (total of three or more tuned circuits) and super-heterodyne receivers have a generally satisfactory standard of selectivity but even so derive some benefit from the use of the filter in areas where the field strength of broadcast stations is very high.

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DRAWINGS ATTACHED:- WL 60964, 61162-72 inclusive
RADIO REPORTS REFERRED TO:- 785, 1427 and 1436

1. INTRODUCTION

It has been found that interference with radio reception on ships frequently arises in coastal areas near to powerful long and medium wave broadcast transmitters. The trouble is particularly serious when it occurs in the distress frequency band (485-515 kc/s) since it may result in the loss of distress calls. The interference arises primarily because of the high field strength of the broadcast transmissions over sea areas near to the transmitter, and is aggravated by the large effective height of ships' aerials (often as much as ten metres), and by the relatively poor selectivity of many existing ships' receivers.

In an endeavour to improve the selectivity of ships' receivers a band-pass filter[1], 485-515 kc/s, has been designed for insertion between the aerial and the input to the receiver or the buffer amplifier. (The buffer amplifier is compulsorily fitted before those receivers likely to produce appreciable radiation from the ships' aerial owing to the use of an oscillating detector or local oscillator). The filter is provided with a switch so that it can be removed from circuit when reception on frequencies outside the band 485-515 kc/s is required. The insertion loss characteristic of a representative filter for three values of aerial capacitance

(1) Radio Report No. 1427

is shown in Drawing WL 60964.

The object of the present investigation was to determine the effective selectivity of ships' receivers of several types in common use and to determine in which cases the filter was essential. In this connection it must be noted that the effective selectivity against strong interfering signals may be less than that shown by the selectivity curve measured at low signal levels, since both intermodulation and 'blocking' (reduction of level of the wanted signal by a strong unwanted signal) may occur in an early stage before appreciable selectivity has been provided.

Results of tests to determine the effective selectivity and immunity from interference of 'auto-alarm' equipment used for the automatic reception of distress calls in the 485-515 kc/s range are also included.

2. TYPES OF SHIPS' RECEIVERS

Most of the receivers used on ships employ three valves, (RF amplifier, reacting detector and AF amplifier), and there is usually one tuned circuit preceding the RF amplifier and another between the RF amplifier and the detector. As these receivers do not comply with the Admiralty regulations which limit the permissible radiation from the aerial when it is connected to a receiver they are preceded by buffer amplifiers. The buffer amplifiers are all aperiodic in the long and medium wave-bands, and have an input resistance between 50,000 and 500,000 ohms. The anode of the valve is choke- or resistance-capacity coupled to the receiver input and there is usually a gain of a few decibels when the buffer is used with an average aerial.

A relatively small number of receivers have two RF stages preceding a reacting detector and AF stage, and since there is a relatively large attenuation between the detector and the aerial the sets can be used without a buffer amplifier. In some recent ships installations a superheterodyne receiver, the Marconi type CR300 has been used(2). This has greater sensitivity and selectivity than the 'straight' sets described above, and does not need to be preceded by a buffer amplifier.

Automatic-alarm receivers are fitted on some ships to give a warning when distress signals in the band 485 to 515 kc/s are received during periods when there is no human watch. In these sets reaction is not used and preset circuits are provided giving a fairly uniform sensitivity for all frequencies in the band simultaneously.

Tables 1 and 2 summarize the main features of the receivers and auto-alarms employed in the tests described in this report.

(2) Radio Report No.1436

TABLE 1

SHIPS' RECEIVERS TESTED

Maker	Type	Stages	Tuning	Calibration	Buffer Type
Marconi	730	RF,det*, AF	2 dials	degrees	763
International Marine Radio Co.	22	RF,det*, AF	1 dial	wavelength	SR1
Siemens	SB173A	RF,det*, AF	1 dial	degrees	SB174A
International Marine Radio Co.	20	2RF,det*, 2 AF	1 dial	wavelength & frequency	none
Siemens	SB372	2RF,det*, AF	1 dial	degrees	none
Marconi	CR300	RF,FC,2IF,det,2AF	1 dial	frequency	none

* With reaction

TABLE 2

AUTO-ALARMS TESTED

Maker	Type	Stages	Controls	Type of selector
Marconi	M	2RF,det,rectifier	aerial trimmer & gain control	motor & relays
International Marine Radio Co.	AA.2-B	RF,det,AF,rectifier	gain control	motor & relays
Standard Telephones & Cables Ltd.	DMS1172*	RF,det,2AF, rectifier	gain control	relays
Siemens	SB218	RF,det,AF, rectifier	input condenser	relays

* also known as International Marine Radio Co. type 28.

3. TESTS ON RECEIVERS

3.1 Marconi type 730 receiver and type 763 buffer

With the receiver tuned to 500 kc/s and the reaction control set just short of the point of oscillation an output of 1 mW could be obtained with a signal-to-noise ratio of 15 db when an input signal of 20 db rel. to 1 μV (modulated 30% at 400 c/s) was applied through a dummy aerial of 220 μμF. The actual ouput was very critically dependent on the reaction control setting and the signal-to-noise ratio measured by a power meter was not a good indication of the quality of reception, as the bandwidth was very small. For frequencies 10 kc/s or more from the frequency of 500 kc/s to which the receiver was tuned, the output was much less critically dependent on the setting of the reaction control. In Drawing WL 61162 the full line shows the input required at frequencies between 300 and 2000 kc/s (without the filter) to give the same output as that given by the signal of 20 db rel. to 1 μV at 500 kc/s. By showing the actual input for an output corresponding to the normal listening level rather than plotting the selectivity ratio a more

correct representation of the receiver performance is given. It shows in this case that over most of the long- and medium-wave broadcast band (without the filter) an input of 100 db rel. to 1 μV will cause serious interference. The output from the interfering station is almost unaffected by altering the reaction control setting and consequently even strong wanted signals may suffer the interference. Assuming the average ship's aerial to have an effective height of about 10 metres the interference would result from fields of only 80 db rel. to 1 μV/m.

Interference with the reception of signals also results from blocking(3) i.e. the reduction in level of the wanted signal due to a strong unwanted signal. The chain dotted curve shows the input of interfering signals, at frequencies up to 2000 kc/s, which cause a reduction of 3 db in the output due to the wanted signal. It was found that the blocking occurred chiefly in the buffer due to the lack of selectivity before the buffer.

Measurements have not been made at frequencies below 300 kc/s because of the difficulty in attenuating the harmonics of frequencies which are submultiples of 500 kc/s to a level of at least about 100 db below the fundamental. Since it would be necessary to apply a fundamental signal of several volts level, iron dust core filters would not be suitable because of the risk of harmonic production due to core saturation and as air core filters were not available tests below 300 kc/s have not been included.

The dotted curve shows the performance with the 485 to 515 kc/s filter connected between the dummy aerial and the buffer amplifier. At frequencies outside the range 390 to 690 kc/s it was found that an interfering signal of more than 10 volts was required to give an output equal to that of a 10 uV signal at 500 kc/s, and no blocking was observed. As the filter has an insertion loss of not more than 5.5 db (with an aerial capacitance of only 100 μμF) and may have an insertion gain of up to 4 db (with aerials of 220 to 470 μμF) at some frequencies in the 485 to 515 kc/s band, the sensitivity performance of the system is not appreciably degraded by the use of the filter and the selectivity performance is considerably improved.

3.2 International Marine Radio Co. type 22 receiver and type SR1 buffer

Drawing WL 61163 shows the performance of the I.M.R. type 22 receiver with and without the type SR1 buffer amplifier and the filter. With the receiver tuned to 500 kc/s and the reaction control set just short of the point of oscillation an output of 1 mW could be obtained with a signal-to-noise ratio of 15 db when an input signal of 26 db rel. to 1 μV (modulated 30% at 400 c/s) was applied through a dummy aerial of 220 μμF). Using the buffer with the receiver tuned to 500 kc/s it was not possible to obtain an ouput of 1 mW with an interfering signal at a frequency greater than 940 kc/s no matter how large an input signal was applied. This was found to be due to overloading of the buffer. A selectivity curve of the receiver alone showed that an input of not more than 2V (126db rel. to 1 μV) modulated 30% at 400 c/s is required at frequencies up to 2000 kc/s in order to produce 1 mW output, the receiver being tuned to 500 kc/s. Blocking measurements of the receiver alone and with the buffer showed that the blocking observed in the first test was the result of overloading in the buffer.

With the filter connected between the dummy aerial and the buffer the selectivity is that shown by the dotted curve in Drawing WL 61163. The frequency range beyond which a 10-volt signal gives an output of less than 1 mW is 420 to 620 kc/s.

3.3 Siemens type SB173A receiver and type SB174A buffer

The sensitivity of the Siemens type SB173A receiver was not very high

(3) Radio Report No. 785, Section 4.7.

and an input of 45 db rel. to 1 μV (modulated 30% at 400 c/s) was necessary to produce an output of 1 mW when the dummy aerial capacity was 220 μμF and the receiver was tuned to 500 kc/s. To improve the sensitivity the variable 'aerial coupling' condenser in series with the receiver input was short-circuited and the gain control on the buffer was set at maximum.

Drawing WL 61164 shows the selectivity and blocking characteristics. Without the filter interference results from signals of the order of 1 volt at frequencies up to more than 2000 kc/s. With the filter in use blocking does not occur, and signals of 10V give an output of less than 1 mW if their frequency is outside the range 370 to 700 kc/s.

3.4 International Marine Radio Co. type 20 receiver

The I.M.R. type 20 receiver has two RF stages and consequently a buffer amplifier is not required. With critical reaction an input of 20 db rel. to 1 μV (modulated 30% at 400 c/s) at 500 kc/s gives a signal-to-noise ratio of 15 db and an output which can be adjusted to 1 mW by the AF gain control. Since there are three tuned circuits instead of two, as in the receivers already described, the selectivity (Drawing WL 61165) is greater than that of the simpler receivers, but signals of 10 volts can cause interference over most of the medium wave-band.

