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INTERFERENCE FREE TRANSMITTERS

AND

INTERFERENCE IMMUNE RECEIVERS

SERIAL NO. - 3

ADMIRALTY SIGNAL EST.

JULY 1945.7

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Admiralty Signal Establishment,
Lythe Hill House,
Haslemere, Surrey.

July 1945.

INTERFERENCE FREE TRANSMITTERS AND INTERFERENCE IMMUNE RECEIVERS.

A Survey of remedial measures that have been applied to existing radio receivers and transmitters.

Included Figures 1 - 11.

Introduction.

The serious extent to which local interference in ships has grown during recent years has already been discussed in M.579 "A survey of interference" and the present notes are intended to outline some of the methods that have been developed to minimise this.

2. The work divides itself roughly under four heads:-

(i) Restricting the frequencies radiated by radar transmitters to only those necessary for the purpose to be achieved.

(ii) Proofing communication receivers against impulsive interference such as that caused by radar, navigational aids and engine ignition noise.

(iii) Proofing receivers, both communication and radar, against high level interference on frequencies outside their tuning range.

(iv) Reducing the radiation of harmonic or other spurious frequencies by communication transmitters.

3. The most severe and urgent form of interference was that caused by radar transmitters to communication receivers and up to the beginning of the work, covered by these notes, this interference had been ameliorated by gating circuits (NIS) attached to the affected receivers and synchronised with the radar pulse. These methods, although generally successful in practice, had very definite limitations, and it was felt they were wrong in principle as the real cause was not eliminated. The work done in effecting a cure of existing radar transmitters is covered in Section A under.

4. The next line of attack that was considered likely to yield fruitful results was to investigate the efficacy of various known forms of limiting circuits or pulse proof automatic gate circuits. These had to be considered with a view to their easy fitment to existing receivers rather than incorporation in future models. This work is covered in Section B.

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5. Raising the pre-selection of communication receivers against frequencies outside their tuning range has been effected by the production of a number of aerial filters. These are described in Section C.

6. Although the precautions necessary to minimise the harmonic content of communication transmitters are well known, they are not very conveniently added to existing transmitters. For this reason work in this field has been confined to ascertaining what minor improvements can be effected to transmitters in service by simple modifications only. Transmissions with a very low spurious content can only be obtained from a crude transmitter by a major redesign.

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Section A.

Radar Transmitters.

The first radar transmitter to be taken in hand was Type 291, not because it was necessarily worse than other transmitters, but because its common use in Coastal Craft in unscreened offices and in close proximity to indifferently screened communication receivers had resulted in intolerable interference. Furthermore, the RIS which had been applied with fair success in larger ships against radar interference with a 50 cycle repetition frequency was not applicable to the 500 cycle repetition frequency of Type 291.

Suppressing a receiver at 500 cycles is more difficult than at 50 cycles. At 500 cycles it is not possible to blank at the output of receivers and blanking at their input terminals introduced frequencies within the receiver's tuning range, and so caused noise other than the radar interference which was being blanked out.

Type 291 transmitter radiates on a declared carrier of 214 Mc/s and with the pulse length and pulse slope in use a band width of ± 2 Mc/s is more than sufficient to effect the purpose of the transmitter. It also radiates spurious frequencies which are components of the pulse envelope, the points at which these occur vary between individual transmitters, but they are closely spaced between about 0.2 Mc/s and 25 Mc/s. These frequencies are radiated from the aerial, from the braided flexible part of the aerial feeder, direct from the transmitter case and also along the mains and blower motor supply leads from any exposed portion of which they are also radiated. These spurious frequencies are present even if the R/F portions of the transmitter are dead, they are generated solely by the modulator circuits.

2. A cure was effected by:-

(a)...

(a) Fitting a high pass filter in the pyrotenax aerial feeder lead. This is shown diagrammatically and in section in Figure 1. Its attenuation curve is Figure 2.

