JOINTLESS TRACK CIRCUITS FOR NON-ELECTRIFIED LINES

1. INTRODUCTION

The problems of high maintenance costs and unsuitability for very high speed running of the fishplated joints in conventional track are at present being overcome by laying continuously welded rail. Nevertheless, although in jointed track the Signal Engineer can easily define the limits of his track circuits by insulated block joints, in continuously welded rail these joints are a source of relative weakness, restricting the top speed for which the track is suitable. The Aster Type 'U' Jointless Track Circuit is one means of eliminating this weakness. It is developed from the Aster 1 watt jointless track circuit installed on the Eastern, London Midland and Western Regions from 1967 to 1969.

2. PRINCIPLES OF OPERATION

2.1 The Short Circuit

The simplest method of separating two track circuits without using insulated block joints is to connect a short circuit across the rails – see Fig. 2.1.

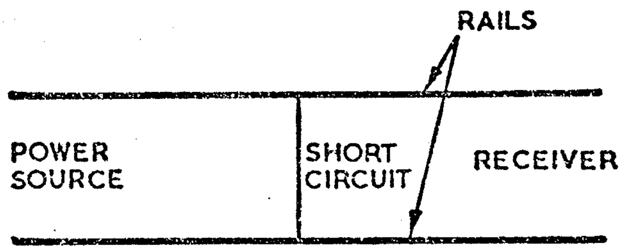


Fig.2.1

With this arrangement power from the source on the left cannot reach the receiver on the right. Although forming the basis of jointless track circuit principles, this arrangement cannot be used for a practical track circuit as the power required to operate it would be excessive and the value of train shunt needed to shunt the track would be unacceptably low.

2.2 The Tuned Short Circuit

To produce a workable track circuit therefore, the effective impedance of the short circuit must be greatly increased. The short circuit and the rails both have self-inductance and this may be used together with a capacitor to produce a parallel tuned circuit – see Fig. 2.2.

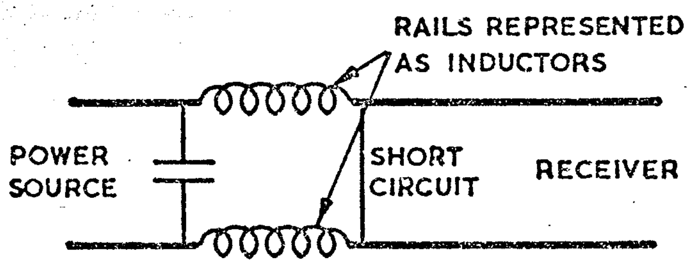


Fig. 2.2

With this arrangement significant power cannot reach the receiver from the power source on the left as the resistance and inductance of the short circuit is low, but to the power source the arrangement as a whole presents a high impedance at resonance.

2.3 Joint Between Two Track Circuits

If two track circuits are required adjacent to one another it is obviously possible to tune the short circuit from both sides - see Fig. 2.3.

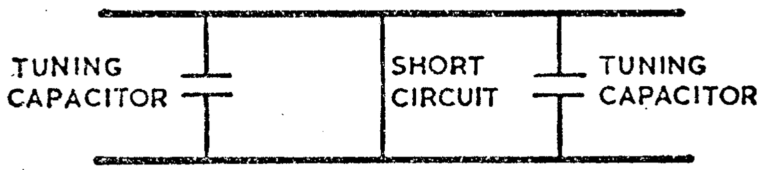


Fig. 2·3

This suffers from the disadvantage that it cannot guarantee to detect short wheelbase vehicles in the immediate vicinity of the short circuit. One solution to this problem produced the 1 watt Aster jointless track circuit (described elsewhere). The Z bond employed with this system is however, attractive to thieves and is to be avoided if possible.

2.4 Type 'U' Track Circuit

In the type 'U' the short circuit is provided by a series tuned circuit so that it is only a short circuit at one frequency. This enables the tuned circuits of two adjacent track circuits operating at different frequencies to be overlapped and therefore detect a short wheelbase vehicle. The arrangement of a typical joint is shown in Fig. 2.4.0.

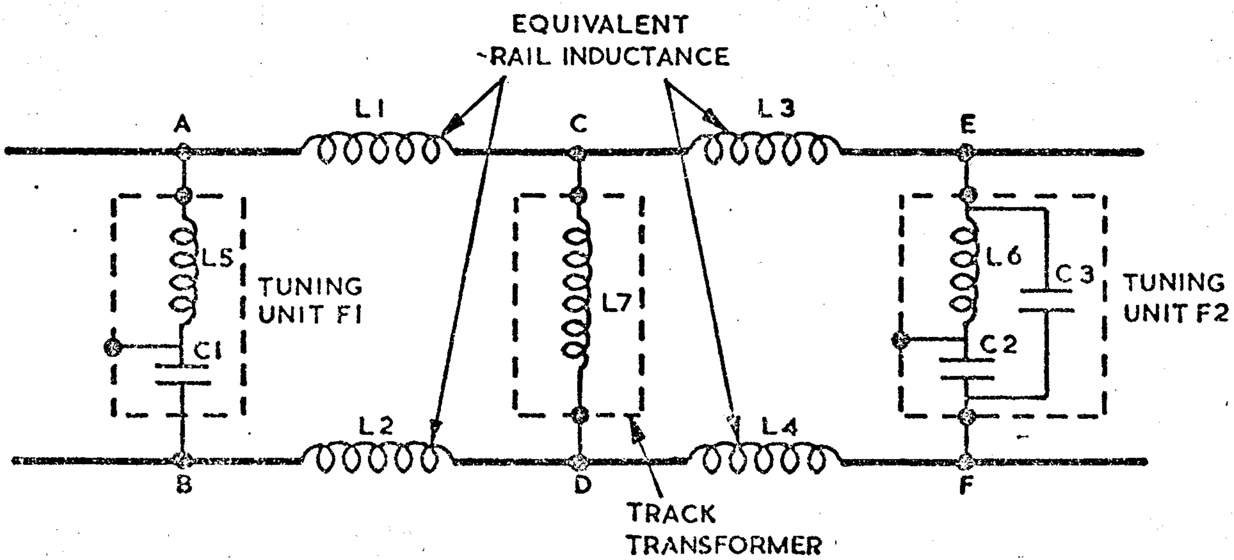


Fig. 2.4.0

At frequency F1, C2 and L6 are series resonant, shorting out C3.

2.4 Type 'U' Track Circuit (contd)

The equivalent circuit at frequency F1 is shown in Fig. 2.4.1.

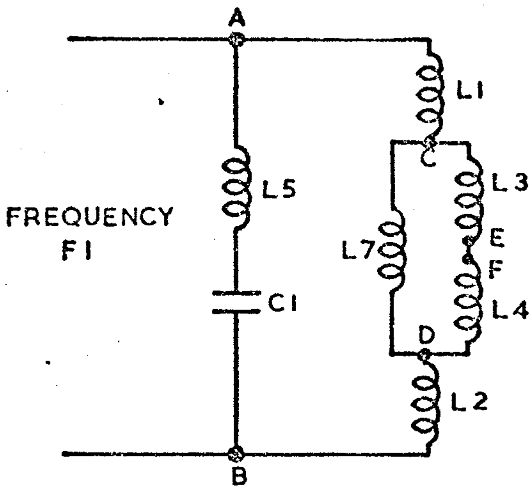


Fig. 2.4.1

The value of C1 is chosen so that the whole circuit is parallel resonant, exhibiting a high impedance, at frequency F1. Thus the end of track circuit F1 is clearly defined.

At frequency F2, C1 and L5 are series resonant. The equivalent circuit at frequency F2 is shown in Fig. 2.4.2.

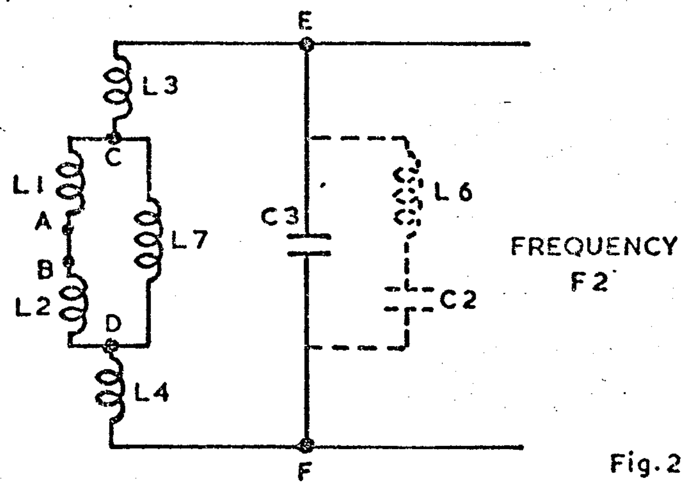


Fig. 2.4.2

The value of C3 is chosen so that the whole circuit is parallel resonant, exhibiting a high impedance at frequency F2 and clearly defining the end of the track circuit. C2 and L6 are off tune at frequency F2 and are a high enough impedance to be ignored.