The filter improves the performance so that only in the band 430 to 600 kc/s can interference result from signals of 10 volts or less. The impedance into which the filter works is, in this case, not the high impedance of a buffer amplifier, but the relatively low impedance of the input coupling coil of the receiver.

Measurements of the input impedance at 500 kc/s gave the values shown in Table 3 for various settings of the tuning control. The various settings were used in case, as a result of misganging, the input circuit did not give its maximum resistance at the setting which corresponded to maximum gain of the whole amplifier (including the sharply resonant final circuit to which reaction is applied).

TABLE 3

INPUT IMPEDANCE OF I.M.R. 20 RECEIVER

Tuning relative to 500 kc/s	Impedance ohms
+ 10 kc/s	50 - j 900
0 kc/s	290 - j 800
- 5 kc/s	660 - j 900
- 10 kc/s	350 - j 1400

The insertion loss of the filter when connected between dummy aerials of 100, 220 or 470 μμF and the receiver is shown as an inset on Drawing WL 61165. Although the insertion loss is not the same as when the filter works into a high impedance (Drawing WL 60964) it does not exceed 2 db in the range 485 to 515 kc/s.

3.5 Siemens type SB372 receiver

The Siemens type SB 372 receiver, two RF stages and three RF tuned circuits, gives the performance shown in Drawing WL 61166. An input at 500 kc/s of approximately 40 db rel. to 1 μV (modulated 30% at 400 c/s) in series with a dummy aerial of 220 μμF is necessary to give an output of 1 mW.

An input of less than 10V is needed to give the same output when the signal frequency lies between 340 and 1060 kc/s. Blocking of a wanted signal by an unwanted signal of not more than 10V occurs when the frequency of the latter is within the range 350 to 1400 kc/s. With the filter connected between the aerial and the receiver the performance is that shown by the dotted curve; a signal not exceeding 10V (modulated 30% at 400 c/s) can give 1 mW output only if it is within the frequency range 410 to 580 kc/s.

As two RF stages are used no buffer is needed, and the filter is terminated by the input impedance of the receiver, which varies with the ganged tuning in the manner shown in Table 4.

TABLE 4

INPUT IMPEDANCE OF SIEMENS TYPE SB 372 RECEIVER

Tuning relative to 500 kc/s	Impedance ohms
+ 10 kc/s	265 + j 560
0 kc/s	460 + j 240
- 10 kc/s	190 + j 30

The inset on Drawing WL 61166 shows the insertion loss of the filter for various dummy aerial capacities, the receiver being tuned in each case to the frequency of measurement. It will be seen that, as a result of the low impedance of the receiver input the response of the filter has lost its double-humped character and the insertion loss is as great as 12 db at a frequency of 515 kc/s when the dummy aerial capacitance is 470 µµF. This is partly due to the fact that the receiver is designed to operate most effectively from a low impedance aerial, whereas the filter was lined up for an aerial capacitance of 220 µµF. With an average aerial capacitance of 220 µµF the insertion loss varies from 1.5 db at 505 kc/s to 5.5 db at 515 kc/s and 7.5 db at 485 kc/s.

3.6 Marconi type CR 300 receiver

With the Marconi type CR 300 superheterodyne receiver the frequency band 485 to 515 kc/s can be received on either of two frequency ranges (3 and 4), but the intermediate frequency in use is changed from 570 kc/s on range 3 to 98 kc/s on range 4. The curves on Drawing WL 61167 show the sensitivity and selectivity of the receiver when it has been set on range 3 (IF of 570 kc/s) to receive at 500 kc/s a signal of 20 db rel. to 1 µV (modulated 30%) in series with 220 µµF. This signal will give an output of more than 1 mW at the phone jack or an adequate sound output from the loudspeaker, with a signal-to-noise ratio of 15 db. The response at 570 kc/s (the intermediate frequency) is only 30 db less than that at 500 kc/s. It will be noted that interference is also possible when unwanted signals fall in certain narrow frequency bands. The interference in such cases is due to conversion of the harmonics of the unwanted signal (which may be produced in the RF amplifier or frequency changer) by the fundamental or harmonics of the oscillator. For instance the response at 392.5 kc/s is due to the second harmonic of the oscillator (2 x 1070 = 2140 kc/s) mixing with the fourth harmonic (4 x 392.5 = 1570 kc/s) of the unwanted signal to yield an IF of 2140 - 1570 = 570 kc/s. At the image frequency (500 + 2 x 570 = 1640 kc/s) and at the frequencies at which reception is obtained by the use of oscillator harmonics, an input of considerably more than 0.1V is required for 1 mW output. The frequency bands over which such unwanted reception is obtained are very narrow and the receiver is free from interference except for the rare chance of the frequency of an unwanted signal being within these narrow limits. As there is only one RF stage the receiver does not suffer from blocking except for signals within about 30 kc/s of the wanted signal.

Curves of the insertion loss of the filter are included in Drawing WL 61167; it does not exceed 8 db in the working band. The input impedance on range 3 is shown in Table 5.

TABLE 5

INPUT IMPEDANCE OF MARCONI TYPE CR300 RECEIVER ON RANGE 3

Tuning relative to 500 kc/s	Impedance, ohms
+ 10 kc/s	170 + j 400
0 kc/s	700 - j 150
- 10 kc/s	95 - j 160

The sensitivity and selectivity of the receiver when it is tuned to 500 kc/s on range 4 (IF of 98 kc/s) are shown in Drawing WL 61168. The small ranges of frequency over which an output equal to that due to the wanted signal can be obtained are those corresponding to the image frequency (referred to the fundamental of the frequency-change oscillator) and pairs of frequencies spaced 98 kc/s from the second and third harmonics of the oscillator. If the filter is used, the response at the image frequency is reduced by about 35 db and an input of more than 10V is required to produce an output of 1 mW at the frequencies of the other unwanted responses.

The insert on Drawing WL 61168 shows the insertion loss of the filter when the receiver is tuned to frequencies around 500 kc/s. The maximum loss is 14 db, but as the receiver has more than 14 db reserve of gain at this frequency the effective sensitivity is not decreased. The insertion-loss curves differ considerably from those obtained when the filter works into a high impedance. This is again due to the relatively low impedance of the receiver input which is shown in Table 6.

TABLE 6

INPUT IMPEDANCE OF MARCONI TYPE CR300 RECEIVER ON RANGE 4

Tuning relative to 500 kc/s	Impedance, ohms
+ 10 kc/s	150 + j 350
0 kc/s	290 - j 300
- 10 kc/s	55 - j 120

In view of the large response to the intermediate frequency of 570 kc/s when range 3 is used it is preferable to use range 4 for the reception of 500 kc/s signals. On this range there are only narrow frequency ranges over which interference can result from strong signals, so the use of the filter is not essential with this receiver.

4. TESTS ON AUTO-ALARM RECEIVERS

4.1 Marconi Auto-alarm type M

4.1.1 General Description

The Marconi auto-alarm type M has two controls which are set on

installation. One is the tuning of the aerial, which is one of three coupled tuned circuits preceding the first of two RF amplifier valves. This tuned circuit was adjusted for maximum output for a 500 kc/s signal, the output being indicated by a meter in the anode of an anode-bend rectifier valve to which the tone resulting from the rectification of the ICW Signal by the detector is applied. In the anode circuit of this valve is a relay which operates the selector mechanism. The second control is a gain control which is set so that a signal with a field strength of 50 µV/m operates the relay. The signal voltage to be applied to the receiver to simulate this minimum signal is calculated by multiplying the field strength by the estimated effective height of the aerial.

4.1.2 Sensitivity and selectivity

An average effective height of 10 metres was assumed and the gain was set so that with the signal at any frequency in the working band 485 to 515 kc/s the current in the rectifier valve increased to the value of 5 mA necessary to operate the relay. This gain was found to be the maximum that could be employed without the danger of the receiver oscillating.

Drawing WL 61169 shows the selectivity of the receiver on the same scales as used for the previous receivers, the inset being a reproduction of the pass-band on an enlarged scale. The selectivity is very satisfactory and/there is no need to use a filter with this equipment.

4.1.3 Operation of auto-alarm equipment in presence of interference

The alarm signal consists of 4-second dashes separated by 1 second intervals and three consecutive dashes must be received to operate the alarm bell. The selector consists of a mechanism driven by a motor at constant speed, together with magnetic clutches operated by the signal (or any interference exceeding the value shown in the selectivity curve). For the selector to work, the dashes and spaces in the signal must have a duration which is within certain limits. If the first dash lasts for less than 3.5 seconds or more than 4.7 seconds the apparatus resets, but if, after the first dash has been registered, there is interference in the space the mechanism operates intermittently until the next dash holds it steadily operated. A considerable amount of interference is therefore tolerable, but it is necessary for a gap to occur between the cessation of a dash and the elapsing of 4.7 seconds from its commencement, though this gap need not last for more than the time taken by the relay to release, which is much less than 0.1 second. It is also necessary for a gap in the interference to occur near the end of the 1 second 'space', or the time during which the mechanism is operated by the interference will add to the length of the subsequent dash, and if this total exceeds 4.7 seconds the apparatus resets. As these gaps in interfering signals during the 'space' in the alarm signal need be of only short duration it is unlikely that failure will result even if there are several keyed transmissions simultaneously in the working band.

A reduction in the length of the 'space' below the standard value of 1 second is permissible if the length of the dash does not exceed 4.7 seconds. With such a signal there is a much greater chance that interference will occupy the whole of the 'space', especially if the length of the latter is less than 0.1 second. The greatest length of 'space' with which correct operation is obtained is 1.5 seconds.

4.1.4 AF response

The AF response is uniform (within 2 db) from 150 to 1500 c/s, but as ICW signals usually have an interruption frequency of about 1000 c/s the only advantage of a restricted AF response would be the reduction in the response to noise.