(b) The length of flexible aerial feeder cable between the transmitter and the pyrotenax feeder was originally shielded by copper braiding only. This is inadequate and additional shielding is added by a flexible metal tubing outside the existing braided cable.

(c) The transmitter case which contains the modulator and R/F circuits has been fitted inside an outer case of perforated metal (about ¼-inch holes). This case has about one inch clearance all over from the original case and also includes within the outer case the filters for the supply leads.

(d) Filters are fitted in the 500 cycle supply leads and also in the 24V D.C. supply to the blower motor. Their attenuation curve and circuit are shown in Figure 3.

3. With these modifications the radiated field adjacent to the transmitter (2-feet distant) was reduced by more than 60 db over the frequency range 0.2/25 Mc/s. At a few feet from the transmitting aerial the reduction of the field strength of unwanted frequencies follows the curve of Figure 2. Under these conditions it has been possible to install and use communication receivers immediately adjacent to the radar transmitter with the following limitations:-

(a) Where the radar and the communication aerials are closely adjacent, the receiver may not have sufficient pre-selectivity to prevent break through of the radar fundamental frequency. This can be cured by fitting a filter in the aerial lead to the receiver, except .

(b) Where there may be direct pick up by the internal circuits of the receiver from the radar aerial.

This, however, is the fault of an inadequately screened receiver and only becomes serious in wooden hulled craft where no protection is afforded by the walls of the office.

4. A similar restriction of spurious frequencies has been effected for Type 281. Here no effort has been made to screen the transmitter as it is usually installed in its own office, the steel walls of which form an adequate screen. A filter has been designed for insertion in the aerial feeder lead. This is shown diagrammatically together with its characteristic curve in Figure 4. It consists of high and low pass sections in series, the cut off on the high frequency side of the pass band being necessary as interference had been caused by Type 281 on the harmonics of its carrier frequency. This filter is considerably larger than the simple one used with Type 291 as it has been designed to withstand a peak power of one megawatt. A photograph is shown in Figure 5.

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In introducing aerial filters into radar installations it is essential to connect them on the aerial side of any diode switch, spark gap or other device used for protection of the radar receiver as such devices themselves generate spurious frequencies which it is the function of the aerial filter to remove. An additional advantage of this arrangement is that the aerial filter, though primarily provided to prevent radiation of unwanted frequencies, also gives additional preselection to the radar receiver against high level interference outside the radar band.

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Section B.

Receiving Limiters.

1. If impulsive interference of the type emitted by a radar transmitter could be limited at the input to the communication receiver to a level not much above the peak level of the required signal, the interference would be negligible, the energy content of the interference after limiting being low due to its very short duration.

As a short impulsive signal during its progress through a receiver lengthens considerably due to persistence of circuits, by the time that it reaches the output terminals its duration is so long that if it is then limited to the same peak height as the desired speech, it may still be very audible due to its greater energy content. For this reason output limiters on receivers are generally unsuccessful except at the lowest repetition frequencies. Limiters cannot be fitted at the input to receivers as the voltages occurring at this point are generally too low to operate any known form of limiter or rectifier. The first part of a receiver at which the voltage level is such that limiting rectifiers can act efficiently is at the second detector. Usually at this point the impulse has not become too long, most of the lengthening in an average receiver occurring in the audio frequency circuits. Most of the lengthening before this point occurs in the case of a superheterodyne receiver in the I.F. stages; the radio frequency stages especially if in the H/F or V.H/F bands, not being very persistent. The persistence of an interfering pulse at the point where limiting is applied depends entirely on its initial energy and on the band width of the intervening circuits. The smaller the initial amplitude and the greater the bandwidth the smaller will be the duration over which the limiter is required to operate. The duration of the pulse at the point of limiting is a very important factor, for, it must be understood that quite apart from the actual audible interference due to the pulse, a portion of the wanted signal is affected every time the limiter comes into action.

