INSTRUCTION MANUAL FOR

Radio Frequency Bridge Type B.601

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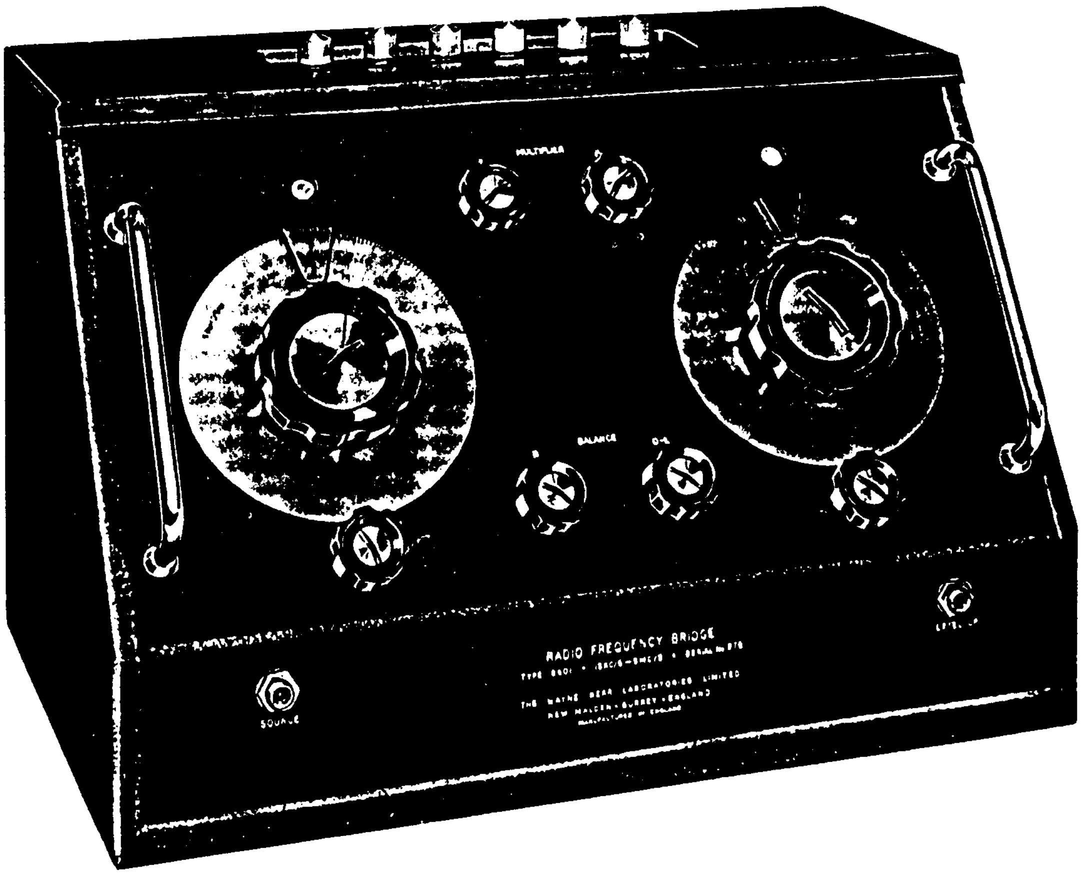
BALANCE
RADIO FREQUENCY BRIDGE

Radio Frequency Bridge Type B.601

Introduction

The B.601 R.F. Bridge is a multi-ratio instrument for the measurement of resistance, capacitance, and inductance over a wide range of values. It employs the tapped transformer principle, and is provided with co-axial leads for connexion to a separate source and detector.

The bridge has the advantage of extreme stability, due to the fact that the impedance looking back into the terminals and the impedance to ground at balance are both exceedingly low.

Range of Measurement

In addition to measuring resistance, inductance, and capacitance, the bridge will measure complex impedances, balanced or unbalanced, or balanced with the centre point earthed.

It will also measure the impedance between any pair of terminals in a three-terminal network, and is extremely suitable for measurement of impedances of the very low Q elements. The impedance is given as a combination of the parallel equivalents of resistance and capacitance or resistance and inductance.