4.2 International Marine Radio Co. Auto-alarm type AA.2-B

4.2.1 General description

The I.M.R. auto-alarm type AA.2-B employs a receiver in which the tuning is entirely preset, there being a pair of tuned circuits preceding the RF amplifier valve and another pair between it and the detector. The gain of the RF amplifier is adjustable by means of a knob. The tone resulting from detection of the ICW signals is amplified, rectified and the resultant DC is used to operate a relay controlling the operation of the selector. The selector mechanism consists of a constant-speed motor which drives a shaft carrying magnetic clutches and timing segments. These segments are connected to relays which cause a bell to ring if three dashes are correctly received. The length of the dashes may vary from 1.5 to 4.5 seconds, and the spaces may vary from 0.2 to 1.5 seconds.

4.2.2 Sensitivity and selectivity

The sensitivity and selectivity with the gain at maximum are shown in Drawing WL 61170; the sensitivity is more than sufficient for reception of signals of 500 μV in the range 485 to 515 kc/s. The selectivity is such that a signal of 10 volts will operate the selector if its frequency lies between about 200 and 800 kc/s; some reduction of this range can, however, be obtained by such a reduction of gain as would normally be permissible.

4.2.3 Operation of auto-alarm in presence of interference

As there are wide tolerances on the lengths of dashes and spaces which will cause correct operation a large amount of interference can be tolerated, the main requirement being that gaps occur during the 'space' periods.

4.3 Standard Telephones & Cables Ltd. Auto-alarm type DMS1172 (I.M.R.28)

4.3.1 General description

The S.T.& C. auto-alarm equipment type DMS 1172 is also known as International Marine Radio Co. type 28. The four valves in the receiver unit are employed as RF amplifier, detector and two AF amplifiers. The amplified tone from ICW signals is rectified by metal rectifiers and the resultant DC operates a relay which controls the selector. Motors and other mechanical devices are not used in the selector which consists essentially of relays, some of which pulse in a time sequence and measure the duration of the signals received.

4.3.2 Sensitivity and selectivity

Drawing WL 61171 shows the sensitivity and selectivity of the receiver. The sensitivity is more than sufficient for the reception of signals of 500 μV even with the gain control (which has a range of 10 to 15 db) at minimum. The selectivity, which is contributed by three tuned circuits before the RF amplifier and two between it and the detector, is inadequate to prevent the reception of signals of 10 V at frequencies between 260 and 2000 kc/s. The dotted curves in Drawing WL 61171 show the improved performance obtained with the 485 to 515 kc/s filter in use.

4.3.3 Operating of auto-alarm in presence of interference

The selector operates correctly and rings the alarm bell when three dashes of length between 3.5 and 4.5 seconds are registered. The space between the dashes may vary between the few milliseconds required for the release

of the relays and 1.5 seconds.

4.4 Siemens auto-alarm type SB 218

4.4.1 General description.

In the receiver of the Siemens type SB 218 auto-alarm the tuning is entirely preset; there are two tuned circuits before the single RF amplifier valve and one between the amplifier and the detector. The detector is followed by an AF amplifier and a grid-leak rectifier, in the anode circuit of which is the relay controlling the action of the selector. The selector consists of a system of relays, the timing being done by the discharge of condensers through resistance.

4.4.2 Sensitivity and selectivity

Drawing WL 61172 shows the input (modulated 100% at 400 c/s) required at various frequencies to reduce the anode current of the rectifier from 7 to 4 mA and so to release the relay. The only gain control provided is a condenser in series with the input coupling coil; this was set at maximum. It will be seen that, over most of the working band, the sensitivity is about 18 db less than that which would be required for operation with the specified field of 50 uV/m with a 10 metre aerial. The signal levels at the grids of the valves were checked when the input was the minimum signal at 500 kc/s which would operate the selector, and are shown in the following table.

TABLE 7

SIEMENTS AUTO-ALARM TYPE SB218

LEVELS AT INPUT AND GRIDS OF VALVES

Position	AF or RF	Voltage
V_4 grid	AF	2.0 V
V_3 "	AF	0.1 V
V_2 "	RF	101 db rel.1 µV
V_1 "	RF	80 " " "
Input (in series with 220 µµF)	RF	71 " " "

The gain of the RF amplifier and the sensitivity of the detector (V2) were both low. This appears to be the result of connecting the anodes of these valves to taps on the coupling impedances so that the impedances in the anode circuits are relatively low.

The frequency range over which a signal of not more than 10V operates the selector is 380 to 940 kc/s. In some areas interference from broadcasting stations might occur and an improved performance might result from the use of the filter. The performance of the receiver with the filter is shown by the dotted curves; signals which produce a voltage of not more than 10V operate the selector if their frequency lies between 425 and 590 kc/s. The sensitivity over the working band is reduced by up to 10 db for frequencies above 500 kc/s; the asymmetrical response is probably the result of the "stagger-tuning" of the two circuits which precede the first valve. As the sensitivity is deficient, even without the filter, the use of the filter is not recommended.

4.4.3 Operation of selector in presence of interference

With this equipment (as with the other auto-alarms) it is not necessary for interference to be absent during the whole of the 'space' between the dashes. The tolerance on the length of the dashes is 3.5 to 4.5 seconds and the 'space' may have any length from the short interval required for the operation of the relays to 1.5 seconds. Intermittent interference in the spaces does not cause failure, but interference which extends the length of the dash excessively causes the apparatus to reset. Continuous interference causes an interrupted buzzing signal to be sounded.

Like the other auto-alarms, this equipment will work with a signal in which the spaces are reduced in length, but the chance of failure resulting from interfering signals is then increased.

4.4.4 AF response

The AF response is uniform (within 2 db) over the range 100 to 2000 c/s.

5. INTERMODULATION TESTS

If two signals of sufficient strength with a frequency sum or difference of 500 kc/s are applied to a receiver the curvature of the characteristic of a valve (usually the first) causes an intermodulation component at 500 kc/s to be produced. If the receiver is tuned to 500 kc/s this component is amplified and produces an AF output derived from the modulation of both the original signals. The greater the selectivity before the valve at which the intermodulation can occur, the greater the input required to produce an intermodulation product of strength equal to the minimum signal to which the receiver is required to respond.

Thus a pair of unwanted signals spaced by 500 kc/s or whose frequencies add up to 500 kc/s, might give rise to interference with a wanted signal at 500 kc/s and tests were made to determine the susceptibility of various ships' receivers to interference of this type.

The tests were made with the following pairs of frequencies for the unwanted signals: 230 and 270 kc/s, 270 and 770 kc/s and 600 and 1100 kc/s, the receiver being tuned to the sum or difference frequency of 500 kc/s. In each case the equal inputs of the two signals were adjusted in level to the value required in order to produce the same output (1 mW) when either was modulated as a wanted signal of 500 μV at 500 kc/s. In the tests on the auto-alarms the criterion was the operation of the relay, the gain control setting being those used in the previous tests. From the results shown in Table 8 it will be seen that in receivers with good selectivity before the first valve, such as the Marconi Auto-alarm, an input of 5 volts (134 db rel. to 1 μV) or more is required for all the combinations of frequencies. In some cases, marked *, measurements could not be made on the third pair of frequencies, 600 and 1100 kc/s, as the rejection of the 600 kc/s signal was insufficient to permit the level of the input signals to be increased to the value required to produce the intermodulation product.

TABLE 8

INPUT FOR INTERMODULATION PRODUCT EQUIVALENT TO A SIGNAL OF 500 μV AT 500 kc/s.

Receiver	Input (db rel. to 1 μV) at frequencies stated to produce 1 mW output signal from 500 kc/s intermodulation product.		
	230 and 270 kc/s	270 and 770 kc/s	600 and 1100 kc/s
Marconi 730 and buffer	106	107	105
I.M.R. 22 & buffer	105	106	104
Siemens SB173A & buffer	106	108	> 106*
I.M.R. 20	138	134	121
Siemens SB372	130	120	108
Marconi CR300	137	137	131
Auto-alarms			
Marconi M	138	140	134
I.M.R.AA.2-B	136	139	> 125*
S.T. & C.DMS1172	133	131	> 107*
Siemens SB218	138	138	> 130*

* At these inputs the 600 kc/s signal alone gives the standard output.

From Table 8 it can be seen that whereas receivers which are not used with buffer amplifiers perform satisfactorily with interfering signals of up to about 5 volts (134 db rel. to 1 μV), those used with buffer amplifiers suffer from intermodulation, with little limitation in respect of frequency, with interfering signals of about 0.2 volt (106 db rel. to 1 μV), a level which may easily be exceeded in practice.

Table 9 shows that when the 485 to 515 kc/s filter is used in front of the buffer amplifier the performance is satisfactory. Tests on the performance of the S.T. & C. auto-alarm with the filter showed that the break-through of the 600 kc/s signal no longer occurs.