2. Many circuits for effecting limiting of impulsive signals have been published; these can be sub-divided into four types:-

(a) Series, in which the limiting device is in series with the load and it open circuits on overload;

(b)...

(b) Parallel, in which the limiting device is in shunt with the load and it short circuits the output on overload.

(c) Constant level, in which the point at which limiting occurs remains fixed wherever it may be set manually;

(d) Variable level, in which the limiting point is varied by the incoming required signal to occur at a point a predetermined level above the peak of the modulation. Most published circuits come under one or any combination of the above divisions.

3. Figure 6 shows the outline of the alternative arrangements.

(a) Is a typical non-limiting detecting circuit.
(b) Is the same with a limiting diode in series with the load;
(c) Is the parallel limiter version and
(d) Is a series limiter with a variable bias on the cathode of the diode supplied from the AVC circuits.

Generally, the series arrangement is the more effective as, in the condition where the diode is limiting, it is completely non-conducting, whereas in the parallel arrangement the diode limits when in the conducting condition and can never be a complete short circuit but still has an effective resistance of some hundreds of ohms. The effectiveness of the series arrangement is limited by the inter-electrode capacity of the diode which must be as low as possible including the capacity of the holder and the leads thereto. The parallel arrangement has the possible advantage that when it is limiting it is also damping the previous circuit and thus shortening the pulse length.

If no auto variable bias is applied to the limiting diode, the level at which limiting occurs remains fixed, so the required R/T signal must not exceed this level; if this level gives an adequate signal and is maintained constant by AVC in the receiver, this arrangement is satisfactory. If, however, it is required that the limiting level should always be just above the peak signal irrespectively of signal amplitude, then it becomes necessary for the diode bias to be varied either by the AVC circuit or the diode can be arranged to produce its own bias from a steady signal. In either case the time constants of the bias circuits must be such that they are unaffected by the voltages produced by the impulsive interference whilst being operated by the steady signals.

4. The choice of which circuit or combination of circuits to use is conditioned by the individual application. If a new receiver is being designed, the best possible combination will be chosen but if, as in most cases, it is necessary to improve the performance of receivers already in service in large numbers, the modification must be kept to the simplest possible, and must be capable of being fitted on site without skilled supervision. This being so, the simple series limiter has been found to give the best answer for the minimum amount of fitting work. A typical modification to the

B28...

B28 receiver, is shown in Figure 7(a), the added parts being within the dotted line. A switch is added to provide for alternative non-limited working. The added components necessary for the auto variable level limiter are shown in Fig. 7(b) which has been applied to a number of existing receivers.

5. The general boundaries within which these limiters give satisfactory performance are:-

(a) They are only suitable for use in receivers which have some H/F or I/F gain and rectify at a fairly high level, at least 0.1 volt. More crude forms of receivers which rectify at a very low level and rely on audio frequency gain for their output are not suitable.

(b) L/F receivers are generally not very suitable due to the persistence of the R/F circuits over lengthening the interfering pulse before it gets to the rectifier.

(c) Low repetition frequency pulses, below 100 per second, which includes engine ignition noises, are very completely suppressed. Higher rates (500) are very considerably reduced, the amount of residue noise depending on the receiver, a V.H/F receiver with wide band width being more immune than a H/F or M/F receiver. The latter receivers should be operated at their widest band acceptance.

A variation of these circuits is shown in Figure 7(c). Here both parallel and series limiting diodes are fitted, the parallel one acting as a damper across the input and so shortening the pulse and the series limiter eliminating the residue. This circuit is very effective but is only suitable for incorporation in a new receiver as it is not quite simple enough to be fitted to an existing receiver by ship's staff.

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Section C.

Filters for Receivers.