2.5 Frequencies

In choosing the frequency of operation a compromise must be reached between the size of capacitors required to tune the rails and the maximum length of track circuit attainable. Frequencies in the range 1.5 kHz to 3 kHz have been found to achieve this compromise. Two pairs of frequencies are used, 1.7 kHz and 2.3 kHz, and 2 kHz and 2.6 kHz, one pair for the up line and other for the down line. (See Section 7.1).

3. EQUIPMENT AND ITS MARKING

3.1 Transmitters

There are 4 different transmitters, 1 type for each frequency. The different frequencies may be readily distinguished by colour coding of the front-plates and name-plates as shown in the following table.

Track	Frequency	Colour of Front Plate	Colour of Name Plate Lettering
1	1.7 kHz	Red	Red
	2.3 kHz	Red	Black
2	2.0 kHz	Yellow	Red
	2.6 kHz	Yellow	Black

The overall size of the transmitter is $5\frac{3}{4}$" x $5\frac{3}{4}$" x 8" (146 mm x 146 mm x 203 mm) and it will fit on a relay rack for BR 930 Series Miniature Relays, occupying the space of 3 relays. It uses 3 of the 6 fixing holes and is secured with 2 BA bolts screwed into 2 BA inserts in either end of the transmitter. It can, therefore, be mounted with the terminals, which are on one $5\frac{3}{4}$" x $5\frac{3}{4}$" (146 mm x 146 mm) face, at either the front or the back of the rack. Alternatively, the transmitter may be shelf mounted. No fixing lugs are provided for this as the transmitter is heavy enough to sit safely without being secured.

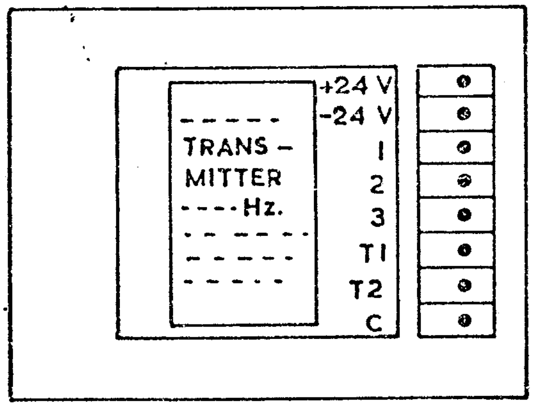


Fig.3·1

The electrical connections are brought out to an 8 way bulkhead terminal block. The wiring of the transmitter should be terminated on a terminal fanning strip which is a separate catalogue item. This slides directly under the screws of the terminal block and allows the wiring to be quickly disconnected in the event of a transmitter failure, without any risk of the wiring being wrongly reconnected. The terminal markings are shown in Fig. 3.1.

3.2 Receivers

There are 4 different receivers, one type for each frequency. They are the same size, have the same type of fixing and similar colour codes as shown for the transmitters. (See Section 3.1). The method of connection is the same except that there are two 8 way bulkhead terminal blocks. The terminal markings are shown in Fig. 3.2.

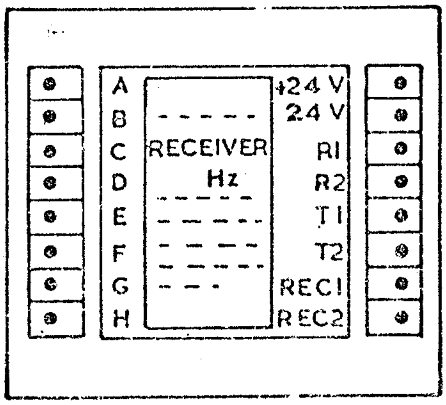


Fig. 3.2

3.3 Tuning Units

There are 4 different tuning units, 1 type for each frequency. The same type of tuning unit is used at the transmitter and receiver end of the track circuit. The units are housed in a fibre-glass case 16" x 15" x 4½" (406 mm x 381 mm x 114 mm) and mounted on a metal stake which is embedded in the ballast shoulder. The 4 types of tuning unit fall into 2 groups of 2, i.e., the low frequency types for each Track, F1, and the high frequency types for each Track, F2. The internal wiring is shown in figs.3.3.0 and 3.3.1.

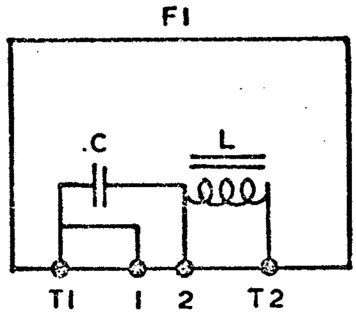


Fig.3.3.0

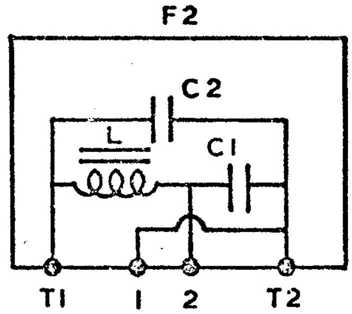


Fig.3.3.1

Terminals T1 and T2 are screwed 3/8" BSF or M10. Connections to these terminals must always be by 19/1.53 copper cable with soldered or crimped tubular lugs. Terminals 1 and 2 are a standard 2BA terminal block. A small quantity of units are fitted with a 3-way Klippon type BK terminal block and in these cases terminal 3 is not used although being wired internally. The connecting cable to terminals 1 & 2 should be a 2 core with a minimum conductor size of 7/0.67. A cable clamp is provided for this cable, suitable for either armoured or unarmoured cable.

3.4 Track Transformer

The same type of air-cored transformer is used for track circuits of all frequencies. It is housed in the same type and size of fibre-glass case as the tuning units and mounted on the same type of metal stake. The transformer is wired internally as shown in Fig. 3.4.

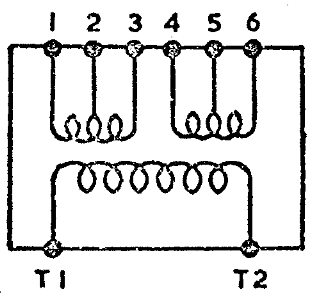


Fig.3.4

Terminals T1 and T2 are screwed 3/8" BSF or M10. Terminal 1, 2, 3, 4, 5 and 6 are standard 2 BA terminal block although a small quantity of units are fitted with a Klippon type BK terminal block. The connections and connecting cables should be the same type as those used for the tuning units except that a 4 core cable may be substituted for the 2 core cable in some circuit applications.

3.5 Track Relay

The Track relay associated with each receiver is a BR Miniature Relay to BR specification No. 968. It is equipped with two front contacts only, A1-A2 and D1-D2, and the coil is connected to R1-R2. When planning the relay rack or location case layout care should be taken to position each track relay as near as possible to its receiver. This is to ensure that the temperature compensation circuit in the amplifier is, as far as possible, at the same temperature as the relay.

3.6 Transformer/Rectifier Set

A transformer/rectifier set to BR Specification No. 929 should be used as a power supply whenever a reliable signalling supply is available. It can supply a maximum load of 4 amperes. (See Section 7.10). Tappings are provided for either 90-110 or 200-240 volts on the input.

3.7 Battery Charger

A battery charger to BR Specification No. 928 should be used, in conjunction with a suitable battery, as a power supply whenever a reliable signalling supply is not available. It can supply a maximum load of 4 amperes (See Section 7.10) and also charge the battery as necessary. An external shunt may be provided in the battery circuit to allow the technician to measure the battery charging current without breaking the circuit to insert an ammeter.

3.8 Batteries

Two sizes of batteries are used in conjunction with the battery charger described in Section 3.7. The smaller size is 12 lead acid cells of 30 ampere-hour capacity and the larger size is 12 lead acid cells of 60 amper-hour capacity. The smaller battery will give 12 hour stand-by for a 2 ampere load and the larger will give 12 hours stand-by for a 4 ampere load. (See Section 7.10).

3.9 Surge Arresters

Surge arresters are used to suppress over-voltage from nearby lightning strikes which can enter the elctronic equipment either from the rails or from an overhead power line, if used.

Triple path arresters type 16A are used on the track connections, one arrester being connected across each cable pair from the tuning units or track transformer. (See Figs. 8.1 to 8.11).