Specification

Frequency range :	15kc/s to 5 Mc/s.
Capacitance range :	0.01 pF to 20,000 pF in 5 ranges on the dial.
Resistance range :	10 ohms to 10 megohms in 6 ranges on the dial.
Inductance range :	0.5 μH to 0.05 H.
Accuracy :	General direct-reading accuracy is 1% over the major part of the range. Accuracy of inductance measurement depends on accuracy of frequency source (see p. 4).
Dimensions :	15" by 11" by 9½" deep.
Weight :	25 lb. approximately.

Operating Instructions

Setting up the Bridge

1. *Source and Detector*

The bridge requires an oscillator source capable of supplying at least 0.1 V, and preferably 1–3 V, into an impedance of 100 ohms.

The detector should have a sensitivity of the order of 1–5 microvolts.

It is important that both the source and detector are well screened from each other and from the impedance under test, since any direct coupling between them will give rise to an error in measurement.

With the detector at maximum sensitivity no measurable signal should be observed when the output plug is withdrawn from its socket on the bridge and its " outer " earthed to the bridge framework.

2. *Connexion to Terminals*

The internal connexions of the six terminals of the bridge are as follows :

EARTH	To chassis and transformer screening.
COMMON	To one end of transformer T_1 (source).
× 0.1 – × 1 – × 10 –	To appropriate tappings on the output transformer T_2.
NEUTRAL	To centre tap of Transformer T_1.

Connexion of Earth Terminal

Before making a preliminary balance of the bridge, the Earth terminal must be connected according to the type of measurement to be made. The connexions are given in the table below.

Type of Measurement	*Earth Terminal*
Small components directly connected across bridge	Left free
Unbalanced impedances	Connect to COMMON and earth side of unknown
Balanced impedances free from earth connexion	Left free
Balanced impedances with centre point earthed	Connect to earth of unknown

Use of Neutral Terminal

(i) *With long leads.* If the component is connected to the bridge through long screened leads, the screens can be connected together and to the Neutral terminal.

If the series impedance of the leads can be neglected, the only effective impedance is that of the unknown. (See Fig. 1.)

(ii) *With three-terminal impedances.* If it is required to measure the impedance between the terminals O and P of a 3-terminal impedance (Fig. 2) having a third terminal Q, the terminals O and P are connected to the COMMON and RANGE terminals of the bridge and Q is connected to the NEUTRAL terminal.

The impedances O–Q and P–Q are then in shunt across the transformers and do not affect the balance of the bridge.

Selecting the Range Terminal

The value of an unknown resistance or capacitance is obtained by multiplying the dial reading at balance by two factors :

(a) the range factor, shown in the window above the dial

(b) the terminal factor, marked against the terminal to which the unknown is connected.

For a given reading on the dial, it is possible to select one of three combinations of range switching and terminal factor.

In selecting the best combination of range switching and terminal, it is important to remember that the terminals marked

R × 0.1	R × 1	R × 10
C × 10	C × 1	C × 0.1

are connected respectively to 0.1 turn, 1 turn, and 10 turns on the output transformer, so that, as a general rule, very low impedances are measured between the terminal marked COMMON and the " R × 0.1 " terminal.

Correspondingly, very high impedances are measured between the COMMON terminal and the " R × 10 " terminal.

The choice of terminal is in most cases determined by the value of R or C associated with the unknown impedance.

When using the bridge at higher frequencies, the terminals selected should give the lowest possible tapping on the transformer in order to minimise error due to the leakage inductance.

When using the outer terminals at high frequencies, care must be taken to prevent errors arising from the inductance and capacitance of the external connexions.

Balancing the Bridge

Before any measurements are made, the bridge must be balanced with the unknown disconnected.

To do this, connect the EARTH terminal to the appropriate point (see p. 2), set the C dial to zero, and the R dial to " infinity."

Set the Range Switch to the estimated value of the unknown. If desired, a preliminary rough measurement can be made to determine the range required and the unknown then disconnected.

Balance the bridge as accurately as possible, using the Balance Controls.

It should not be necessary to rebalance the bridge unless the frequency of the source or the range is altered.

