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ABSORPTION WATTMETER
CT443

GENERAL AND TECHNICAL INFORMATION

BY COMMAND OF THE DEFENCE COUNCIL

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Ministry of Defence

FOR USE IN THE
ROYAL NAVY
ROYAL AIR FORCE

ABSORPTION WATTMETER CT443

LEADING PARTICULARS

Ref. No.	6625-99-999-3591
Function	Power measurement, with fast response, over the range 1kc/s to 1000Mc/s
Input impedance	50 ohms ±5 per cent
Ranges of measurement...	0 to 100mW 0 to 300mW 0 to 1·5W
Accuracy of measurement (disregarding v.s.w.r.)	±5 per cent over upper four fifths of scale. ±10 per cent below 20mW on 100mW range, 40mW on 300mW range and 100mW on 1·5W range
V.S.W.R.	Up to 250Mc/s 1·04 250 to 500Mc/s 1·06 At 1000Mc/s 1·4
Connecting lead	Coaxial, 2ft. long, impedance 50 ohms ±2 per cent
Ambient temperatures	Operational:- Min. 0°C Max. 55°C Storage:- Min. -20°C Max. 70°C
Temperature coefficient	Instrument is calibrated at 20°C. For other temperatures, a positive coefficient should be applied as follows over the upper four fifths of scale:- 100mW range, 0·5mW per °C 300mW range, 1mW per °C 1·5W range, 2mW per °C
Rectifier diode	CV103 or suitable equivalent
Instrument case	R.A.E. standard equipment case No. 46 (watertight)
Overall dimensions...	Width $8\frac{3}{4}$ in., height $8\frac{3}{4}$ in., depth 7 in.
Weight	$7\frac{1}{2}$ lb.

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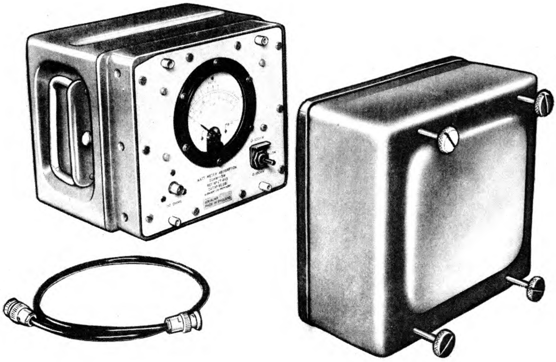

Fig. 1. Absorption wattmeter CT443, general view with cover removed

INTRODUCTION

1. The absorption wattmeter CT443 (fig. 1) is a portable instrument for measuring power up to 1·5W over the frequency range 1kc/s to 1000 Mc/s. A notable feature of the instrument is its fast response. It is therefore suitable for output measurements on radio transmitters such as switched air-sea rescue beacons, where transmissions are made alternately and rapidly at different power levels; a comparatively sluggish bolometer type of instrument could not conveniently be used for this purpose.

2. Fig. 2 shows the front panel of the wattmeter. An internal view is given in fig. 3 and the circuit in fig. 4.

3. The wattmeter is housed in an R.A.E. standard equipment case No. 46. This is a very strong case equipped with carrying handles and a detachable front cover which incorporates a waterproof sealing gasket. The equipment is thus protected against diverse climatic and service conditions.

4. No external power supply is required as the instrument is operated by the signal power applied to the input socket.

CIRCUIT (fig. 4)

5. The input to the wattmeter is accurately matched to 50 ohms by the use of a coaxial load resistance, consisting of resistors R1 and R2 in series, mounted in an exponential cavity. These resistors are of the carbon fired-on-ceramic type.