Two single path arresters type LV 280W are used on an overhead power line, one arrester being connected between each line and earth. (See Fig. 8.12).

3.10 Ordering Descriptions and Catalogue Nos

85/300	Track Relay	BR Specification No. 968, 250 ohms resistance, 2F contacts pin code 111.
86/1775	Battery Charger	BR Specification No. 928. Input 50 Hz 90/100/110/200/220/240 V. To charge 12 lead acid cells, load current 4 A reducing to 0.25 A.
86/34526	Transformer/ Rectifier	BR Specification No. 929. Input 50 Hz, 90/100/110/200/220/240 V. Output 24 V, 4 A d.c.
6/108750	Cable	Single core 19/1.53 mm black PVC. Insulated to BS 6004.
54/15862	Cable Lugs	Tubular socket tinned copper to BS 91 ref. 7E type 1 sweated type for 19/1.53 mm cable.
54/19105	Terminal	L.H. Carr Fastener Co. type 44/77/534/8
54/19106	Fanning Strips	R.H. Carr Fastener Co. type 44/77/534/8
86/590	Arrester and Mounting	A.E.I. Type 53A, for two wires fitted with arrester 86/591.
86/591	Arrester	Gas filled, striking voltage 150-350 V d.c., A.E.I. Type 16A.
86/650	Arrester	Metrosil surge diverter type for single wire. Maximum working voltage 280 V. Type LV 280W

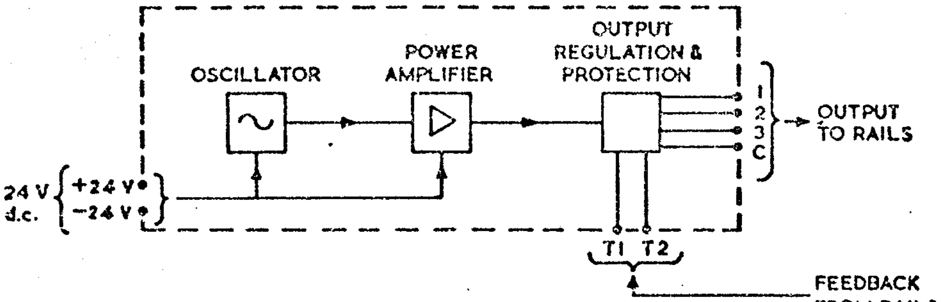
Ordering Descriptions and Catalogue Nos

COMPONENTS	CATALOGUE NO	QUANTITY REQUIRED							
TRACK 1 FREQUENCY 1.7 kHz									
Transmitter	86/43741	1				1			
Receiver	86/43742	1				1			
Tuning Unit	86/43743	1				1			
TRACK 1 FREQUENCY 2.3 kHz									
Transmitter	86/43747		1				1		
Receiver	86/43748		1				1		
Tuning Unit	86/43749		1				1		
TRACK 2 FREQUENCY 2.0 kHz									
Transmitter	86/43765			1				1	
Receiver	86/43766			1				1	
Tuning Unit	86/43767			1				1	
TRACK 2 FREQUENCY 2.6 kHz									
Transmitter	86/43771				1				1
Receiver	86/43772				1				1
Tuning Unit	86/43773				1				1
Air Cored Transformer	86/43744	1	1	1	1	2	2	2	2
Mounting Stake	86/43745	3	3	3	3	4	4	4	4

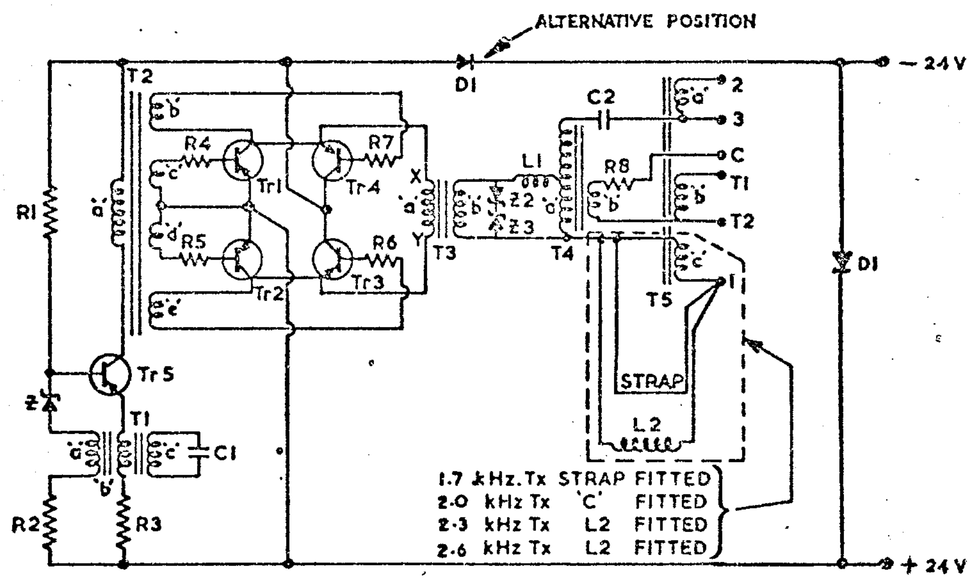
COMPLETE SETS	
STANDARD TRACK SETS	
Track 1 Frequency 1.7 kHz	86/43740
Track 1 Frequency 2.3 kHz	86/43746
Track 2 Frequency 2.0 kHz	86/43764
Track 2 Frequency 2.6 kHz	86/43770
CENTRE FED TRACK SETS	
Track 1 Frequency 1.7 kHz	86/43788
Track 1 Frequency 2.3 kHz	86/43794
Track 2 Frequency 2.0 kHz	86/43812
Track 2 Frequency 2.6 kHz	86/43818

4. TRANSMITTER

The transmitter consists of an oscillator, a power amplifier and output regulation and protection circuits. Fig. 4.0 shows the block schematic diagram and Fig. 4.0.1 the circuit diagram.



TRANSMITTER BLOCK SCHEMATIC DIAGRAM. Fig. 4.0



TRANSMITTER CIRCUIT DIAGRAM. Fig. 4.0.1

Add internal connection between Terminals T2 and 1.

4.1 Oscillator

Transistor Tr5 functions as a class A amplifier having the necessary positive feed back to make it oscillate. The primary winding of transformer T2 forms the collector load and provides coupling to the next stage. When the supply is first switched on the transistor is biased sufficiently to conduct by resistors R1 and R2. As the current flows in winding 'b' of transformer T1 a voltage is induced in winding 'a' which drives the base more negative with respect to the emitter causing the transistor to conduct more. This continues until the transistor 'bottoms' when there is no induced voltage across winding 'a' as there is no change in current in winding 'b'. The transistor then drives to its 'cut-off' state and the cycle starts again. The frequency of oscillation is determined by the parallel resonant frequency of capacitor C1 and winding 'c'; oscillation at any other frequency would be heavily damped by the low impedance of this circuit. Capacitor C1 has a negative temperature coefficient nominally equal to the positive temperature coefficient of winding 'c' of transformer T1. This assures stability of oscillation frequency against changes due to temperature variation.

The resistance R3 is provided to limit the mean d.c. current conducted by the transistor and thus prevent it from overheating. Zener diode Z1 assures voltage stability of the oscillator

4.2 Power Amplifier

Transistors Tr1, Tr2, Tr3 and Tr4 constitute the power amplifier of the transmitter. The biasing is arranged so that Tr1 and Tr2 operate as one class C amplifier and Tr3 and Tr4 as another. With the current increasing in winding "a" of transformer T2, transistors Tr1 and Tr3 will conduct and the current will flow from the positive rail, through transistor Tr1, through winding "a" of transformer T3 from X to Y and through transistor Tr3 to the negative rail. When the current is decreasing in winding "a" of transformer T2, transistors Tr2 and Tr4 will conduct. The current flow from positive to negative through winding "a" of transformer T3 will now be from Y to X. The net result is that the oscillator output voltage has been amplified into a square wave of the required power. The output regulation circuits filter this to produce a sinusoidal waveform at the rails.

Resistors R4, R5, R6 and R7 are provided to limit the base current to each transistor.

4.3 Regulation and Protection

From winding "b" of transformer T3 the transmitter power is fed through choke L1 to auto-transformer T4. The zener diodes Z2 and Z3 do not normally conduct and are included to protect the transmitter amplifier from voltage surges caused by lightning. Auto-transformer T4 operates in a saturated state if the power supply is above 22 volts and thus maintains a constant value of output voltage if there are variations in the supply voltage.

Choke L1 and capacitor C2 form a series tuned circuit which is partly de-tuned by auto-transformer T4 thereby improving output regulation. It is further de-tuned by the passage of a train thus limiting the output power delivered by the transmitter when the train is in the immediate vicinity of the tuning units.