TABLE 9

INPUT FOR INTERMODULATION PRODUCT EQUIVALENT TO A SIGNAL OF 500 μV AT 500 kc/s WITH 485 to 515 kc/s FILTER IN USE

Receiver	Input (db rel. to 1 μV) at frequencies stated		
	230 and 270 kc/s	270 and 770 kc/s	600 and 1100 kc/s
Marconi 730 & buffer	134	135	131
I.M.R.22 & buffer	138	137	137
Siemens SB173A & buffer	137	136	132
S.T.& C.DMS 1172	132	132	125

6. CONCLUSIONS

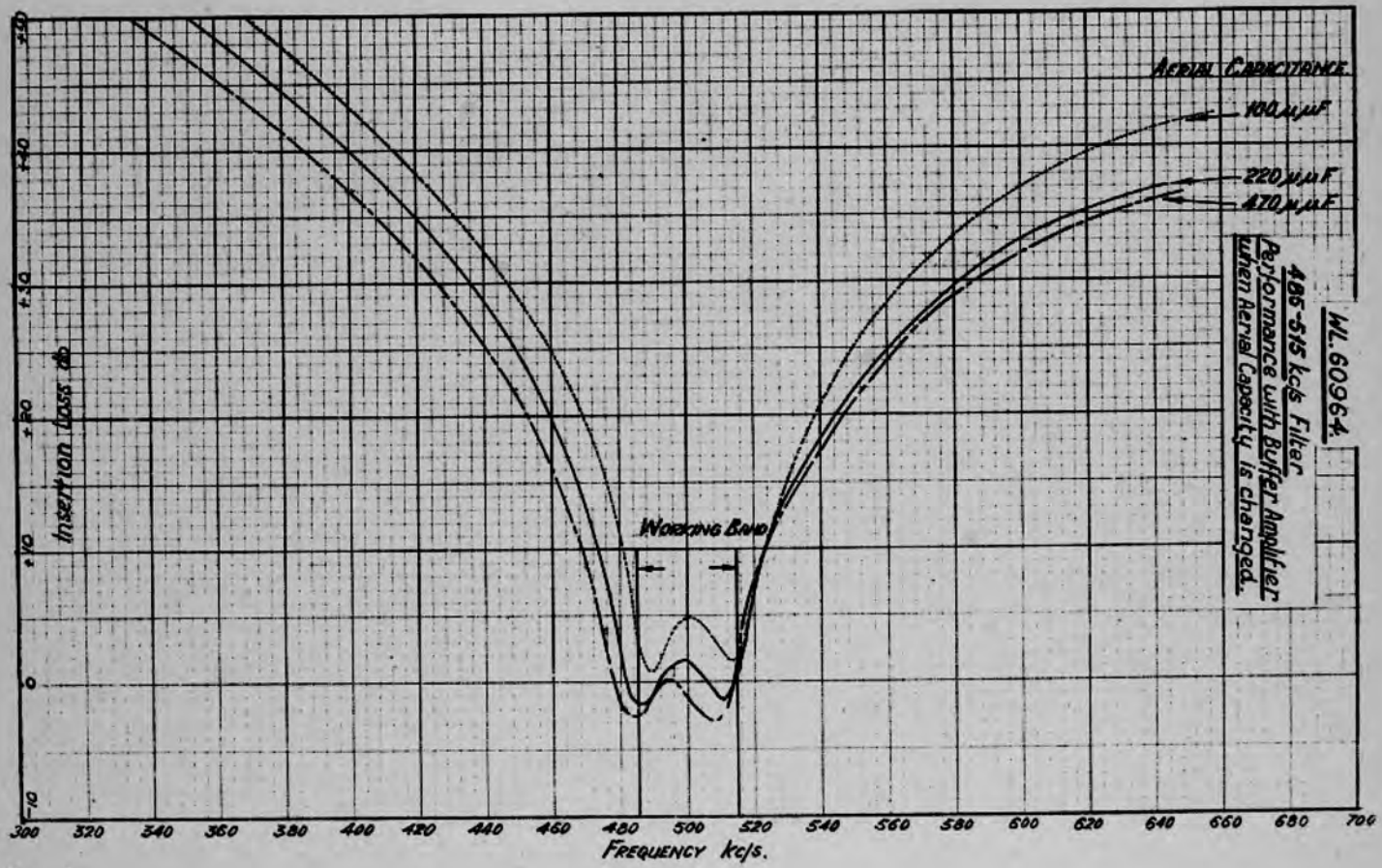
The tests on ships' receivers have shown that the types employing a single RF amplifier and reacting detector (total of two tuned circuits) have, when tuned to the 485 to 515 kc/s distress band, insufficient selectivity against signals in excess of 1 volt (corresponding for instance to a field of 0.1 volt/metre received on an aerial of 10 metres effective height) to be suitable for use in areas where strong fields exist from medium wave broadcasting stations. Receivers of this type are the Marconi type 730, International Marine Radio type 22 and the Siemens type SB 173A.

Spurious signals which fall in the distress band can be produced by intermodulation in the buffer amplifiers when two signals of 0.2 volt or more, having a frequency sum or difference of approximately 500 kc/s, are present.

The 485 to 515 kc/s filter designed to improve the performance of these types of receivers is very effective in removing interference resulting from lack of selectivity and from intermodulation.

Receivers having two RF stages (total of three or more tuned circuits) and those of the superheterodyne type yield a generally satisfactory performance, but in areas where unwanted signals are very strong the filter is of value. Superheterodyne receivers (e.g. Marconi type CR 300) are liable to interference in certain narrow frequency bands (corresponding to conversion of unwanted signals or their harmonics by harmonics of the oscillator) for unwanted signal levels of about 0.1 volt or more, but this interference can be removed by the filter.

The performance of the auto-alarms appears generally satisfactory, though a detailed investigation has not been made of the selectors. The selectivity of the Marconi type M auto-alarm is very good, but that of the S.T. & C. type DMS 1172 can be usefully improved by the 485 to 515 kc/s filter. The sensitivity of all the alarm equipments, except the Siemens type SB 218, is sufficient for signals of 50 µV/m received on an aerial of 10 metres effective height to be recorded.

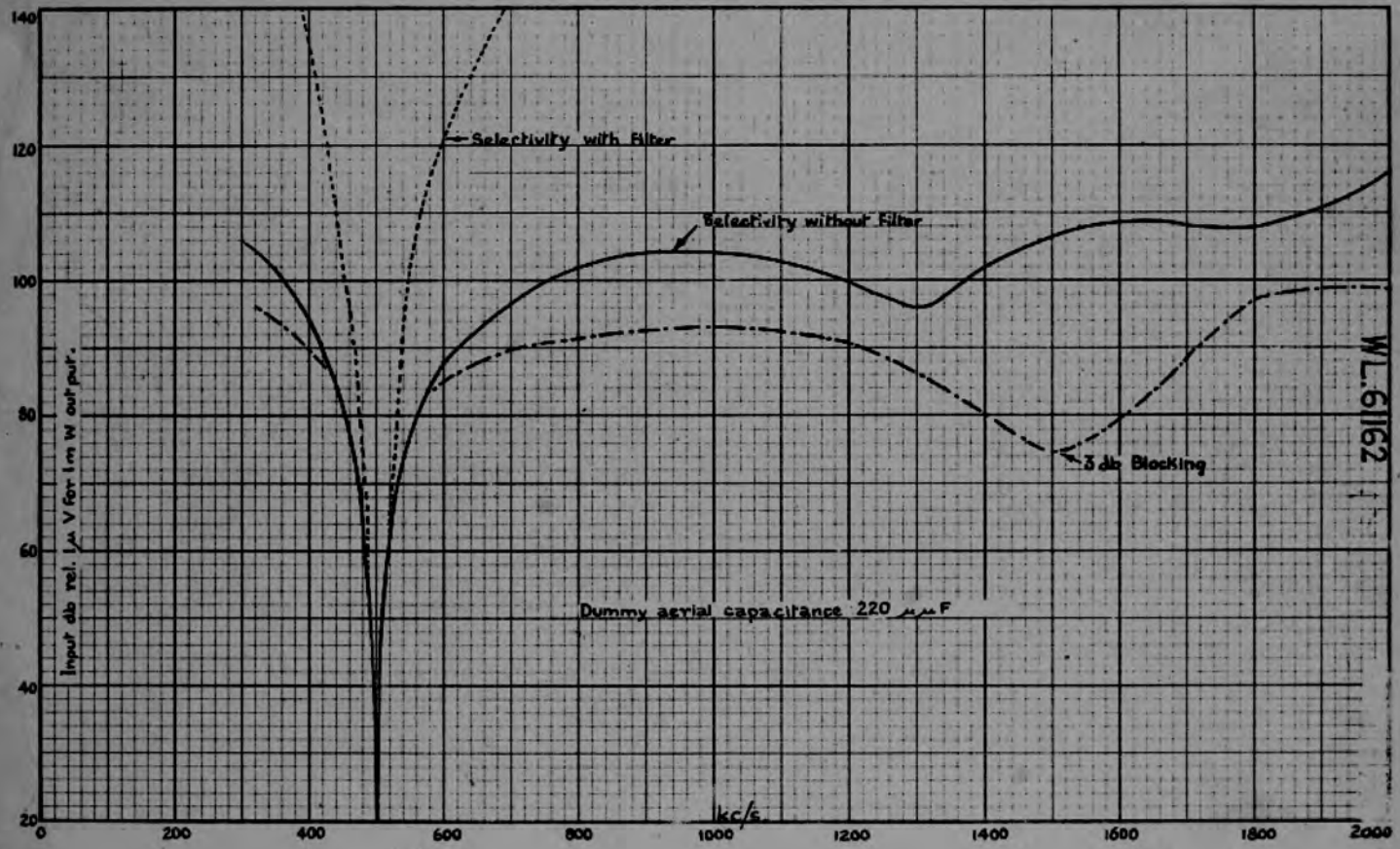


WL.60964.

485-515 kcls Filter
Performance with Buffer Amplifier
when Aerial Capacity is changed.