6. A silicon diode, MR1 (CV103), is used to rectify the signal at the junction of R1 and R2. The by-pass capacitors C1 and C2 serve

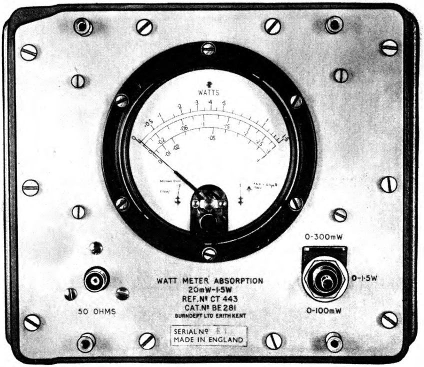

Fig. 2. Front panel

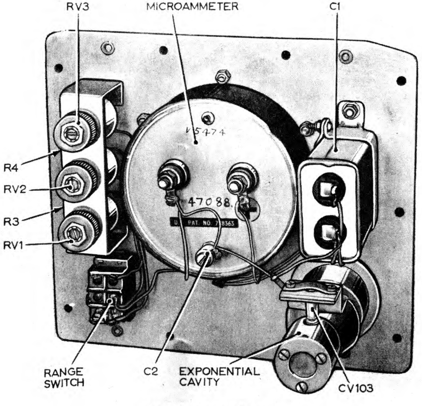

Fig. 3. Internal view

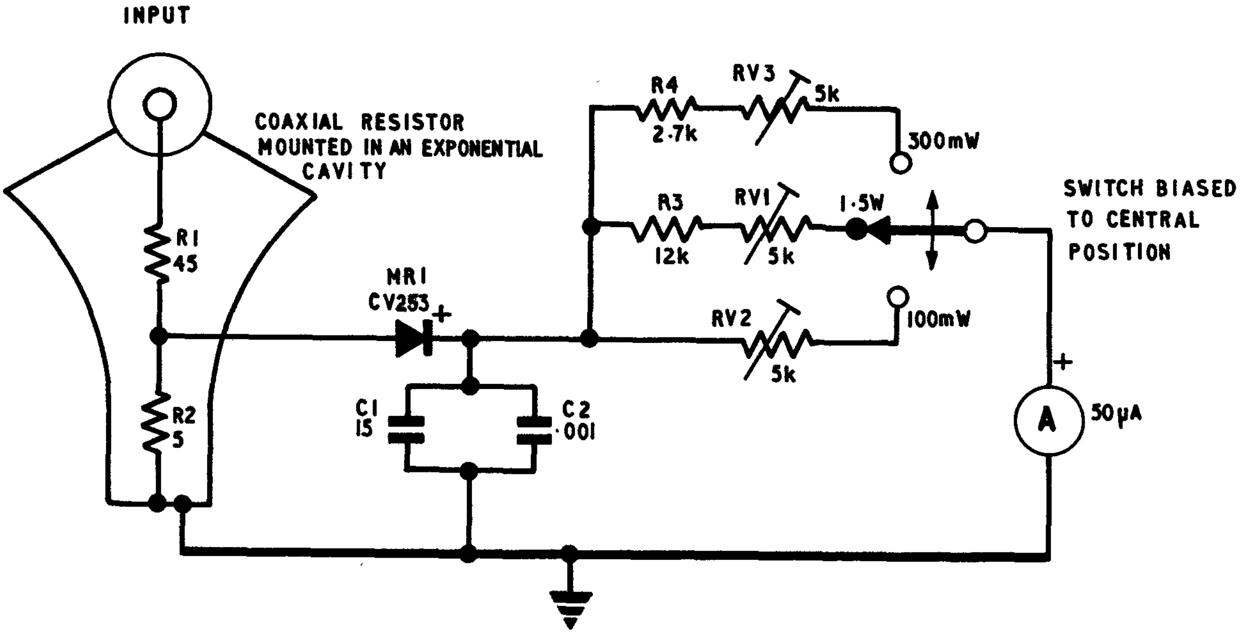

Fig. 4. Circuit

to prevent any stray a.c. reaching the indicating circuit.

7. The rectified signal from MR1 can be switched via three different preset attenuation circuits so that alternative signal levels of 100mW, 300mW and 1·5W provide full scale deflection of the meter. This function is performed by a three-position, spring-loaded toggle switch, which is mechanically biased to the 1·5W position thus protecting the more sensitive 100mW and 300mW ranges.