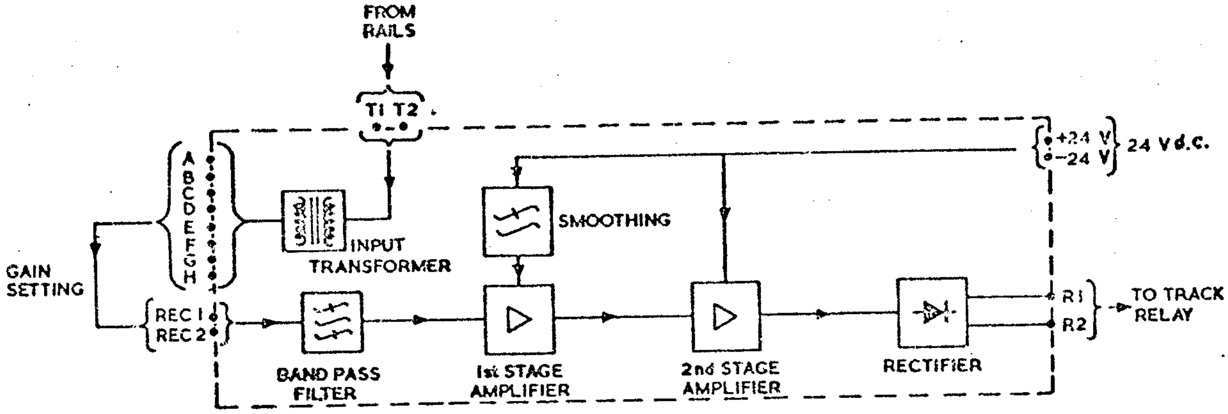
Transformer T5 regulates the output against changes in ballast impedance. It is designed for a minimum ballast impedance of 2 ohms and if this value rises the transformer saturates maintaining a constant output from terminals 1 and 2. The second function of T5 is to improve the train shunt between the tuning unit and track transformer. Transformer T5 will only be saturated if power from the track transformer is fed back to winding "b" on terminals T1 and T2. When a train is between the tuning unit and the track transformer, this feed back power is cut off by the wheels, transformer T5 de-saturates and the impedance of winding "a" (and "c" in the 2.0 kHz transmitter) is increased thereby reducing the output power and hence improving the train shunt.

When the transmitter is centre feeding a track circuit the output power from terminals 1 and 3 is supplied by winding "b" on T4 and terminals 3 and C are joined together to give improved regulation. Inductor L2 is included in the 2.3 kHz and 2.6 kHz transmitters to limit the current taken when a train is in the immediate vicinity of the air cored transformer and tuning unit. This only applies to these two frequencies because their tuning units exhibit capacitive reactance when shorted by a train.

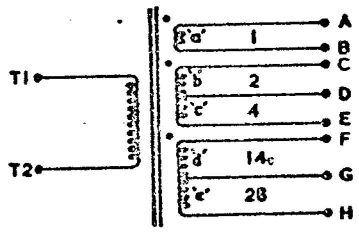
Diode D1 is included to prevent damage to the transmitter if the power supply is wrongly connected.

5. RECEIVER

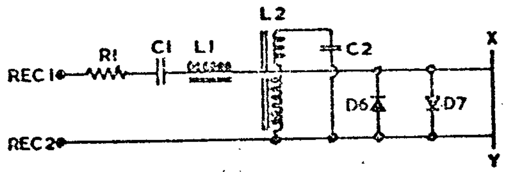
The receiver consists of a two-stage amplifier fed from a narrow band pass filter. Fig. 5.0 shows the block schematic diagram and Fig, 5.0.1 the circuit diagram of the receiver.



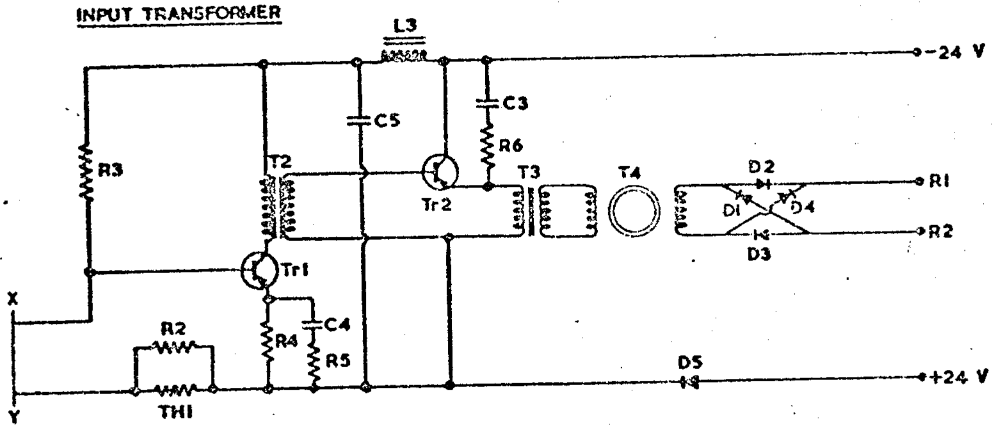
RECEIVER BLOCK SCHEMATIC Fig.5.0



INPUT TRANSFORMER



BAND PASS FILTER



RECEIVER CIRCUIT DIAGRAM Fig. 5.0.1

5.1 Input Transformer

The audio frequency energy from the transmitter is taken from the rails by a secondary winding on the track transformer which is connected via the receiver input terminals T1 and T2 to the primary winding of input transformer T1. Secondary windings "a", "b", "c", "d" and "e" are provided as a means of adjusting the overall gain of the receiver and by selecting taps the gain may be adjusted in 49 steps each equal to 1/49 of the maximum gain, (see Fig. 5.0). This is necessary as the voltage received from the rails will vary widely according to the length of track circuit and the connecting cables, while the relay can only tolerate a much smaller variation to function correctly.

5.2 Band Pass Filter

The selected output taps of the input transformer are connected to terminals REC1 and REC2 from which the signal passes into the amplifier proper. The 2-stage band pass filter consists of capacitor C1 and inductor L1 series resonant at the receiver frequency and capacitor C2 and inductor L2 parallel resonant at the same frequency. L2 is tapped to reduce the capacitance and therefore the physical size of C2. Capacitors C1 and C2 have a negative temperature coefficient nominally equal to the positive temperature coefficient of inductors L1 and L2. This assures stability of tuning against changes due to temperature variation. Diodes D6 and D7 do not conduct significantly, although forward biased on alternative half cycles, as the signal voltage does not exceed the knee in the diode characteristic. They are provided to protect the receiver from any excess voltages due to lightning.

The overall effect is that a high impedance is presented to T1 at frequencies other than that desired, and at the desired frequency current is fed to the base of the transistor Tr1 from the transformer T1 with little loss. Resistor R1 is chosen in conjunction with the gain of the amplifier to somewhat dampen the response curve of the tuned circuit and make it flat topped plus or minus 10 Hz about the nominal frequency. This ensures adequate response from the receiver if in service there should be any slight change in frequency of the transmitter due to temperature variation or ageing.

5.3 First Stage Amplifier

Transistor Tr1 functions as the first stage amplifier. The primary winding of the transformer T2 forms the load whilst the transistor is biased to its working point by resistors R2 and R3 and thermistor Th1. The latter is provided to stabilise the amplifier gain against changes in the resistance of the relay coil as the ambient temperature varies.

Resistance R4 is provided to limit the steady current conducted by the transistor and thereby prevent it overheating. The signal however is decoupled by capacitor C4 and resistor R5 which is provided to give a pre-set control of the amplifier gain. The value of this resistance is chosen during assembly to give the correct value of output.

5.4 Second Stage Amplifier

Transistor Tr2 functions as the second stage amplifier. It is connected in the emitter follower configuration which gives the necessary power gain and matching with the relatively low resistance, 250 ohms, of the track relay. There is no d.c. bias on the transistor its base being fed by the secondary transformer T2 and it only conducts therefore when the signal is present. This is necessary with a 2-stage amplifier to avoid the risk of self oscillation which might give an output to energise the track relay even though the track circuit is shunted by a train. Similarly the load of this stage has to be a transformer, T3, to prevent the power supply from operating the track relay by direct contact. Capacitor C3 and resistor R6 are provided to protect the transistor against voltage transients.

5.5 Smoothing

The power supply to the first stage requires decoupling from Tr2 and this is provided by inductor L3 decoupled by capacitor C5. If either of these components become faulty there is a chance that any 100 Hz ripple on the power supply could provide a significant enough signal for Tr2 and so produce an output from transformer T3. To protect the integrity of the track circuit, transformer T4 is designed to saturate at frequencies below 500 Hz and thereby prevent any unwanted 100 Hz or lower frequency voltage from reaching the relay. Diode D5 is provided to protect the amplifier if the power supply is connected incorrectly.