MARCONI TYPE 730 RECEIVER AND TYPE 763 BUFFER
SENSITIVITY AND SELECTIVITY WHEN TUNED TO 500 Kc/s

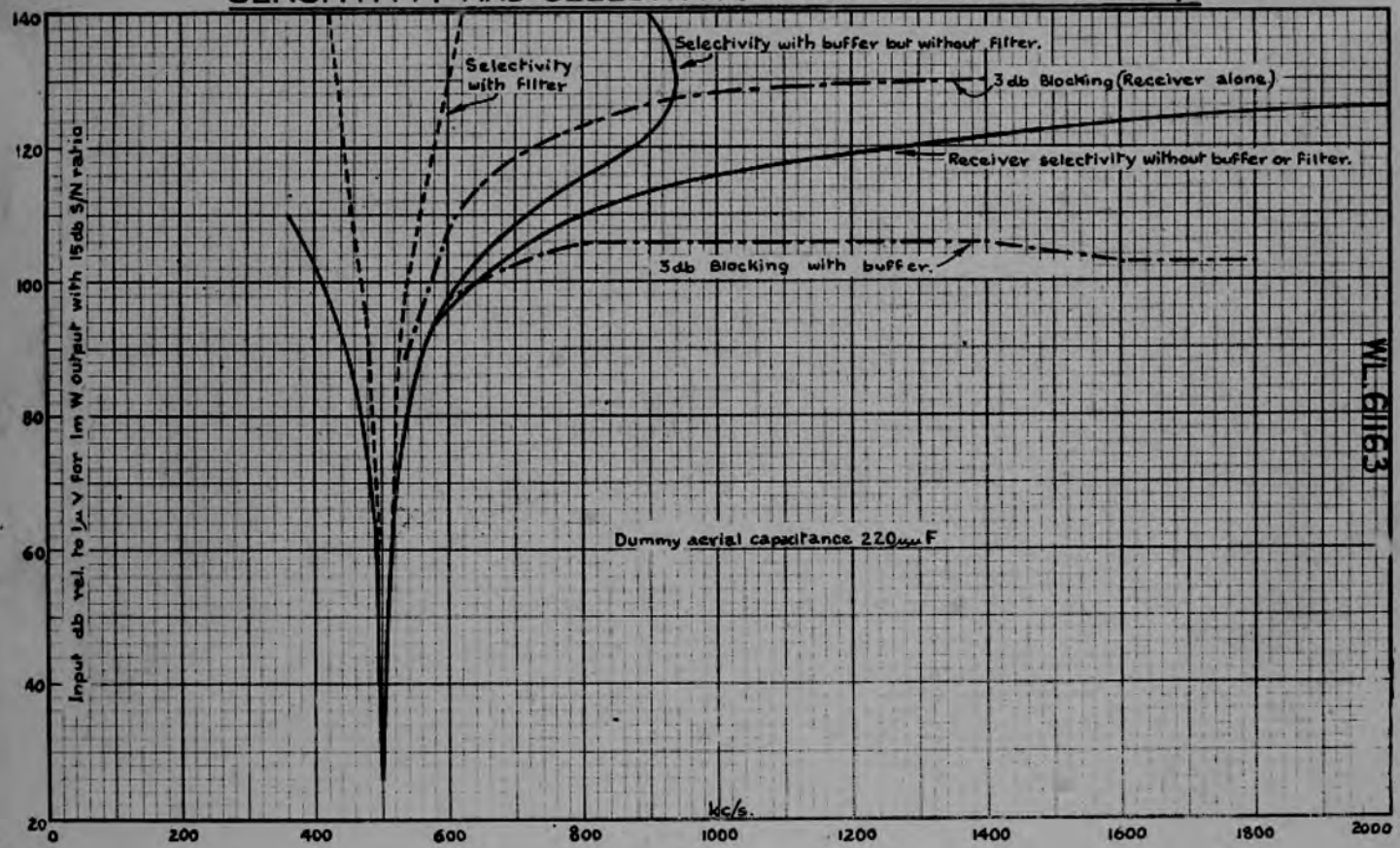
WL61162



INTERNATIONAL MARINE RADIO CO. TYPE 22 RECEIVER AND TYPE SRI BUFFER

WL61163

SENSITIVITY AND SELECTIVITY WHEN TUNED TO 500 kc/s



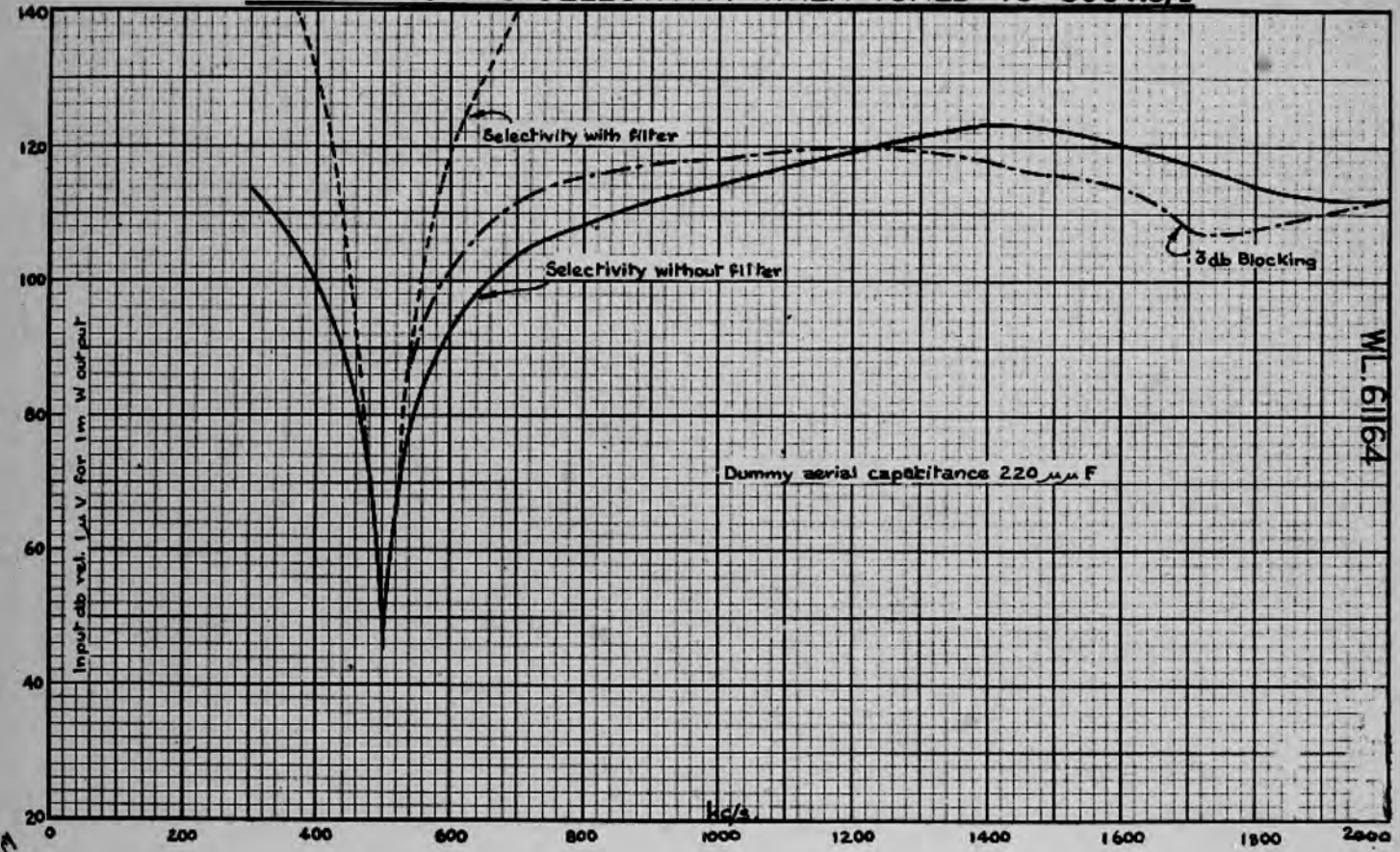
WL.61163

E.M.R.C.