8. Indication is provided on a 4 in. sealed meter with a 50 μA movement. Three scales are provided viz. 0 to 100mW, 0 to 300mW and 0 to 1·5W, the lowest calibrated points on these ranges being 5, 10 and 50mW respectively.

OPERATION

WARNING . . . .
TO PROVIDE THE BEST POSSIBLE MATCHING, NO D.C. BLOCKING CAPACITOR IS INCORPORATED IN THE INPUT CIRCUIT AND, THEREFORE, NO D.C. VOLTAGE MUST BE APPLIED TO THE INPUT. IF NECESSARY, A SUITABLE EXTERNAL D.C. BLOCKING CAPACITOR MUST BE EMPLOYED.

9. The coaxial load, resistors R1 and R2 in series, is capable of dissipating 2W but care should be taken not to feed more than 1·5W into the instrument.

10. The wattmeter should be connected to the power source by means of the special coaxial lead provided. The usual matching precautions must be observed when making this connection; if a plug is not used at the power source end of the connector, a good connection should be made with the circuit, if possible by direct soldering. The use of crocodile clips or similar devices will cause large reflection errors and losses and result in inaccurate readings.

11. Normally, the 1·5W power range should be used first and, only if the reading appears to be below 300mW, should the power range switch be pushed upwards and held in that position. Similarly, on the 300mW range, only if the reading appears to be below 100mW, should the switch be pushed downwards and held in that position.

12. For the convenience of the user, Table 1 lists various r.m.s. values of input voltage across a 50-ohm load corresponding to powers in the range covered by the CT443.

TABLE 1

Conversion of input voltages across 50 ohms to corresponding power values

Power input mW	Volts across 50 ohm load	Power input mW	Volts across 50 ohm load
1500	8•660	150	2•738
1400	8•366	125	2•500
1300	8•062	100	2•236
1200	7•746	90	2•121
1100	7•416	80	2•000
1000	7•070	70	1•870
950	6•890	60	1•732
900	6•708	50	1•581
850	6•519	40	1•414
800	6•324	30	1•224
750	6•123	20	1•000
700	5•916	10	0•707
650	5•700	9	0•671
600	5•477	8	0•632
550	5•244	7	0•591
500	5•000	6	0•547
450	4•743	5	0•500
400	4•472	4	0•447
350	4•183	3	0•387
300	3•873	2	0•316
250	3•535	1	0•223
200	3•162		

SERVICING AND FAULT DIAGNOSIS

13. In view of the simplicity of this instrument, the servicing chapter which normally appears in Part 2 of this volume and the detailed description and fault diagnosis chapter which normally appears in Part 3, will not be provided. In place of the servicing chapter, the following brief notes on servicing are provided. Before any servicing work is done on this instrument, reference must be made to A.P.3158, Vol. 2, wherein the limitations on first and second line servicing of electronic test equipment are laid down.

Calibration check

14. If the calibration is suspect, it can be checked by feeding the output from a suitable low-powered 1 kc/s audio oscillator into the wattmeter; the oscillator must have amplitude monitoring facilities accurate to within ±1 per cent and its waveform should be sinuoidal and of low distortion.

Rectifier replacement

15. Each CT443 is initially given an individual calibration against a sub-standard instrument

with an accuracy of ±1 per cent. Should it become necessary to replace the silicon diode rectifier CV103, the adjustable series resistor (for each power range) must be set so that the best agreement with the scale readings is obtained. In practice, the scale calibration is substantially independent of the diode over the upper four-fifths of the meter deflection. Also, the bottom fifth of the meter scale is only accurate within ±10 per cent and, therefore, there should not be much difficulty when a diode is replaced. Occasionally a diode will be found to possess a bottom-bend characteristic which differs widely from the average; this should not be used. The calibration should be carried out at an ambient temperature of 20°C. The temperature coefficient of the CT443 is positive and is about 2mW per °C on the 1·5W range, 1mW per °C on the 300mW range and 0·5mW per °C on the 100mW range.