5.6 Rectifier

The final stage of the amplifier is an encapsulated bridge rectifier containing diodes D1, D2, D3 and D4, which provide the d.c. signal for the relay.

6. ANALYSIS OF SAFETY

6.1 Transmitter

The transmitter could malfunction in several ways. It could either fail to oscillate, oscillate with increased or reduced power or oscillate at a frequency other than the correct one.

Failure to oscillate or oscillation with reduced power will produce a right side failure.

Oscillation with increased power output would reduce the ohmic value of the train shunt of the track circuit. This is most unlikely to arise with the type of power amplifier used and would in any case be detected by routine track circuit testing. The risk is therefore negligible.

The worst failure would be for the transmitter to oscillate at the frequency of the adjacent track circuit. This will produce a right side failure of its own track circuit. It might possibly, however, produce a wrong side failure by energising the adjacent receiver if the transmitter and receiver are connected in the arrangement shown in Fig. 8.2 and the train is far enough away from the receiver for the train shunt to be ineffective because of rail impedance. For this to happen three simultaneous faults must occur, i.e.:-

i) The tuned circuit controlling the transmitter frequency must be faulty. (C1 and T1 "c" in Fig. 4.0.1).

ii) The tuned output filter of the transmitter must be faulty. (L1 and C2 in Fig. 4.0.1).

iii) The tuning unit must be faulty. (F1 in Fig. 8.2).

It is most unlikely that all three would fail simultaneously and the failure of only one of them would produce a right side failure. It is still less likely that all three would fail in such a way as to be responsive to the same frequency and extremely unlikely that this would be the frequency of the adjacent receiver. This therefore constitutes a quite negligible risk.

6.2 Receiver

The receiver could also malfunction in several ways. It could either go into self oscillation, drift in tuning frequency or change its gain or alternatively there could be direct contact between the power supply and the relay coil connections.

A wrong side failure could occur if the receiver went into a state of self oscillation. This is prevented by careful construction of the receiver. If the biasing circuit of Tr1 (Fig. 5.0.1) becomes altered to give the maximum gain, the power supply is at its maximum value and the transistor itself happens to have maximum gain then the design is such that self oscillation does not result. Tr2 can not self oscillate since it has no d.c. bias and only conducts when the signal is present. There is therefore negligible risk from self oscillation.

6.2 Receiver (contd)

A wrong side failure could also occur if the receiver became tuned to the frequency of the adjacent track circuit. This would require both parts of the receiver input filter L1 and C1 and L2 and C2 (Fig 5.0.1) and the tuning unit across the rails to drift simultaneously, without first causing a right side failure, to the adjacent frequency. As with the transmitter this is considered to be a negligible risk.

For the gain of the receiver to increase unexpectedly one of the biasing resistors would have to have a short circuit fault. An open circuit fault would give a right side failure. It is considered that an open circuit fault is much more likely than a short circuit and, therefore, the risk from an unexpected increase in gain is very slight. As with the transmitter this fault would show itself during routine testing by an increased relay voltage and a reduced train shunt.

The relay coil is energised by rectified a.c. delivered by transformers T3 and T4 (Fig. 5.0.1). There is no chance therefore of both transformers simultaneously breaking down in such a way as to let the power supply energise the relay coil without first causing a right side failure.

6.3 General

The use of differing frequencies as explained in Section 7.1, prevents false energisation by stray feeds from adjacent track circuits. However, an effective rail to rail short circuit must exist between two track circuits of the same frequency, on the same track.

It is therefore essential to ensure that the transmitter and receiver end tuning units are <u>never</u> disconnected simultaneously where there is a risk of feed through between two track circuits.

7. PLANNING AN INSTALLATION

7.1 Frequencies

There are four available divided into two groups of two.

Frequency	F1	F2
Track 1	1.7 kHz	2.3 kHz
Track 2	2.0 kHz	2.6 kHz

It is essential that on one track only the paired frequencies are used e.g. 1.7 kHz and 2.3 kHz even if it runs for many miles. It is not possible to use, say 1.7 kHz and 2.6 kHz as track circuits on the same pair of rails. If it is necessary to change from one pair of frequencies to another then block joints must be used and each track circuit terminated as described in section 7.6.

7.2 Standard Track Circuit Configuration

The nominal length of the track circuit is the distance between the rail connections of the track transformers at each end. The maximum permitted nominal length for a single track circuit is 1 000 m with a tolerance of 25 m. Fig. 7.2 shows the normal layout of tuning units and track transformers for joints between successive track circuits and Figs. 8.1, 8.2 and 8.3 show the wiring.

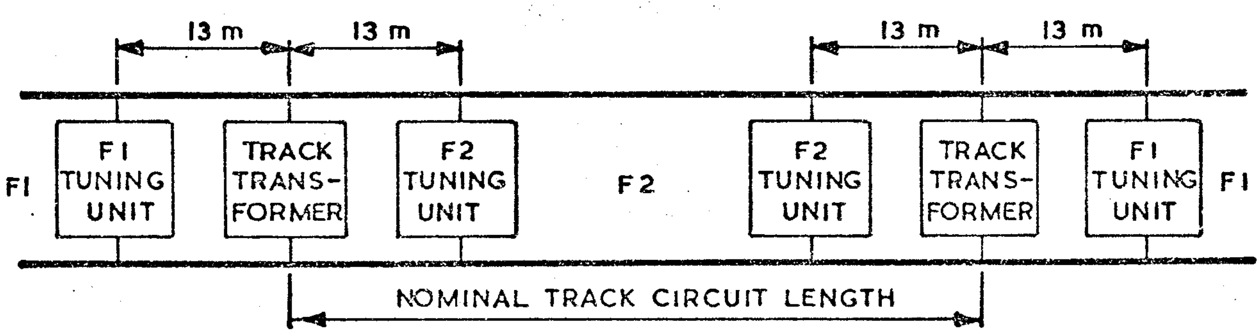


Fig.7.2

The minimum nominal length of track circuit using this standard configuration is 50 m between track transformers. The effective length (defined as the length of track actually shunted by the train) for a minimum length track circuit is 62 m (See section 7.7).

The type 'U' may be connected with the train striking in at either transmitter end or the receiver end first. Thus the junction between two track circuits may be with two receivers adjacent, two transmitters adjacent, or transmitter and receiver adjacent. These arrangements may be used without restriction and require no special connections.

7.3 Centre-Fed Track Circuit Configuration

An economy of equipment may be made if one transmitter is made to feed a receiver in each direction as shown in Fig. 7.2. It is wired as shown in Figs. 8.5 and 8.6.

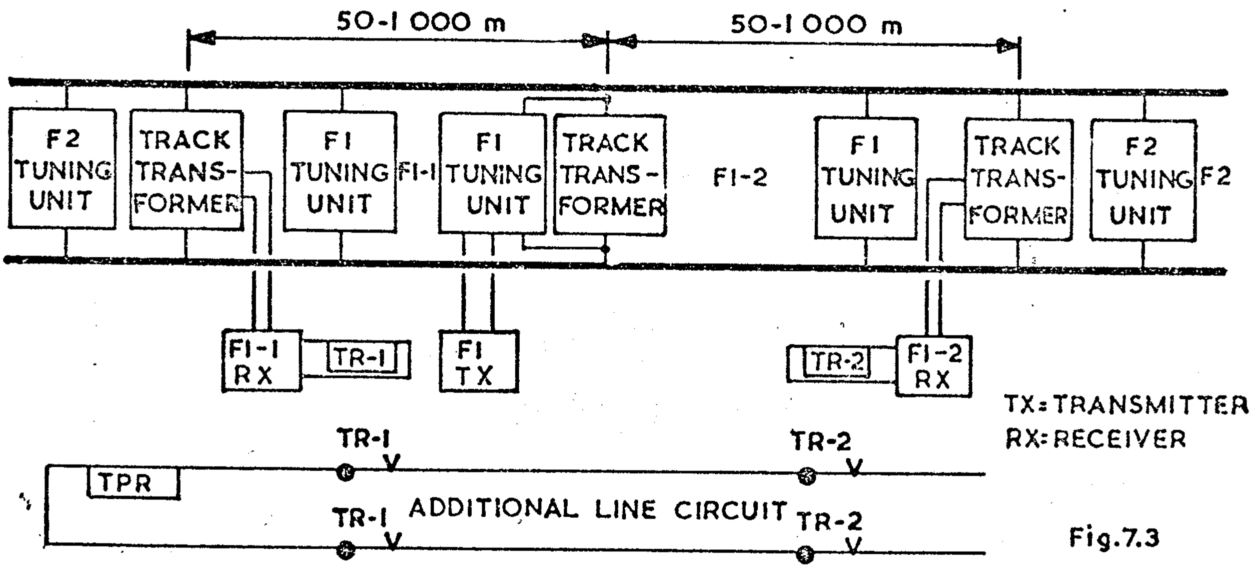


Fig.7.3

The two halves of the track circuit function completely independantly and may be used as two separate track circuits providing the somewhat coarse overlap at the centre does not cause any problem. (See section 7.7). If required to work as one track circuit an extra line circuit must be provided to link the two track relays as shown in Fig. 7.3. The minimum length of each section is 50 m and the maximum length is 1 000 m with a tolerance of 25 m. It is not necessary for the two sections to be the same length which can be an advantage when siting track-side location cases.