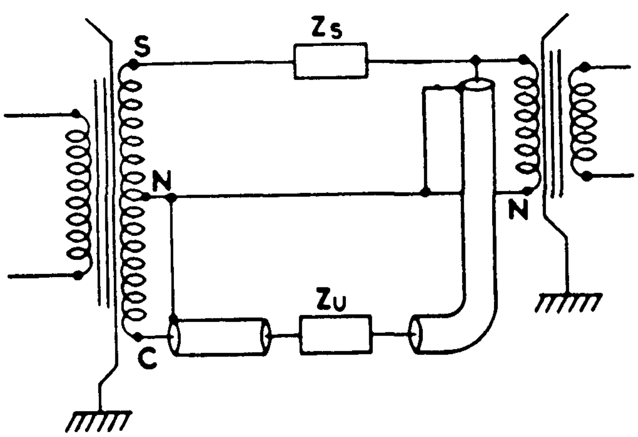

Fig. 1

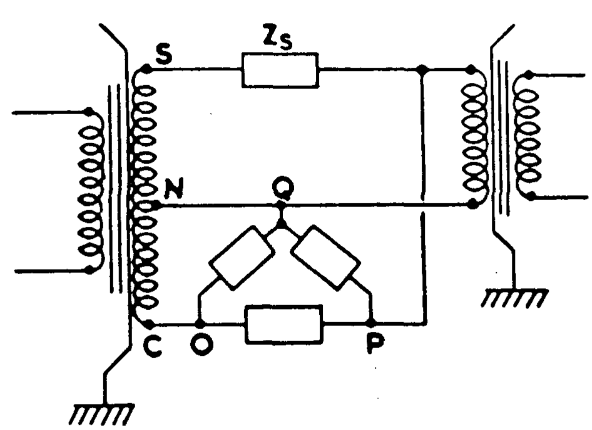

Fig. 2

Measurements

(1) Measurements of R and C

Once the bridge is balanced, the dials give a direct reading of values of unknown R and C, using the appropriate range and terminal factors as described on p. 4.

If the values for the equivalent series circuit for the unknown are required, they can be obtained from the relations:

$$R_s = \frac{R}{1+(R^2/X^2)} = \frac{R}{1+\omega^2 C^2 R^2} = \frac{R}{1+Q^2} \quad \ldots(1)$$

$$X_s = \frac{X}{1+(X^2/R^2)} = \frac{X}{1+(1/Q^2)} \quad \ldots\ldots\ldots\ldots(2)$$

$$C_s = C\left[1+\frac{1}{\omega^2 C^2 R^2}\right]$$

$$= C\,[1+(X^2/R^2)] = C\,[1+(1/Q^2)] \quad \ldots(3)$$

where $Q = R/X$.

R_s, C_s, and X_s are the resistance, capacitance, and reactance of the equivalent series circuit and R, C, and X the resistance, capacitance and reactance of the parallel circuit as measured by the bridge.

For values of Q greater than 10, the difference between the equivalent series and parallel capacitances is less than 1%.

(2) Measurements of R and L

The bridge measures values of R and L as a parallel combination, the inductive component being balanced in terms of equivalent negative capacitance, i.e., the value of capacitance which has the same reactance as the unknown at the frequency of measurement.

In order to arrive at the value of inductance, the frequency must be known, and the accuracy of measurement is dependent on the accuracy of measurement of the source frequency.

The procedure for measurement is the same as that for the measurement of R and C. After the required earthing connexions have been made and the range selected, the bridge is balanced. The unknown is then connected between the appropriate terminals and the bridge rebalanced on the R and C dials.

The R scale is independent of frequency, and the value of L is calculated as follows:

1. From the reading of the C scale and a chart of reactance (or by calculation), find the reactance of the capacitance at the frequency used.
2. From the same reactance chart, find the value of inductance having the same reactance at the frequency used.

Multiply the value so obtained by the terminal and range factors of the bridge.

Example:

Frequency of source: 100 kc/s
Terminal used: L, R × 0.1, C × 10
Range switch: R × 10; L × 0.1
Reading at balance: 8,500 ohms on R dial
100 pF on C dial
Reactance of 100 pF at 100 kc/s
= 15,900 ohms
Equivalent inductance at 100 kc/s
= 0.0253 H.
Scale factors: Terminal 0.1
Range switch 0.1
Value of inductance: 0.0253 × 0.01
= 253 μH.
Effective parallel resistance:
8,500 × 0.1 × 10 = 8,500 ohms.