NOTES ON U.H.F. POWER MEASUREMENTS

Overall accuracy

16. The overall accuracy of u.h.f. power measurements depends primarily on two figures which are quoted for the CT443, viz. percentage accuracy and v.s.w.r.

17. The percentage accuracy refers to the precision with which the wattmeter will measure power that is actually delivered to it, whatever its impedance and regardless of the matching conditions.

18. The v.s.w.r. and impedance of the wattmeter determine how much power can actually be delivered to the meter. The v.s.w.r. figure indicates the accuracy of the actual matching, assuming the wattmeter to be connected to a perfect 50 ohm source via a perfect 50 ohm transmission line.

19. To appreciate the relationship between v.s.w.r. and the accuracy of power measurements, it is useful to consider a typical arrangement of a generator, transmission line and wattmeter, with the latter registering a certain reading. If a small capacitor is placed across the wattmeter input, a very poor v.s.w.r. will result. If, by adjusting the generator output circuit, that is, the generator output impedance, the same voltage is produced across the wattmeter input as was originally produced without the capacitor, the same power will be delivered to the wattmeter and identical meter deflections will be obtained in both instances. This illustrates that, in spite of poor v.s.w.r., power can be delivered to the meter provided that matching conditions are met. For perfect matching, the load and generator impedances must be equal in magnitude but exactly opposite in phase.

20. As a practical example, suppose that a generator of source impedance 25 ohms and a 50-ohm input wattmeter with a v.s.w.r. of 1·2 are connected by a 50-ohm transmission line. The generator v.s.w.r. is 50/25 or 2 which is a typical figure for normal communication work. By reference to fig. 5 it is seen that, under these conditions, a mismatch error of 6·5 per cent can occur. Fig. 5 indicates the possible percentage error in measuring the power output of a mismatched generator into a load, when the load is mismatched to the transmission line.

21. With reference to fig. 5 it should be noted that:-

S_G = v.s.w.r. of the generator

S_L = v.s.w.r. of the load

Percentage error =

$$\frac{(S_L - 1)(S_G - 1)\left[(S_L + 1)(S_G + 1) + (S_L + S_G)\right] \times 100}{4(S_L + S_G)^2}$$

22. From the foregoing it is seen that if two different designs of wattmeter of similar accuracy and v.s.w.r. but of opposite phase are used to make a measurement under the same conditions, their readings may differ by up to 6·5 per cent. Both readings would be absolutely correct within the accuracy claimed and would indicate the power delivered to the meter having a v.s.w.r. of 1·2.

Mismatch errors

23. When measuring the power delivered by a generator, it is essential that good matching is achieved; the generator should match the transmission line which in turn should match the wattmeter. In practice it will be found that perfect matching is unobtainable because the transmission line cannot be manufactured to its exact nominal impedance and, furthermore, there will be unavoidable mismatch errors introduced by the plug-and-socket terminations.

24. The connector used with the CT443 is carefully selected for use with it and has a closely controlled impedance of 50 ohms plus or minus 1 ohm.

25. Ideally the wattmeter should be perfectly matched to the connector, since even a slight mismatch may cause a significant error if the generator itself is badly mismatched to the line. The resultant error cannot be readily corrected by calculation even if the wattmeter v.s.w.r., which may easily be the biggest single factor in the total mismatch