SIEMENS TYPE SB 173A RECEIVER AND TYPE SB174A BUFFER

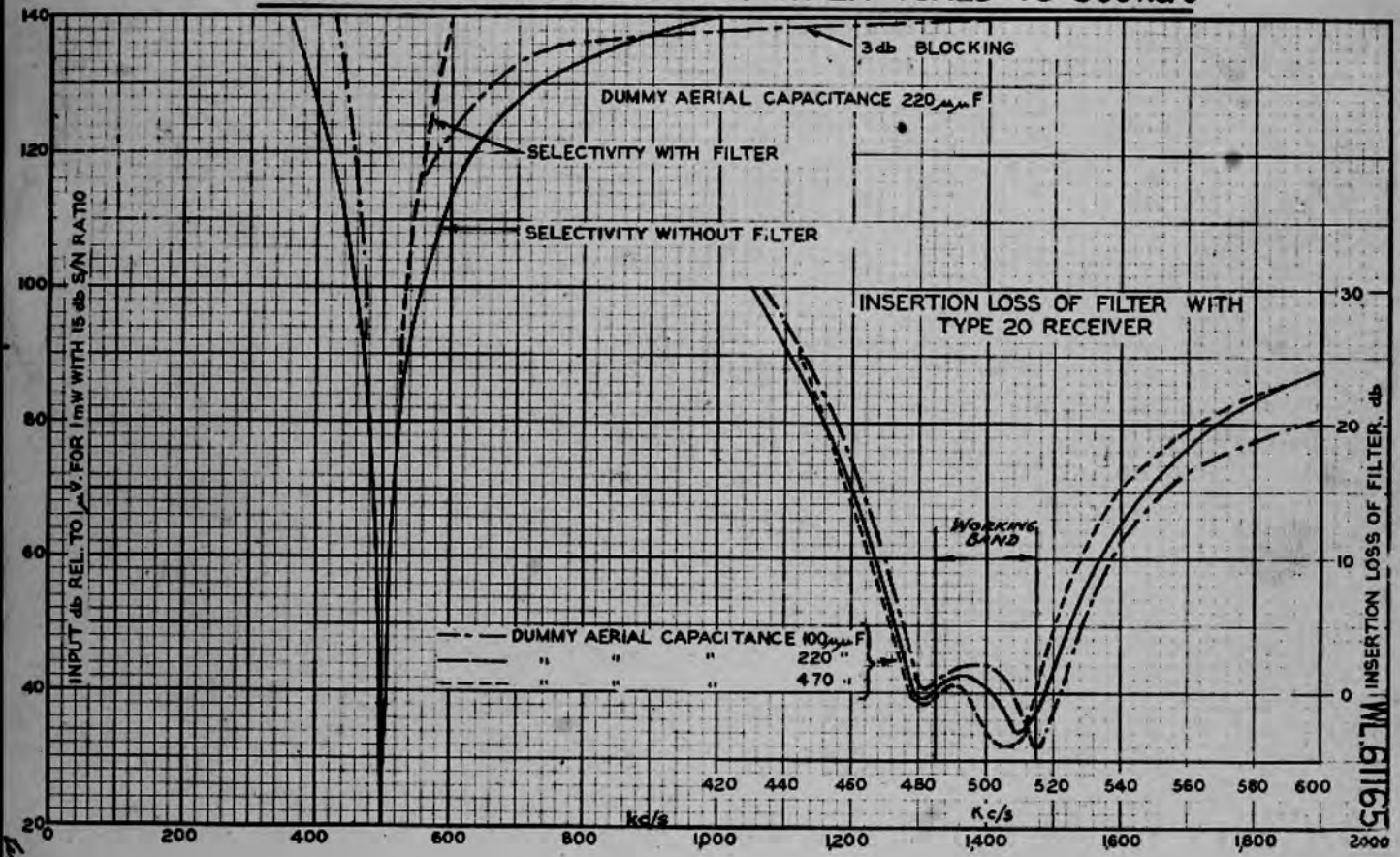
WL 61164

SENSITIVITY AND SELECTIVITY WHEN TUNED TO 500 Kc/s



INTERNATIONAL MARINE RADIO CO. TYPE 20 RECEIVER WL61165

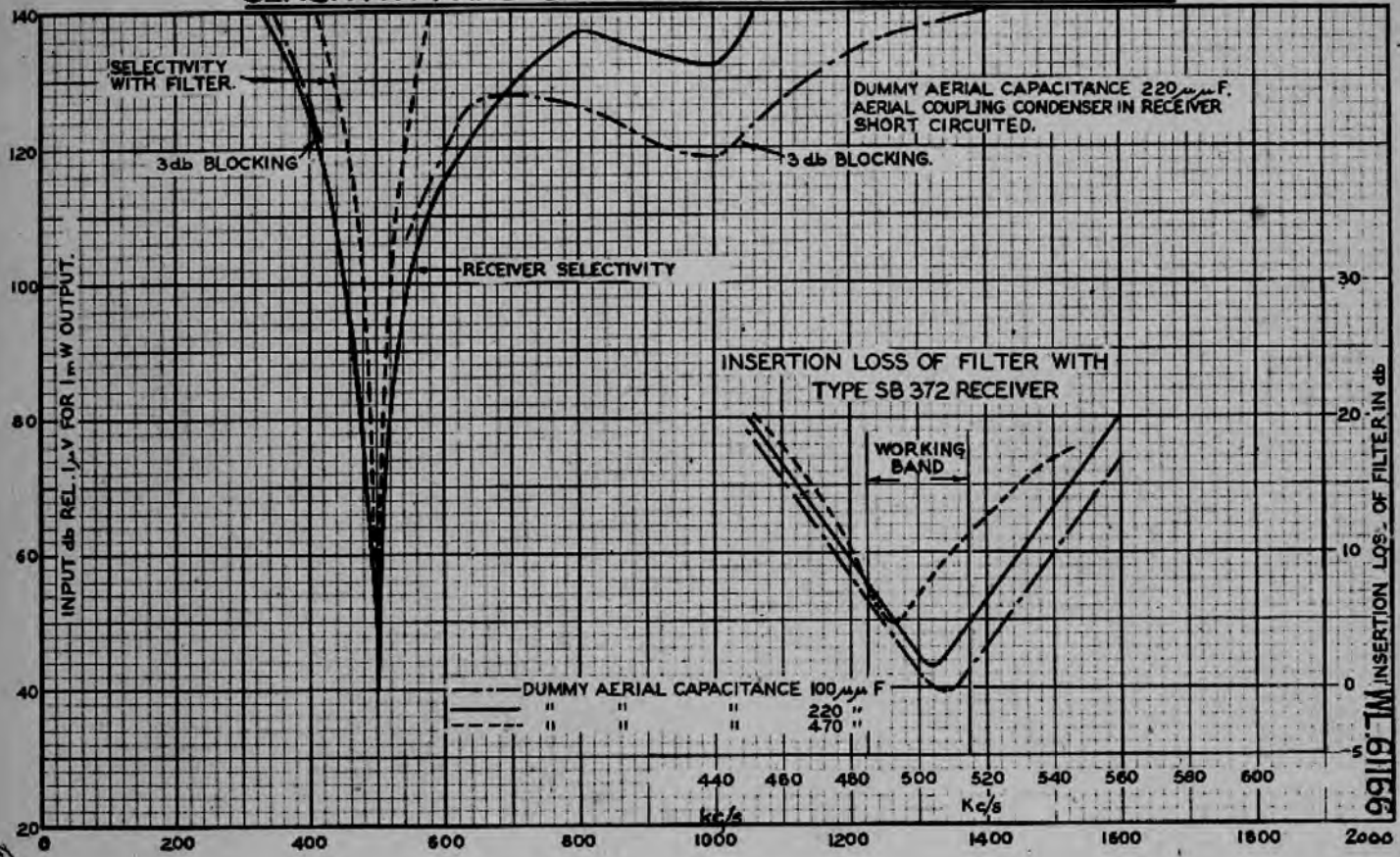
SENSITIVITY AND SELECTIVITY WHEN TUNED TO 500Kc/s



WL 61166

SIEMENS RECEIVER TYPE SB 372

SENSITIVITY AND SELECTIVITY WHEN TUNED TO 500 Kc/s.



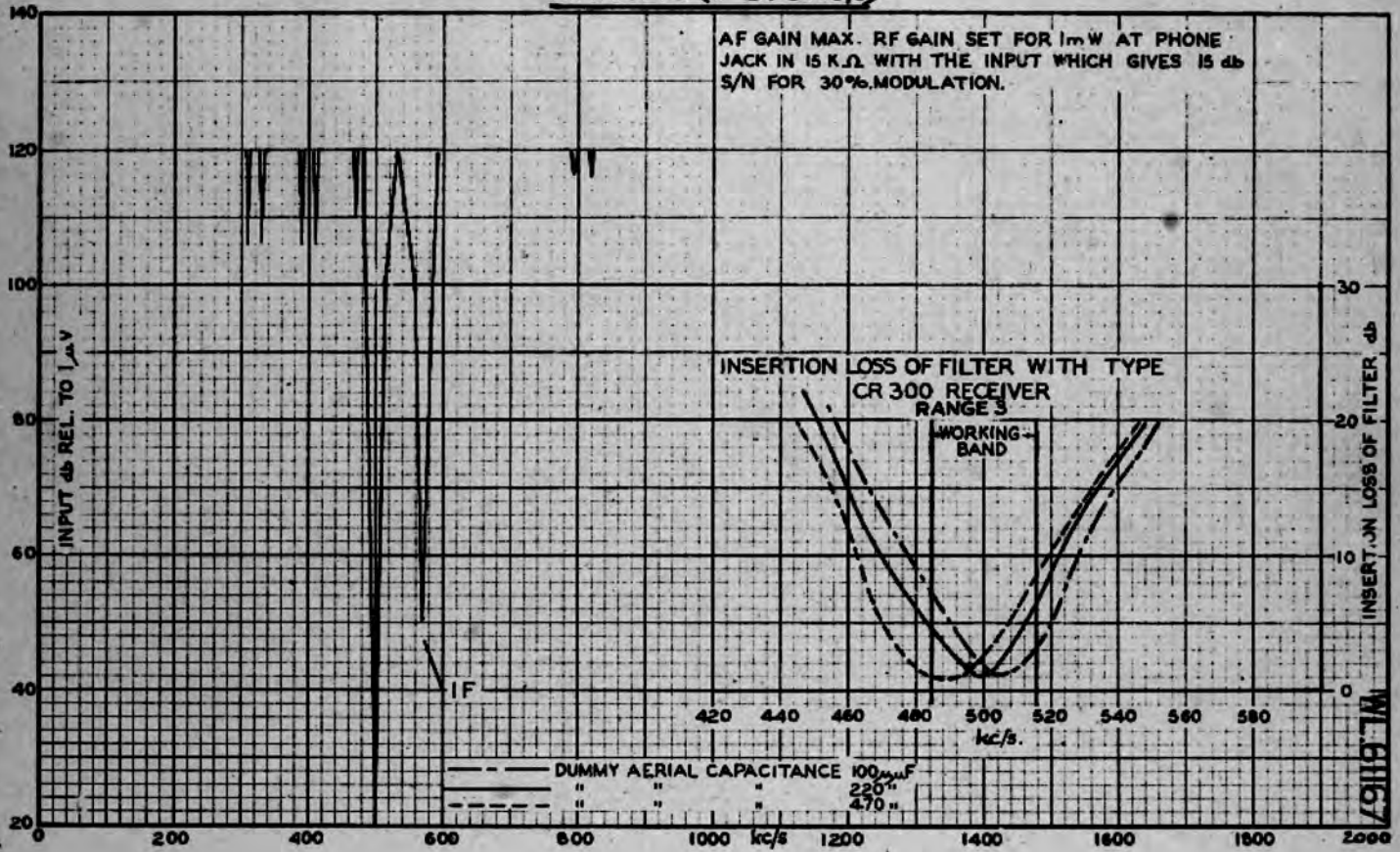
WL 61166

WL 61167

MARCONI TYPE CR 300 RECEIVER

SENSITIVITY AND SELECTIVITY WHEN TUNED TO 500 kc/s.