7.4 Cut Sections

An alternative method of obtaining a longer track circuit is to use one track relay to control the supply to the next transmitter. The cut section arrangement is shown in Fig. 7.4 and the wiring in Fig. 8.4.

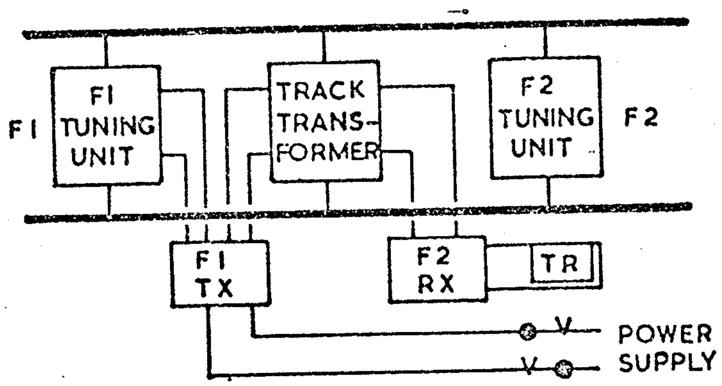


Fig. 7.4

7.5 Adjoining Non-Track Circuited Lines

When track circuiting ends an economy may be made by installing a 19/1.53 copper cable across the rails instead of one tuning unit. This arrangement is shown in Fig. 7.5 and applies whether this is the transmitter end or the receiver end of the track circuit. The wiring is shown in Figs. 8.10 and 8.11.

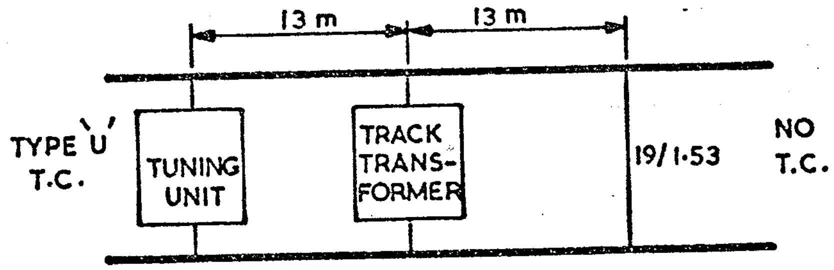


Fig. 7.5

7.6 Adjoining All Other Types of Track Circuit

When the type 'U' has to meet a conventional track circuit, or another type 'U' track circuit of an unrelated frequency a pair of insulated block joints must be installed. The type 'U' equipment is connected as shown in Fig. 7.6 which is suitable for either the transmitter end or the receiver end of the track circuit being wired as shown in Figs. 8.7, 8.8 and 8.9.

For a type 'U' track circuit adjoining a 1 watt track circuit see section 11.

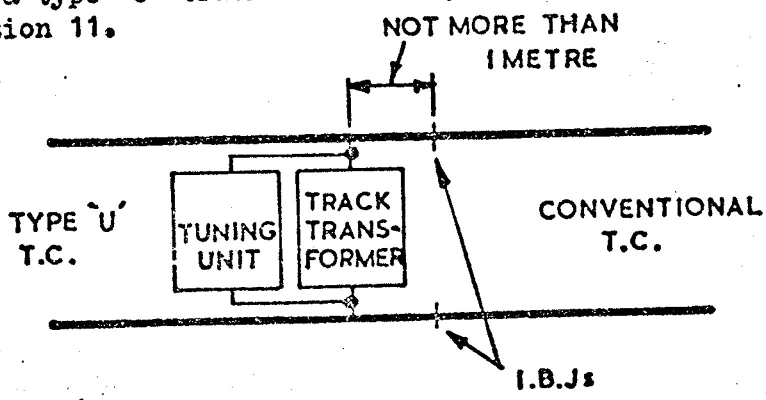


Fig. 7.6

contd/....

(Amended November 1977)

7.6 Adjoining All Other Types of Track Circuit (Cont'd.)

Where an audio frequency track circuit adjoins an a.c. on rails/d.c. relay track circuit, a short circuit across the interposing block joints causes energy from the audio frequency track circuit to be fed to the a.c. on rails/d.c. relay track circuit.

To prevent this situation causing a wrong side failure, the track circuits are to be installed with the audio frequency transmitter and the a.c. feed set connected to either side of the interposing block joints, as shown in Fig. 7.6.1.

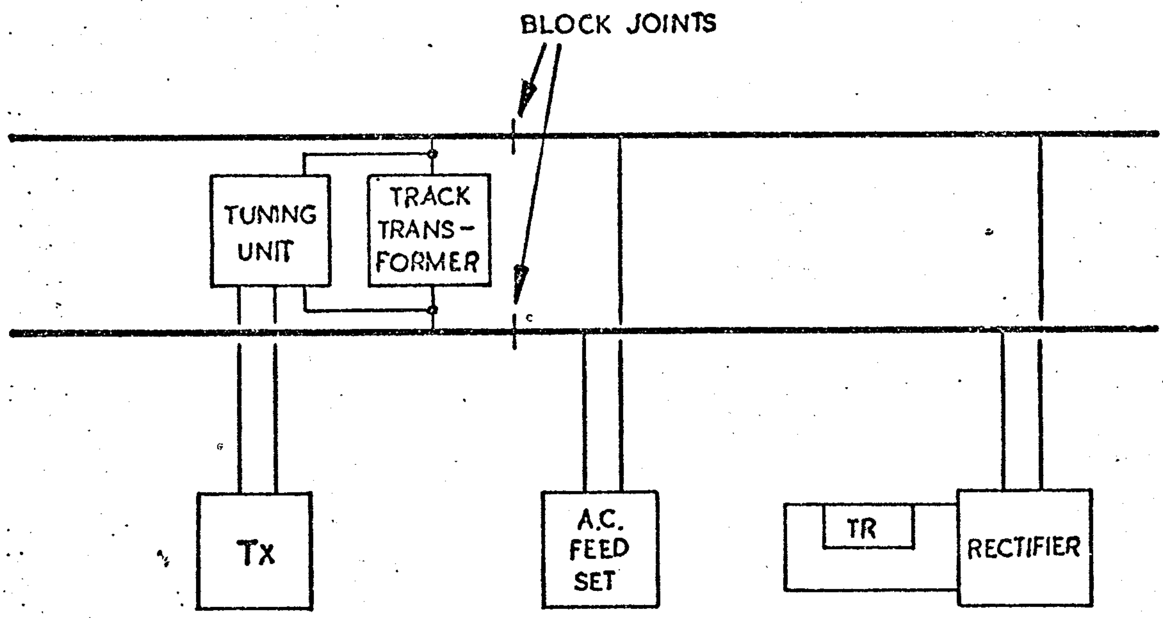


Fig. 7.6.1

7.7 Shunt Zones

As a train passes from one track circuit to the next there is a zone in which both track circuits are shunted and zones in which the effect of the train shunt on one jointless track circuit gradually diminishes. These zones and their lengths are shown in Figs. 7.7 and 7.7.1. All measurements of nominal length of the track circuit should be taken from the track.....

contd/......

7.7 Shunt Zones (contd)

transformer connections. Measurements of fouling points, standing room etc., should however be taken from the edge of the possible shunting zone. Note; for use on reversible lines, the extent of that zone depends upon the direction of travel..