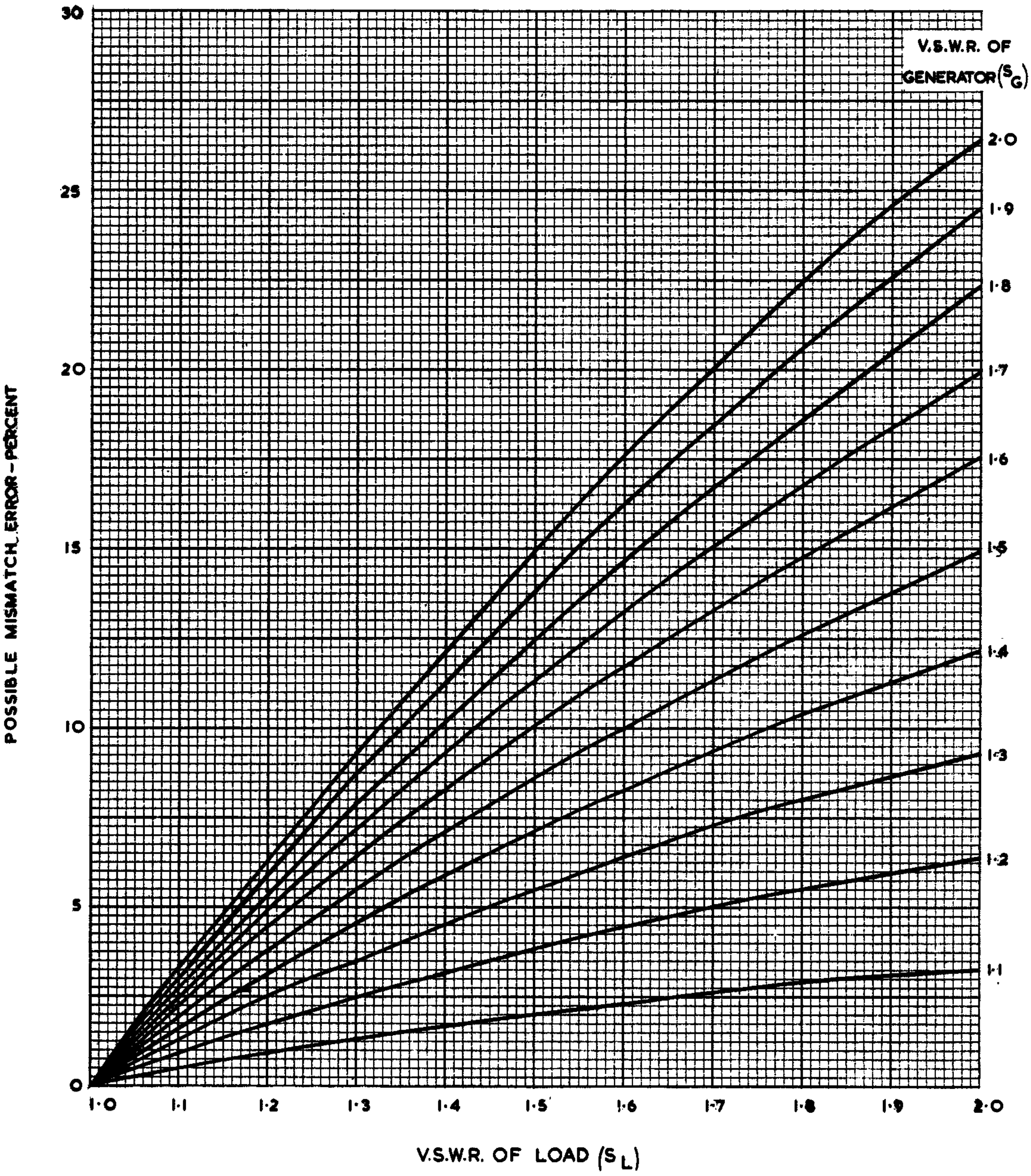

Fig. 5. Mismatch errors

error, is known. Exact determination of correction depending on the known wattmeter v.s.w.r. is only possible if the generator is perfectly matched; this fact is not generally appreciated. However, the possible minimum and maximum error limits can be calculated accurately and these are shown in graphical form in fig. 6.

26. When checking power measurement by comparing the results obtained by the alternate connection of two different designs of wattmeter to the same generator, a major source of discrepancy occurs. This arises because the power delivered by a generator to a wattmeter depends on the complex reflection coefficients of both the generator and the load, i.e. on their magnitudes as well as their phase angles.

27. Fig. 6 shows, in dB, by how much the delivered power in the load may fall short of the maximum possible for v.s.w.r. of generator and load up to 10. The v.s.w.r.