RANGE 3 (IF 570 kc/s)

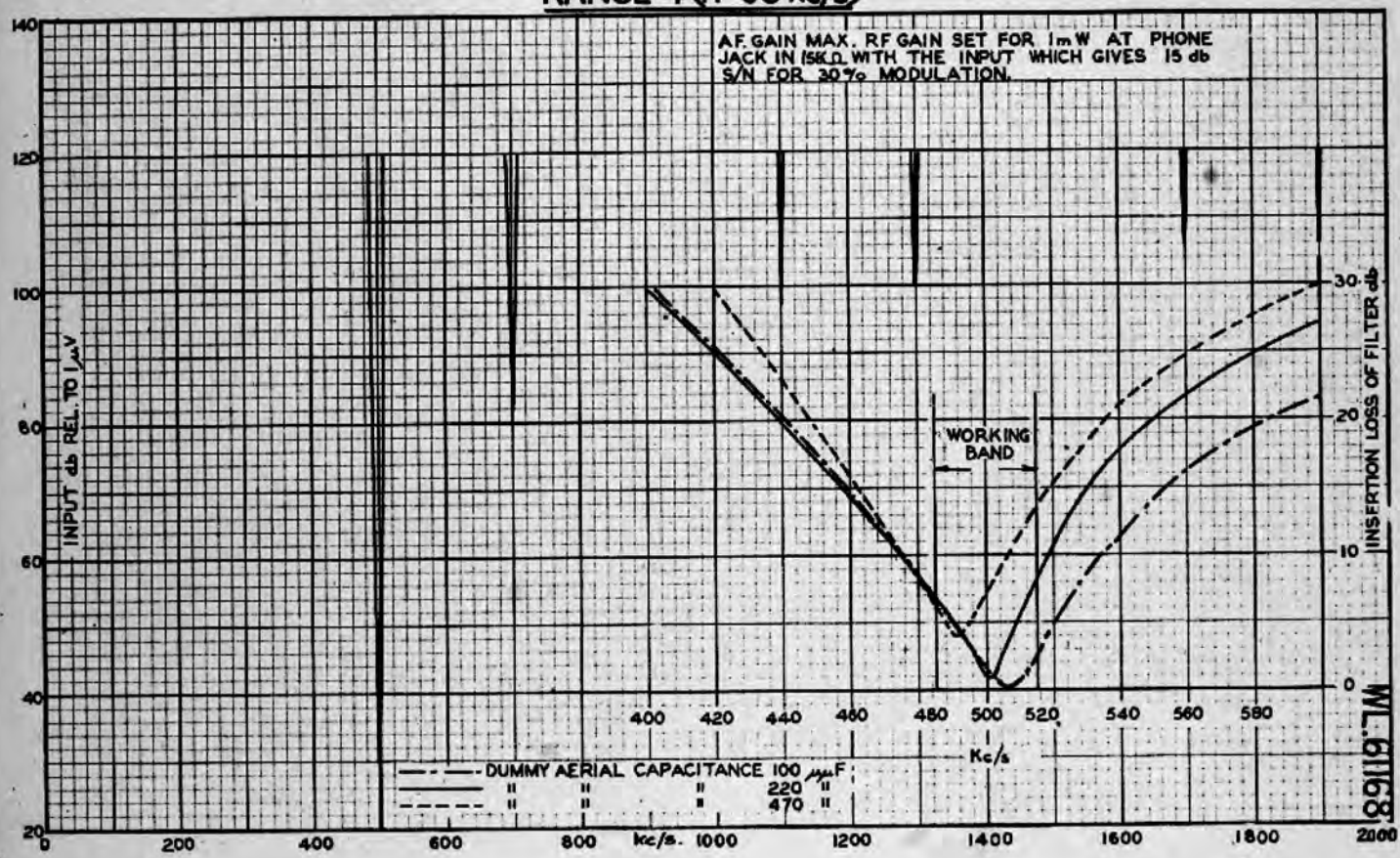


MARCONI TYPE CR 300 RECEIVER

WL 61168

SENSITIVITY AND SELECTIVITY WHEN TUNED TO 500 kc/s

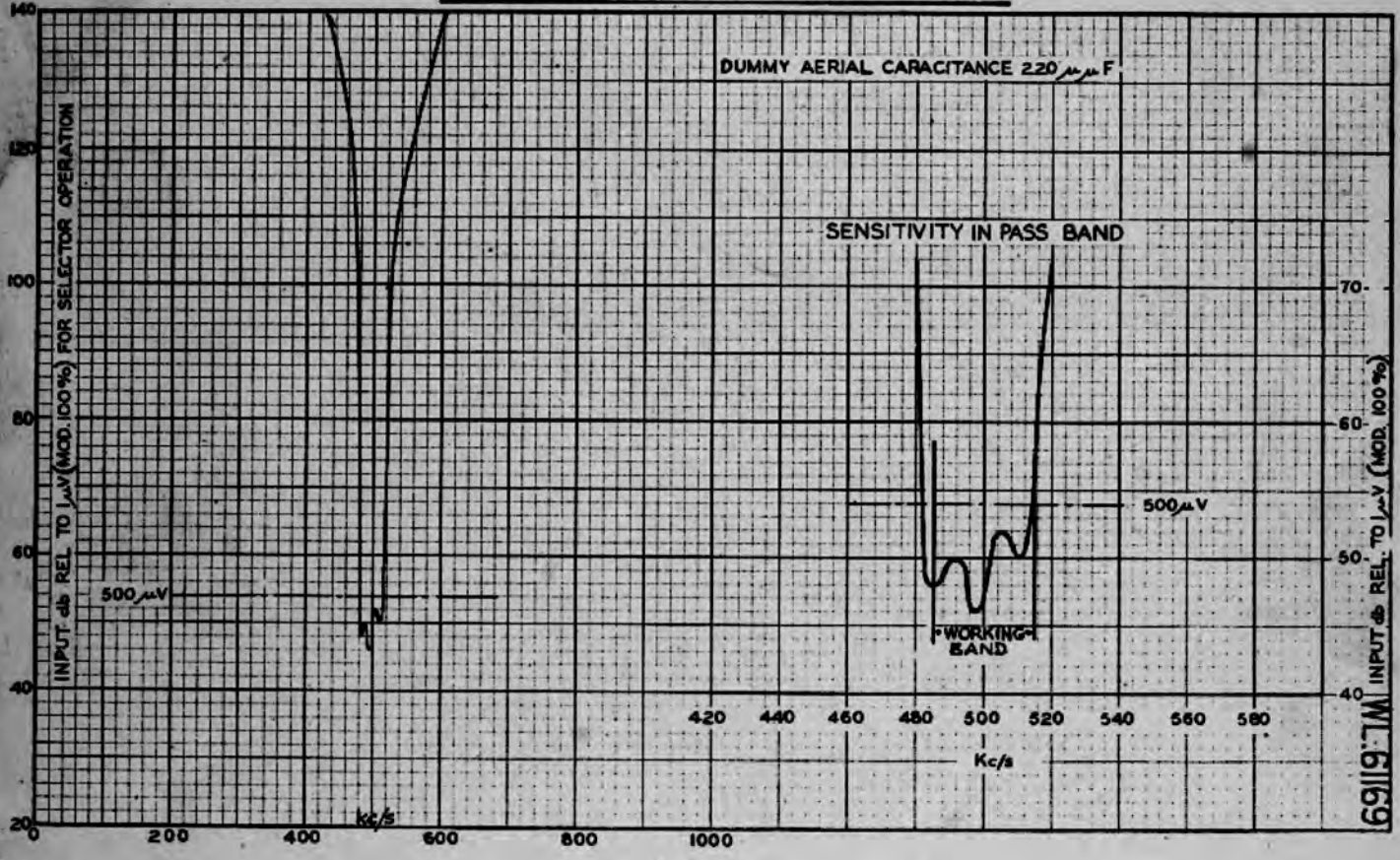
RANGE 4 (IF 98 kc/s)