1. A receiver which has only one tuned circuit before the first grid has sufficient discrimination to reject unwanted signals or interference that are comparable in amplitude to the wanted signal and succeeding stages make this rejection more complete. If, however, the unwanted signal or interference is very high, of the order of volts as it may be from an adjacent transmitter, the interfering voltage, even after attenuation by the first tuned circuit may still be of sufficient amplitude to over-swing the first grid and so modulate the wanted signal, subsequent elimination is not possible.

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The correct remedy against this high level interference is additional preselective tuned circuits before the first valve. This will degrade the circuit noise/signal ratio but there is no point in striving for this good ratio if interference prevents reception anyway. It is not usually practicable to add additional tuned circuits ahead of existing receivers so a series of filters has been prepared to attenuate frequencies outside the frequency range of the receiver concerned.

2. The most widely applicable filter will be a 30 Mc/s low pass. This will protect most communication receivers against most radar interference. The circuit diagram and attenuation curve of this filter are shown in Fig. 8. and a photograph of it in Fig. 9.

3. The inductances and capacities used in these filters are "lumped" - i.e. consist of actual coils and condensers. This practice produces a satisfactory filter provided that the values really are lumped. A condenser must have no inductance and the inductances must be in the arms where they are needed and not mostly in the connecting leads. This can easily be obtained by careful layout for frequencies up to about 30 Mc/s but for higher frequencies the mechanical design must be given special consideration. Fig. 10 shows a filter for 270 Mc/s high pass. The equivalent electrical circuit and the measured attenuation curve is given, also a diagrammatic mechanical cross-section. It will be seen that the capacities consist of suitably dimensioned cylinders and washers assembled on a low loss dielectric and the inductances are straight wires of suitable gauge for the inductance value required. The filter is circular in cross section with the outer case earthed and the radial inductance wires are spaced angularly and not in one plane as indicated in the diagram.

4. Filters similar in design to those have been produced for insertion before communication receivers with characteristic curves cutting above and below all the radar transmitting frequencies. These filters are only completely effective against transmitters whose frequency spectrum is restricted to an adequate bandwidth; if there are spurious transmitted frequencies which come within the pass band of the filter, no protection is afforded.

Where there is a sufficient frequency separation between a radar transmitter and a communication receiver, as for example, on M/F and L/F reception, a receiving aerial filter will often provide complete elimination of interference; in other cases, an aerial filter may greatly increase the effectiveness of the limiter in a receiver by reducing the initial amplitude of the pulse and hence the duration over which the limiter may have to operate.

5. Many receivers are insufficiently protected against unwanted signals which are brought in to the receiver by means of the supply and other leads. They enter the receiver either by radiation from an exposed unshielded mains lead to an insufficiently screened aerial terminal or

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are taken inside the case of the receiver by the supply leads themselves and thence radiated on to the early stages. These unwanted frequencies can generally be prevented from boooming mains borne by filters to suppress them near their source. A number of pattern article filters for various current carrying capacities were in existence but the attenuation of these was low especially at the higher frequencies. A series of filters has been produced to carry 5, 25 and 100 amps. They all have an attenuation better than 50 db over the range 20 kc/s to 150 Mc/s. They have a maximum reactive and ohmic voltage drop at full current not exceeding 2 volts at 50 cycles (20 volts at 500 cycles). The circuit is shown in Figure 11.

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Section D.

Communication Transmitters.

Spurious frequencies generated by communication transmitters are, in order of importance:-

(a) Harmonics.

(b) Sub-harmonics - usually unwated harmonics of the crystal frequencies.

(c) Keying transients.

These are generated in all transmitters but should be prevented from being radiated from the aerial by the provision of low impedance paths to divert all frequencies other than the declared one. This is easily achieved with a single frequency transmitter but is more difficult with a multifrequency ship transmitter. Even if suitable circuits are incorporated in a transmitter the good effect of this can be nullified by wrongful installation. A very common installational fault is to make the earth leads of the draining circuits common with the earth lead of the aerial, thus re-inserting the unwanted frequencies after draining them out. It is not even necessary for these two earth paths to be common - if they run parallel to one another the unwanted frequencies are fed back into the aerial inductively.