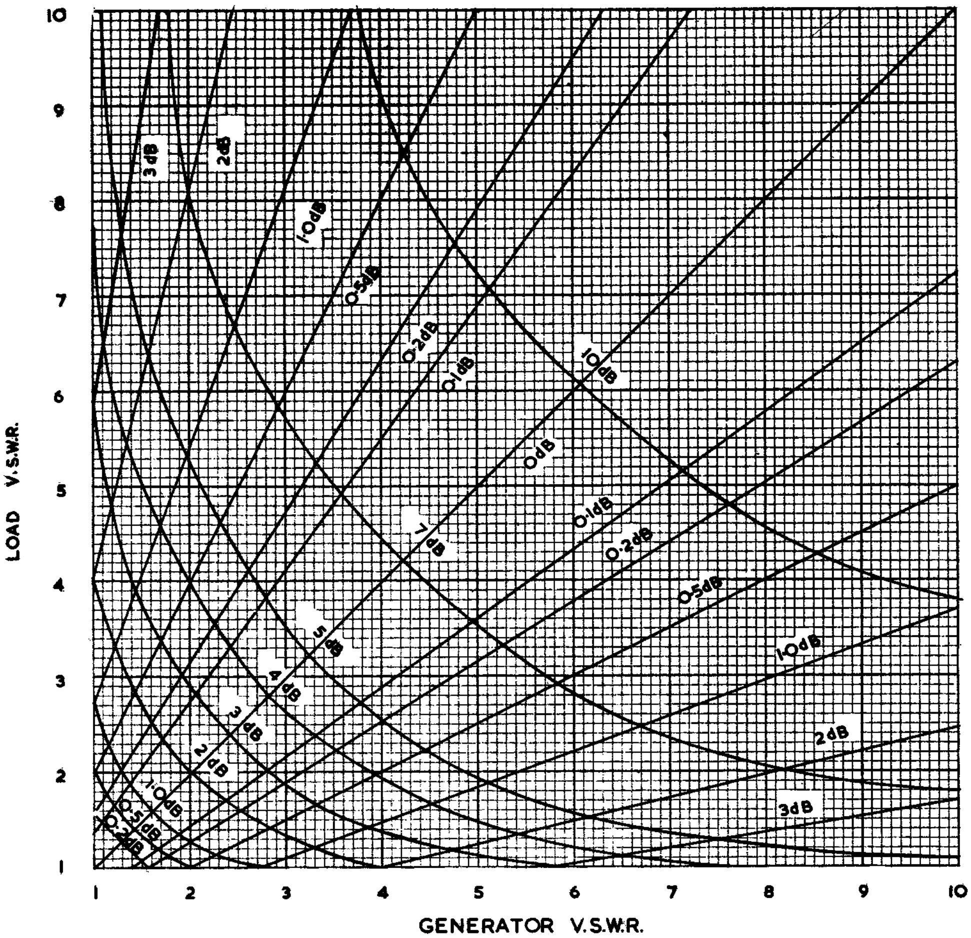

Fig. 6. Loss of power delivered to the load for various values of load and generator v.s.w.r.

figures in this instance are relative to the impedance of the connector. The asymptotic lines indicate the worst possible loss while the straight lines represent the least possible loss. For example, a generator v.s.w.r. of 3·3 and a load v.s.w.r. of 2·4 will give a worst possible loss of 4dB and a least possible loss of 0·1dB.

Reflection coefficient and v.s.w.r.

28. It is often desirable to convert from v.s.w.r. to reflection coefficient. The reflection coefficient is usually a complex quantity and its modulus can be converted to v.s.w.r. by reference to fig. 7.

Connector errors

29. The errors introduced by using a connector with an incorrect impedance may cause seriously misleading results. For example, suppose that a connector of 75 ohms impedance is employed to connect a 10 ohm generator to a 50 ohm wattmeter with a v.s.w.r. of 1·2. The resultant v.s.w.r. due to two v.s.w.r. S_1 and S_2 combined will lie between a best of $\frac{S_1}{S_2}$ and worst of $S_1 \times S_2$. If S_1 and S_2 are numerically the same, the best possible v.s.w.r. is 1, equivalent to a loss of 0dB. Thus:-

For the load, the v.s.w.r. may lie between

$$\frac{75}{50} \times 1{\cdot}2 = 1{\cdot}5 \times 1{\cdot}2 = 1{\cdot}8$$

and $\frac{1{\cdot}5}{1{\cdot}2} = 1{\cdot}25$

The v.s.w.r. for the source impedance will be $\frac{75}{10} = 7{\cdot}5$.