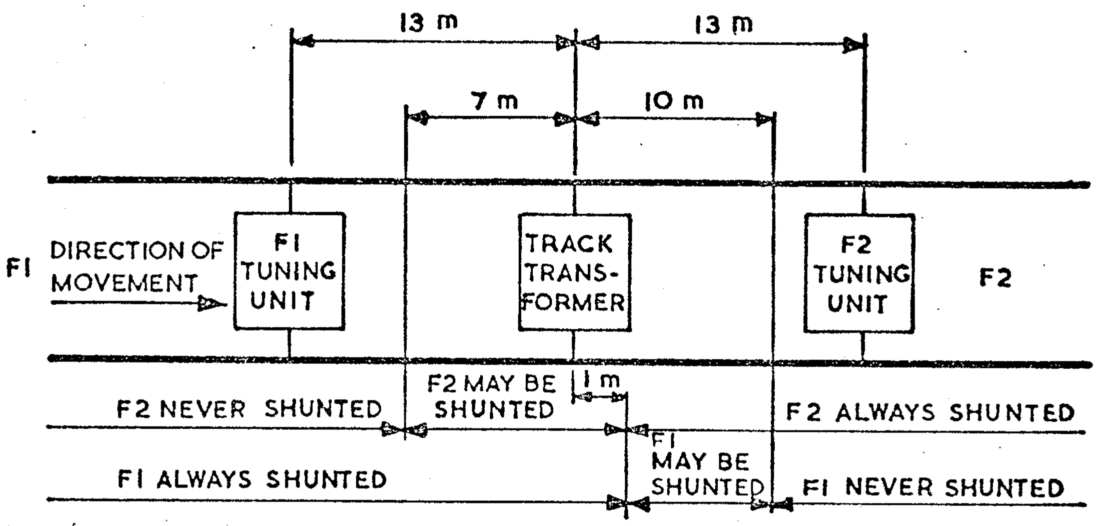


Fig 7.7

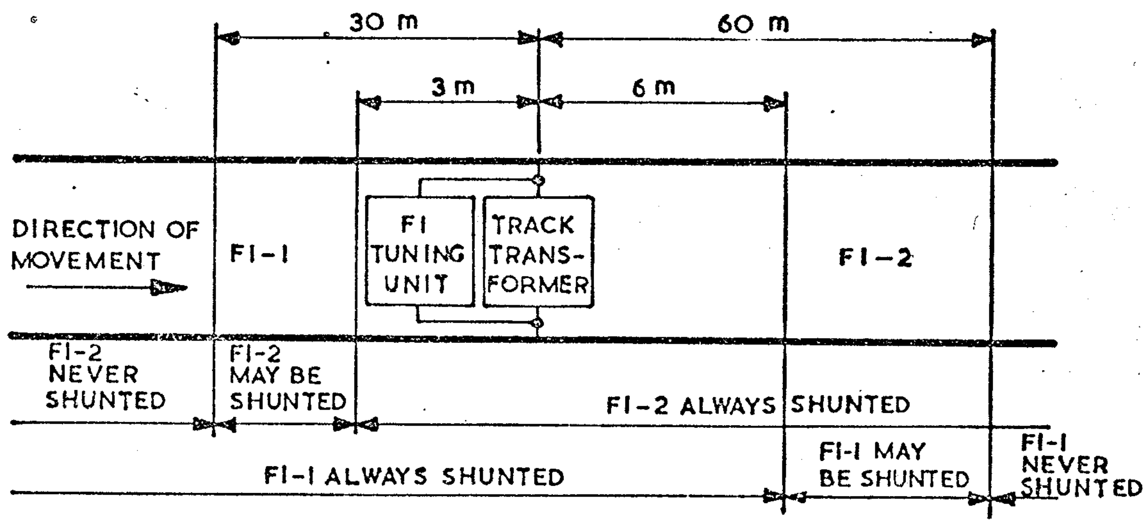


Fig 7.7.1

7.8 Bonding

The tuning units and track transformer must be sited so that no catch points or expansion joints are in the 26 m between tuning units. If the track circuit is installed on conventional 60 ft. track then at least one pair of joints will be between the tuning units and any such joints must be bonded with 19/1.53 copper cable welded or brazed to the rails. Joints in the main part or the track circuit may be bonded with two conventional galvanised iron track circuit bonds.

7.9 Points and Crossings

Aster type 'U' may be used through points and crossings, subject to certain limitations.

7.9.1 Spurs of rail which, although they form part of the track circuit, are not directly in series conducting energy from the transmitter to the receiver must not be longer than 12 m. This is to prevent the train shunt becoming ineffective. They should be solidly connected to the track circuit at each end.

7.9.2 To avoid any chance of an occupied track being by-passed via a parallel track, and to minimise power consumption each spur off the track circuit must be fitted with an insulated block joint in each rail.

Thus a crossover requires 6 block joints as shown in Fig. 7.9.2. To avoid the risk of run-round from a block joint failure two pairs of points should not be closer than 1 000 m, if they are in track circuits of the same frequency.

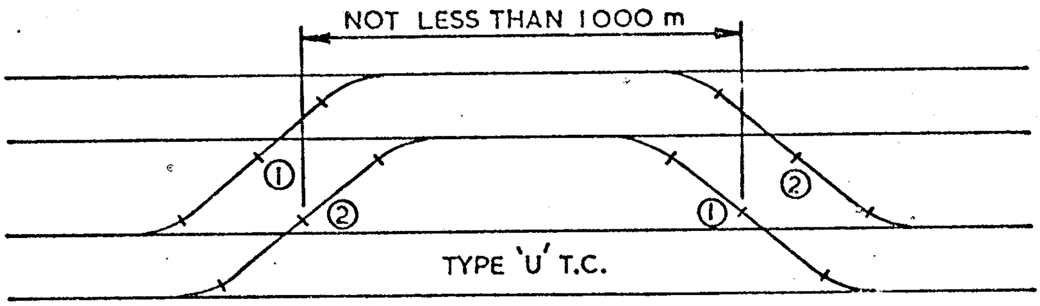


Fig.7·9·2

Unfortunately with much modern permanent way it is not possible to fit joints 1 and 2 without an unacceptable stagger between them which therefore makes application of type 'U' impossible.

7.9.3 Extra Receiver. This method shown in Fig. 7.9.3 uses an additional receiver, tuning unit, track transformer and track relay. It may also require an additional line circuit to link the two track relays.

Where, despite the above restrictions, it is possible to apply type 'U' to a pair of points one of the two following methods should be used.

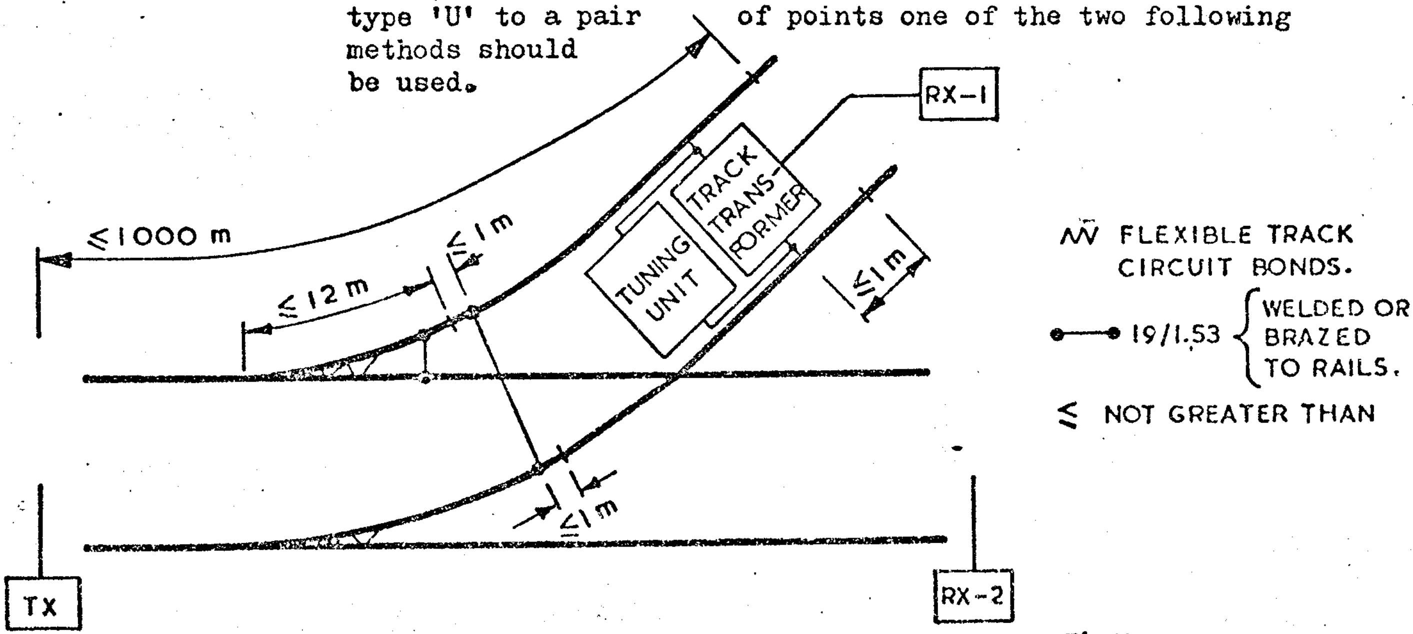
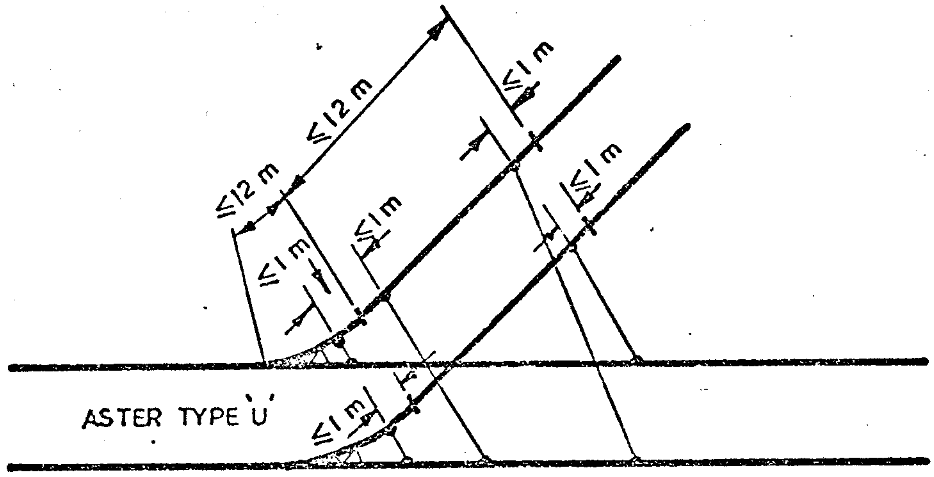