In some commercial type transmitters now in use in the Service the coupling between the output stage and the aerial is direct, either inductively or capacitvely, thus the return path for unwanted frequencies and aerial earth are inseparable. If this coupling is made indirect, it is possible to keep the aerial earth lead well away from the cathode return lead of the output circuit and thus considerably reduce the harmonic output. Unfortunately it is often a major mechanical operation to effect this modification to existing transmitters.

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2. For transmitters whose frequency range does not exceed an octave, it is possible to fit a fixed low pass filter in the aerial lead to attenuate all frequencies higher than the highest of which the transmitter is capable. For this filter to be effective it must be ensured that the unwanted frequencies are not radiated by other means than the aerial, most communication transmitters are unscreened and reliance is placed on the intervention of ship's structure and bulkheads between the transmitter and the affected receiver's aerial. Also spurious frequencies in the transmitter may be fed back into supply or control leads and from some exposed portion of them radiated on to the aerial lead of the affected receiver. This can be prevented by fitting filters in these leads where they leave the transmitting office. In addition, if the transmitter is inadequately screened, spurious frequencies may be radiated to other transmitters or switch boards installed in the same office. The control or supply leads of these other transmitters may be run to some exposed position from which they may radiate on to affected receiver's aerials.

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A list of recently designed devices for the reduction of interference follows. They are all in production but some may not yet be immediately available.

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Limiters.

Description.	For use with
Noise limiter design 1, Patt. 56703.	B28A and B.
Noise limiter design 2, Patt. 57380.	P38, P48.
" " " 3, Patt. 57700.	B34.
" " " 4, Patt. 58358.	CR300.
" " " 5, Patt. 58359.	TCS.
" " " 6, Patt. 58360.	SCR522 (84M).
" " " 7, Patt. 59444.	TBS.
" " " 8, Patt. 59599.	B27, U, D and C.

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Receiving Aerial Filters.

Description.	Patt.	Use.
Filter unit, design 20, 25 Mc/s high pass.	57296	General protection of V.H/F receivers.
Filter unit, design 12, 30 Mc/s low pass.	56152	Communication receivers generally against radar.
Filter unit, design 16, 47 Mc/s high pass.	57292	High pass protection against Type 279.

Filter...

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Receiving Aerial Filters.

Description.	Patt.	Use.
Filter unit, design 17, 76 Mc/s low pass.	57293	Low pass protection against Type 281.
Filter unit, design 18, 100 Mc/s high pass.	57294	High pass protection against Type 281.
Filter unit, design 21, 170 Mc/s low pass.	57673	Low pass protection against Type 291.
Filter unit, design 19, 240 Mc/s high pass.	57295	High pass protection against Type 291.

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Transmitting Filters.

Filter unit, design 11, 150 Mc/s high pass.	56116	For Type 291.
Filter unit, design 31, 70/110 Mc/s band pass.	59366	For Type 281.

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Mains Filters.

Filter unit, design 36, 1 amp mains single.	Patt. 59673.
Filter Unit, design 37, 5 amps, mains dual.	Patt. 59674.
Filter unit, design 38, 25 amps, mains dual.	Patt. 59675.
Filter unit, design 39, 100 amps, mains dual.	Patt. 59676.

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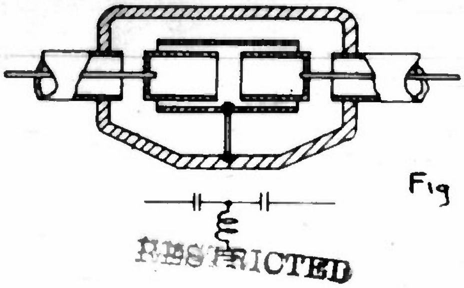

Fig 1.