MARCONI AUTO ALARM EQUIPMENT TYPE M

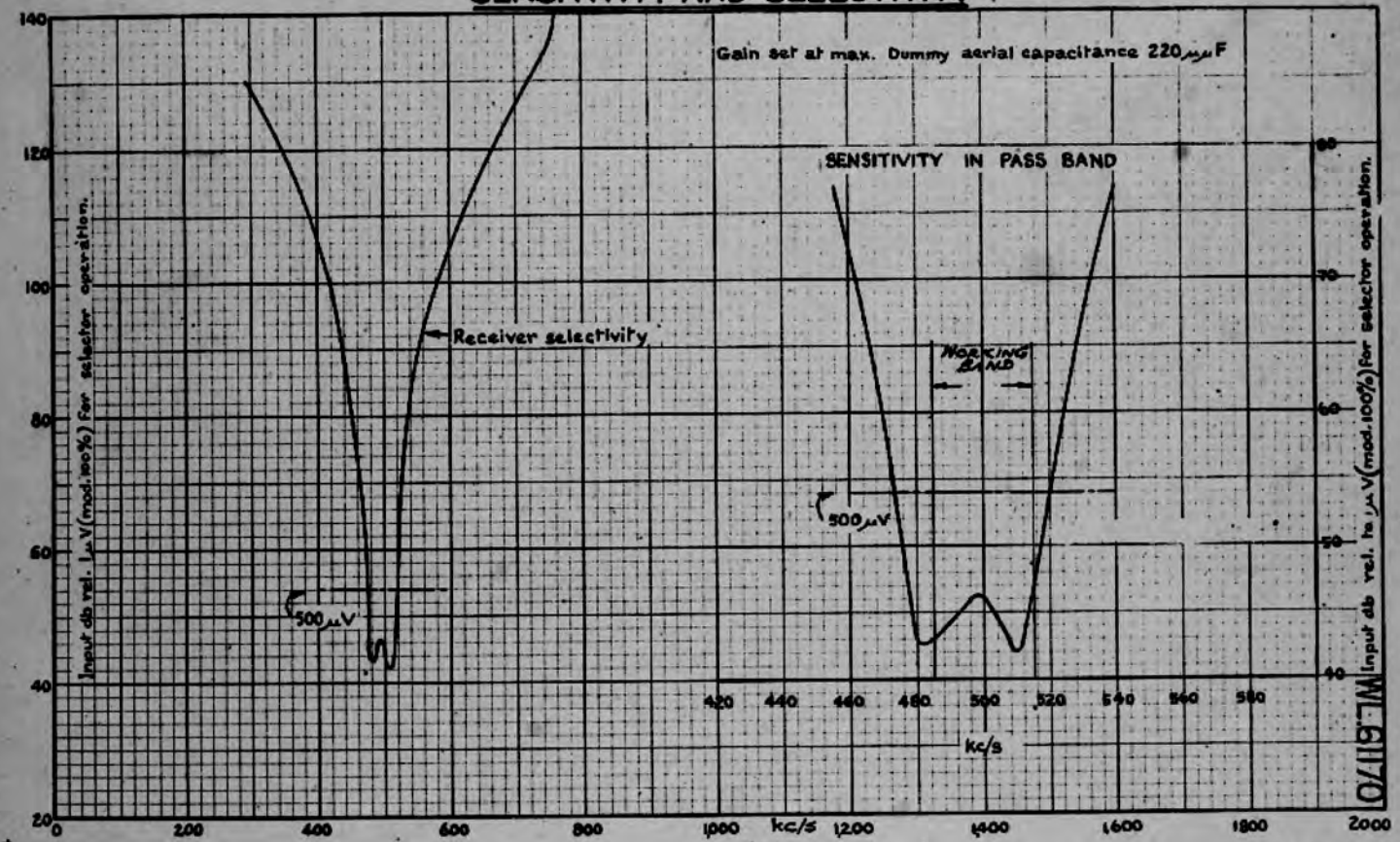
WL 61169

SENSITIVITY AND SELECTIVITY



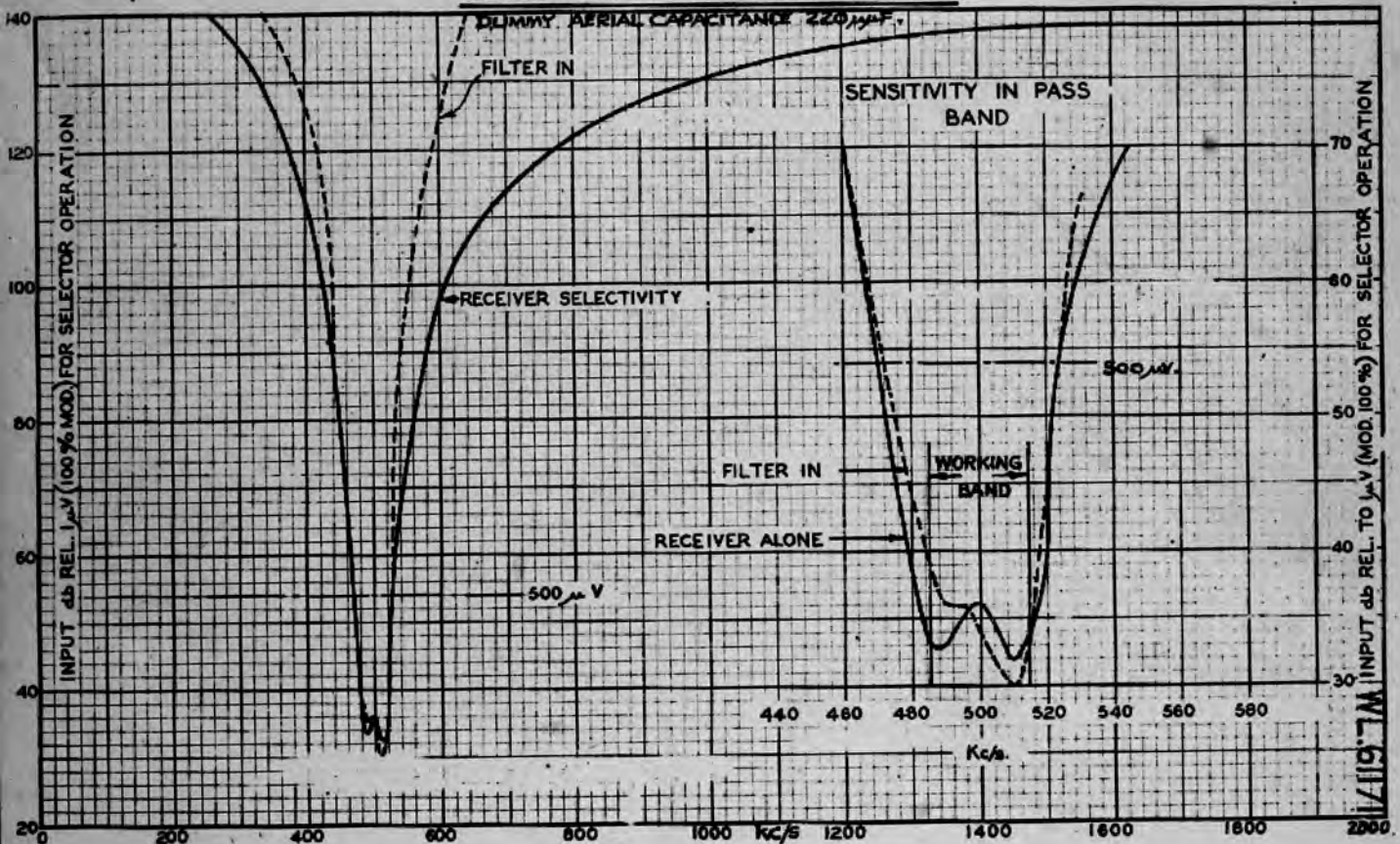
WL 61170

INTERNATIONAL MARINE RADIO CO.
TYPE AA2-B AUTO ALARM EQUIPMENT
SENSITIVITY AND SELECTIVITY

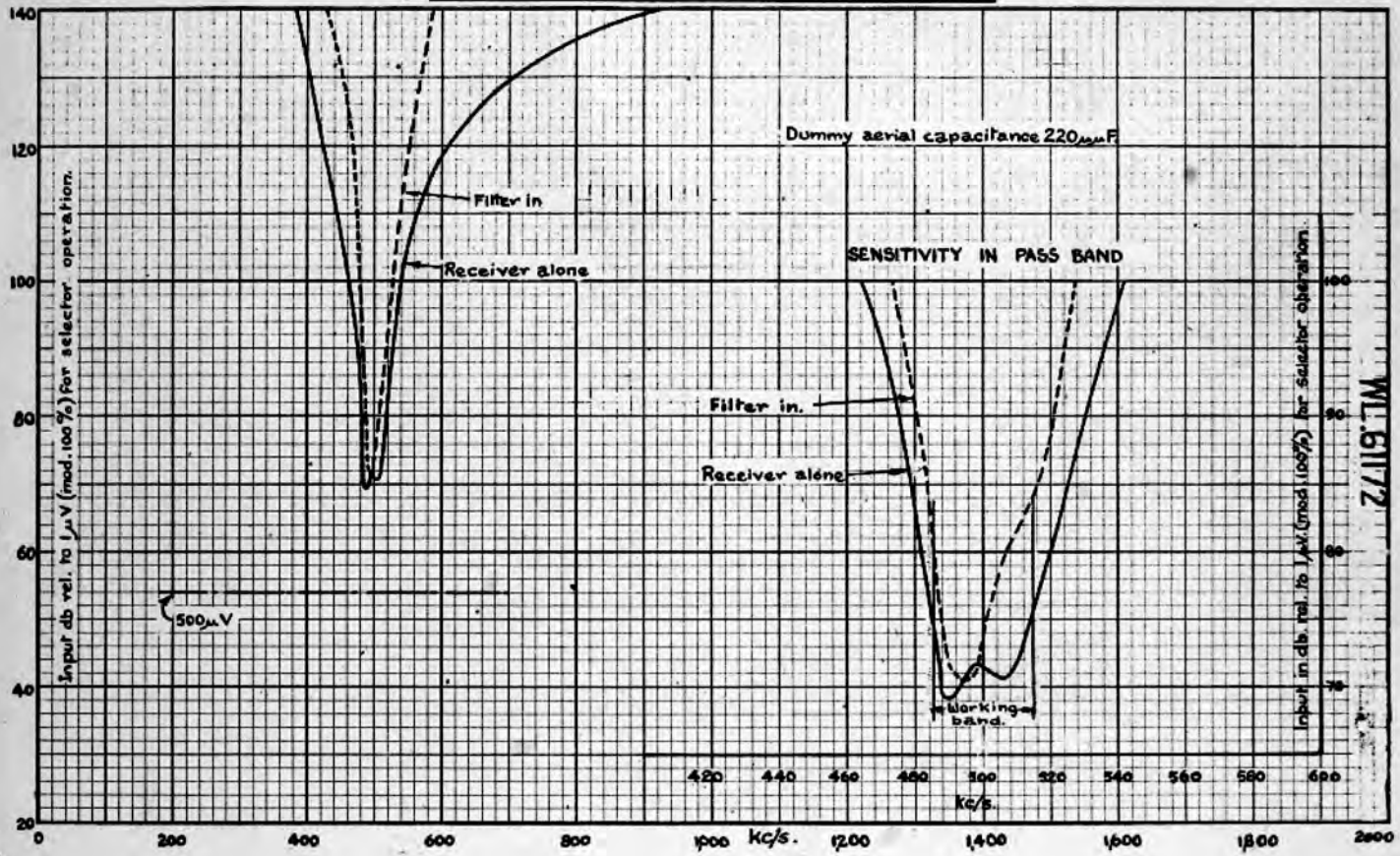


WL 61170

STANDARD TELEPHONES AND CABLES TYPE DMS 1172 WL 61171
(INTERNATIONAL MARINE RADIO CO. TYPE 28) AUTO ALARM EQUIPMENT
SENSITIVITY AND SELECTIVITY.



WL 61171

WL 61172

SIEMENS AUTO ALARM SB218
SENSITIVITY AND SELECTIVITY