(2a) Equivalent Series Circuit

If the constants for the unknown are required in terms of the equivalent series circuit, they can be found from the relations:

$$R_s = \frac{R}{1+(R^2/X^2)} = \frac{R}{1+Q^2}$$

$$X_s = \frac{X}{1+(X^2/R^2)} = \frac{X}{1+(1/Q^2)}$$

$$L_s = \frac{L}{1+(\omega^2 L^2/R^2)} = \frac{L}{1+(1/Q^2)}$$

where $Q = R/X = R/\omega L$.

The values R, X, and L are parallel equivalents obtained from measurements on the bridge. Again it should be noted that for values of Q greater than 10 the difference between the series and parallel inductances is less than 1%.

(3) Measurement of Dielectric Loss

The bridge is not suitable for the direct measurement of dielectric losses in high-grade insulating materials, owing to the H.F. resistance of the switching circuit connexions.

Losses can be measured with the aid of an external air dielectric capacitor by the substitution method, and by making use of the NEUTRAL terminal in conjunction with the three-terminal capacitor, a virtually lossless capacitor can be obtained.

When measuring a capacitor with a very low dielectric loss, the bridge may not balance exactly at the extreme high frequency end of the range owing to the loss on the standard side exceeding that on the " unknown " side. If an exact balance is required for comparison purposes, it is permissible to obtain it by means of the " Balance R " control, which increases the loss of the unknown side without affecting the capacitance.

Measurement of Transmission Lines and Aerials

The bridge will measure accurately the impedance of all transmission lines and aerials whether balanced or unbalanced.

In the case of concentric cables, unbalanced, the EARTH and COMMON terminals are connected together and to the outer of the cable.

In balanced circuits, the EARTH terminal is left free.

The procedure for measurement is the same as that previously described.

It is important that the receiver is adequately screened against radiation from the cable or aerial under test.

The bridge can also be used as a rapid means of lining-up transmitter circuits and matching aerials.

Maintenance

The bridge is a carefully adjusted laboratory instrument and is not proof against rough handling or hard mechanical shock. This may have the effect of upsetting the calibration by disturbing the leads or the trimming capacitors.

To check the accuracy of the bridge setting, if the accuracy of calibration is suspected, the following procedure should be adopted :

1. Set the frequency of the source and detector to approximately 5 Mc/s., and the C and R ranges to C × 1 and R × 1.
2. Select two high-quality fixed capacitors of exactly equal value about 100 pF and connect them in series between the terminals marked COMMON and R & L × 1.
3. Balance the bridge by the main C dial and, if necessary, the "Balance R" control. When this balance has been obtained, connecting the junction of the two fixed capacitors to the EARTH terminal should not unbalance the bridge, although it may be necessary to re-balance on the "Balance R" control.
4. Repeat this procedure with the inductance range switch set to L × 1. Before connecting the fixed capacitors to the bridge, offset the C dial to 50-60 pF and balance the bridge. The fixed capacitors are then connected to the same terminals as before and the bridge rebalanced on the main C dial. The reading will be reduced in value in this case.

   Connecting the junction of the fixed capacitors to the EARTH terminal should not unbalance the bridge by more than 1.0 pF.
5. If the bridge is unbalanced by more than this amount, adjust the trimming capacitor TC_1, which will be found mounted adjacent to the EARTH terminal. The sealing compound on the trimmer can be softened by applying heat from a soldering iron near it.
6. Now check the resistance side of the bridge with the source and frequency setting as before. Set the resistance range switch to R × 0.1, the capacitance range to C × 0.1, and connect the EARTH and COMMON terminals.
7. Balance the bridge as before.
8. Connect a fixed carbon resistor of approximately 25 ohms across the terminals COMMON and R & L × 0.1. Note the reading obtained on the C dial at balance.
9. Remove the fixed resistor and disconnect the EARTH terminal from the COMMON terminal. Change the range switch to L × 10.
10. Rebalance the bridge and remeasure the resistor. The reading on the C dial should not differ appreciably from that obtained previously (see 8).
11. If the difference in reading is appreciable, adjust the trimmer TC_2, which will be found near the terminals of the calibrated potentiometer, until the two readings substantially agree.