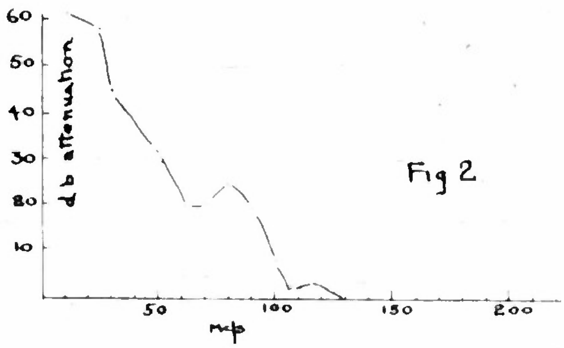

Fig 2

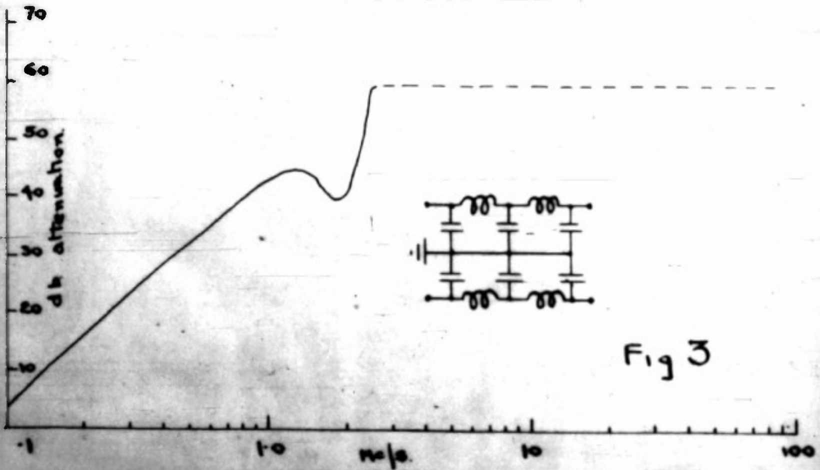

Fig 3

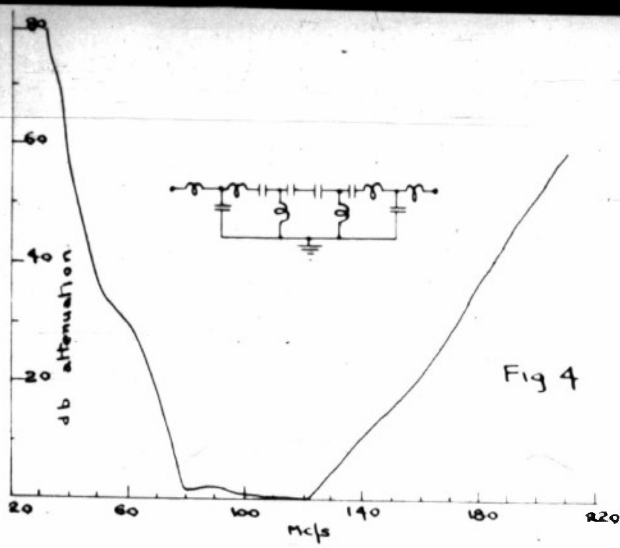

Fig 4

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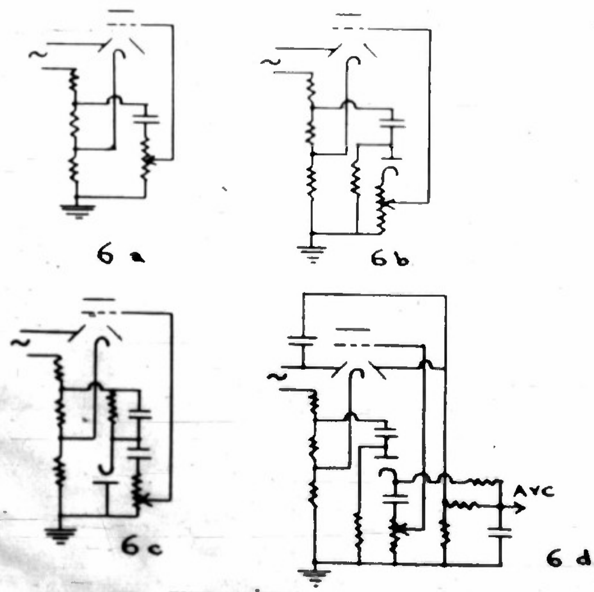