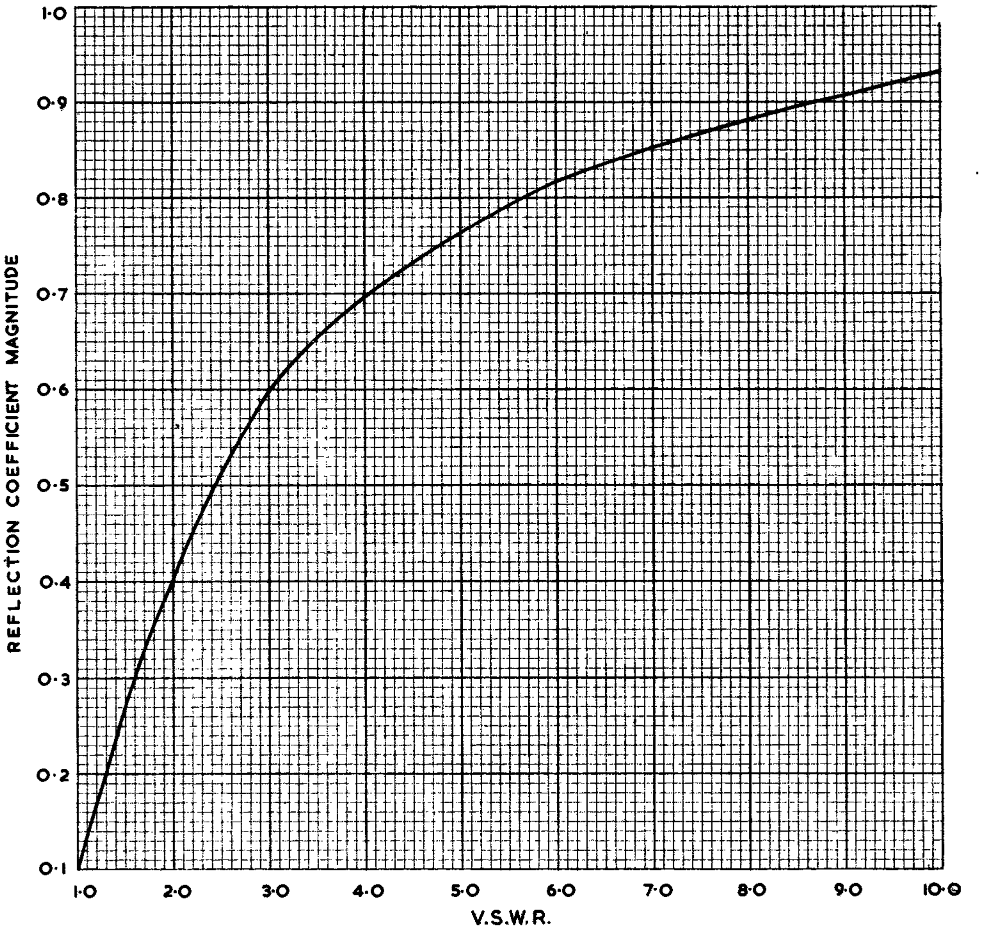

Fig. 7. V.S.W.R. versus reflection coefficient magnitude

30. From fig. 6 it is seen that two apparently similar wattmeters, differing in their input phasing, may give readings with a discrepancy of between 2 and 5 dB. In practice, such large errors are unlikely to occur with the CT443, since its v.s.w.r. is below 1·06 up to 500 Mc/s.

Effect of transmission line loss on v.s.w.r.

31. Any loss in the transmission line between the generator and the load is an advantage from the matching point of view because the generator sees a more constant load, whatever the actual load, while the wattmeter is fed from a more constant impedance.