Component List for **Diagram No. CD. 1003.**

R1	1K ohm 10% 10W, A.P. wound	**C4**	100 pF 20% Ceramic
R2	1K ohm Linear Law, carbon	**TC1**	3–30 pF Trimmer
R3	900 ohms 1% 1/4W	**TC2**	2–8 pF Trimmer
R4	3.3K ohms 5% 1/4W	**S1**	W.K. Type WP979 (2-pole 6-position)
R5	4.7K ohms 20% 1/4W	**S2**	W.K. Type WP980 (1-pole 3-position)
C1	2 × 480 pF ganged	**T1**	Input Transformer W.K. Type CWP213
C2	5–100 pF	**T2**	Output Transformer W.K. Type CWP214
C3	30 pF 10% Ceramic	**T3**	Auto Transformer W.K. Type CWP216

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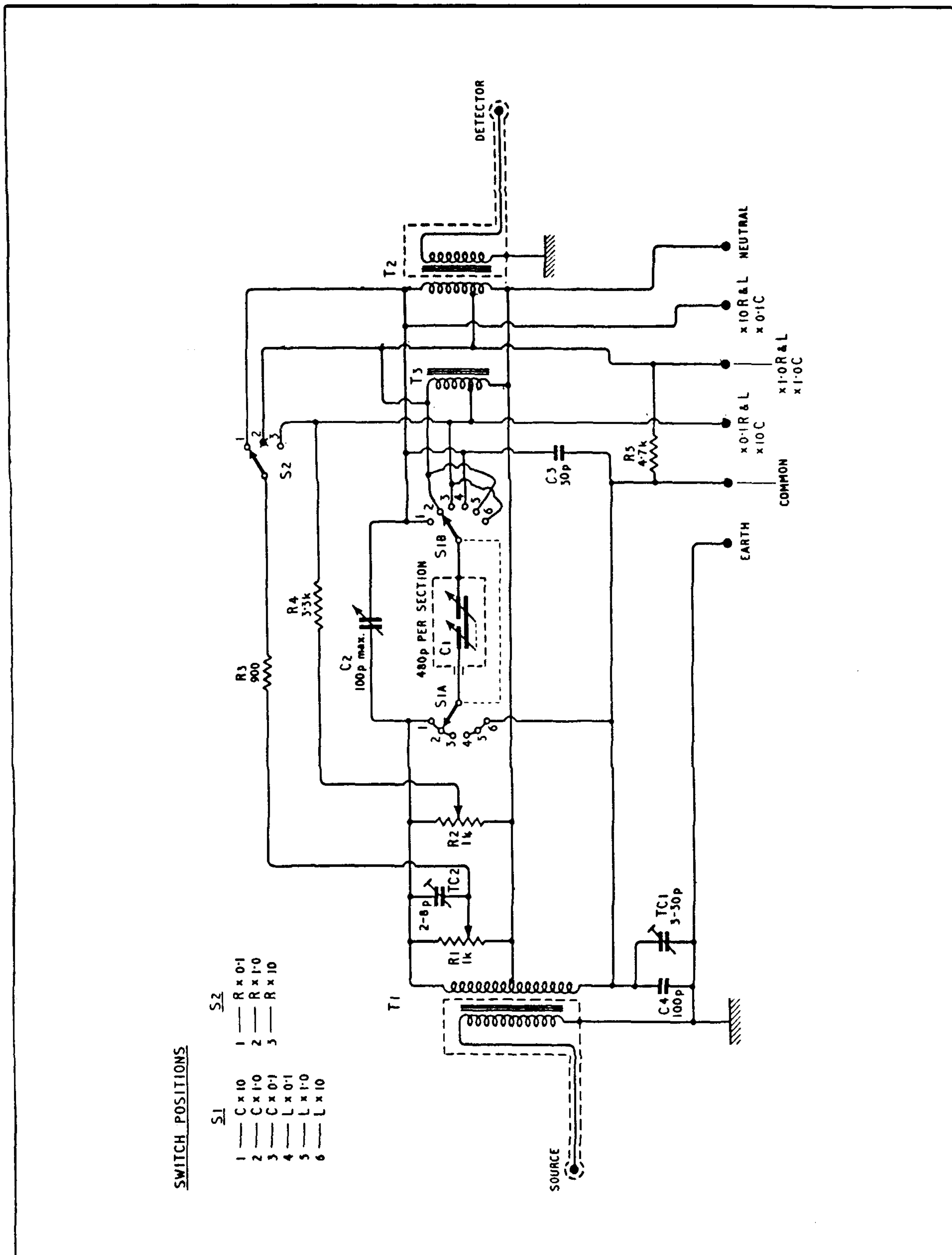

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Type B 601

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DRG No CD1003