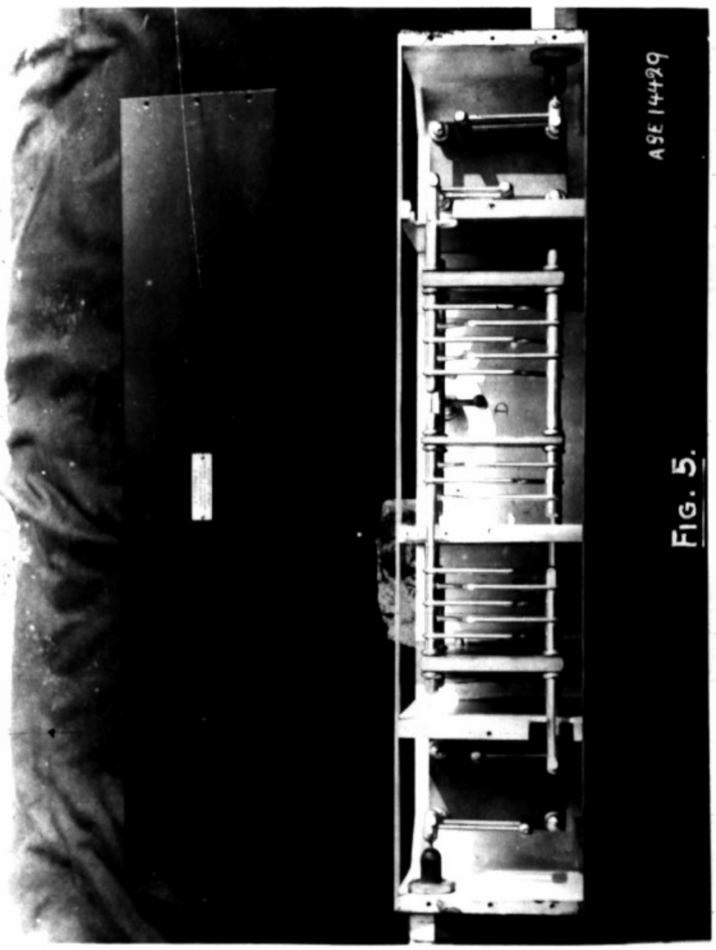
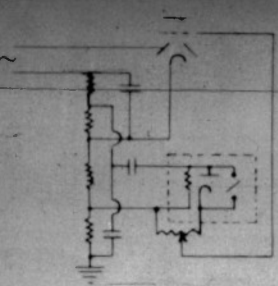


FIG. 5.



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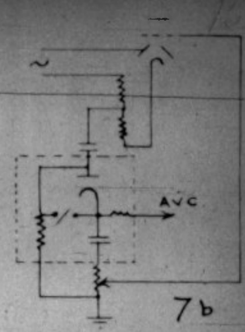

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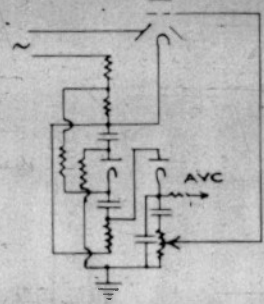

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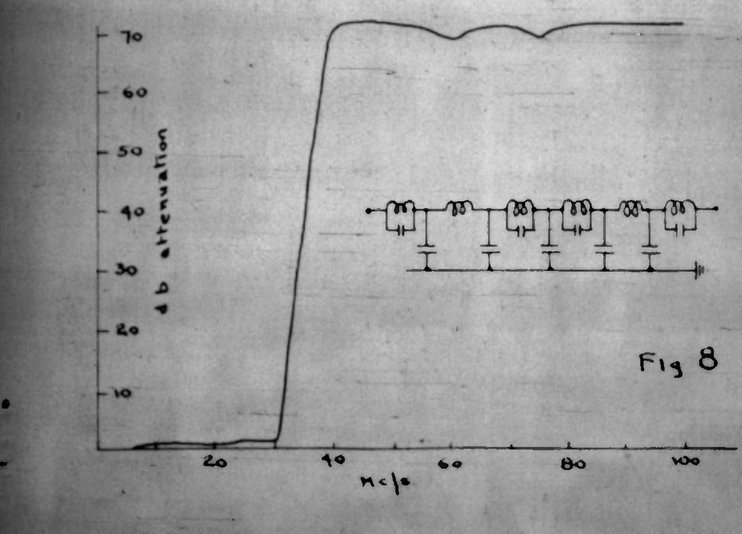

Fig 8

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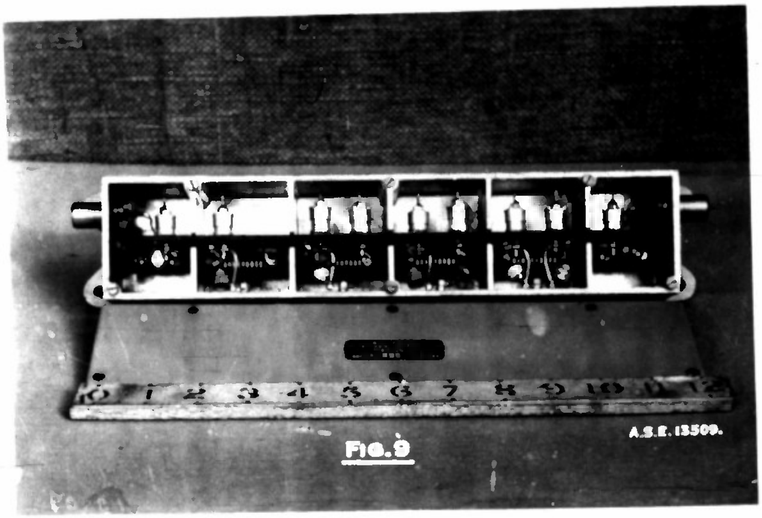

Fig. 9

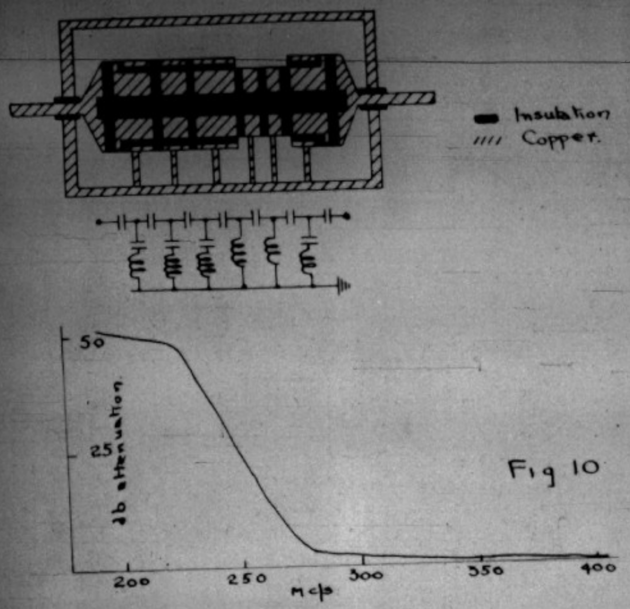

Fig 10

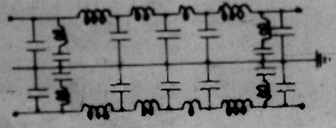

Fig 11

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