Fig.7·9·3

Alternatively, if the track circuiting ends, and space permits, the normal layout of units, as described in Section 7.5 could be used avoiding the need for two block joints.

7.9.4 Spurs up to 12 m. If the length of the spur to be added is not more than 12 m then an economy of equipment may be made by bonding as shown in Fig. 7.9.4.



ʌʌʌ FLEXIBLE TRACK CIRCUIT BONDS

o—o 19/1.53 WELDED OR BRAZED TO RAILS

≤ NOT GREATER THAN

Fig.7.9.4

This bonding ensures that each piece of rail not actually conducting energy from transmitter to receiver is connected to the main part of the track circuit by at least two widely separated bonds, either of which will independantly permit reliable shunting of that part of the track circuit.

7.9.5 If it is not possible to run the type 'U' through the points it should be terminated with a pair of insulated block joints and conventional track circuits used.

7.9.6 There may be circumstances where a pair of points requiring a conventional track circuit occurs in the middle of what could otherwise be a type 'U' track circuit. The arrangement shown in Fig. 7.9.6 may be used. The cable should not exceed 100 m and it must count as part of the total cable permitted in the track circuit (see Section 7.11).

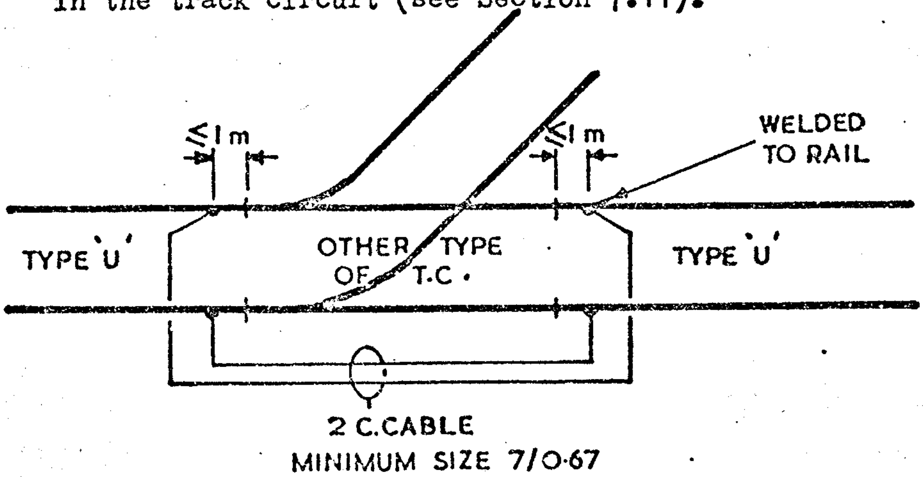
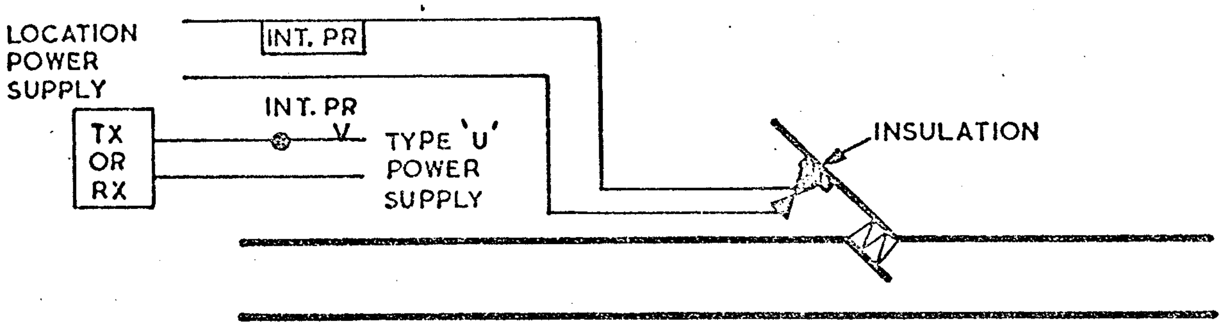


Fig. 7.9.6

7.9.7 Catch points. Since the object of type 'U' is to abolish insulated block joints, the normal track circuit interrupter arrangement using two block joints and having the interrupter in series with one rail should not be used. Instead the interrupter must be insulated from the rails on which it is mounted and an interrupter repeat relay provided which is made to control the power supply of the transmitter or receiver of the track circuit whichever is more convenient, as shown in Fig. 7.9.7.



/\/ FLEXIBLE TRACK CIRCUIT BONDS.

Fig. 7.9.7

7.10 Power Supplies

Two types of power supply may be used; either a transformer/rectifier set to BR Specification No 929, when a reliable signalling supply is available or a battery charger to BR Specification No. 928 and batteries when one is not. Either is capable of supplying a maximum load of 4 amperes and the battery charger is additionally capable of recharging the battery. The loading at any given location can be calculated from the following table which gives the maximum current under any conditions.

Frequency kHz	Max. Current amperes	
	Transmitter	Receiver
1.7	1.6	0.4
2.0	1.7	0.4
2.3	1.8	0.4
2.6	1.9	0.4

Where the power supply is open wires or aerial cable on a pole route the power supply must be protected by suitable surge arresters wired as shown in Fig. 8.12. The maximum input power requirements of the two units are:-

From the above table the Aster equipment VA requirements can be calculated assuming the rated voltage.

If the load is supplied by a transformer-rectifier the input VA from the 50 Hz power supply will be approximately:

60 + [Load VA] at 0.7 p.f.

Where a Battery Charger is used the maximum output power is assumed, i.e., when charging a discharged battery, when the loading on the 50 Hz power supply will be approximately 250 VA at 0.9 p.f.

Under other load conditions the input VA will be reduced and would be approximately: 125 + [Load VA]

7.11 Cable Lengths

In planning a track circuiting scheme there are some restrictions in the lengths of cable which may be used to interconnect a transmitter or receiver with its respective tuning unit, track transformer or power supply. These interconnections should be made with cable having a minimum core size of 7/0.67.

Nominal length up to	Maximum total cable length	Maximum cable between transmitter and tuning unit	Maximum cable between receiver and track transformer
700 m	700 m	50 m	700 m
800 m	500 m	50 m	500 m
900 m	300 m	50 m	300 m
1 000 m	100 m	30 m	100 m

Thus for a track circuit 800 m long the cable between the transmitter and the tuning unit can be a maximum of 50 m. If it is in fact 25 m then the maximum permitted length of the cable between the receiver and track transformer will be 475 m.

As the amount of cable used increases, the gain of the receiver will need to be increased to obtain the correct operating conditions. The table of lengths ensures that the gain required will not be greater than that which is available at the receiver.

A transmitter or receiver may be installed up to 100 m from its power supply providing the loop resistance of the cable does not exceed 0.4 ohm.

TWO ADJOINING TRANSMITTERS

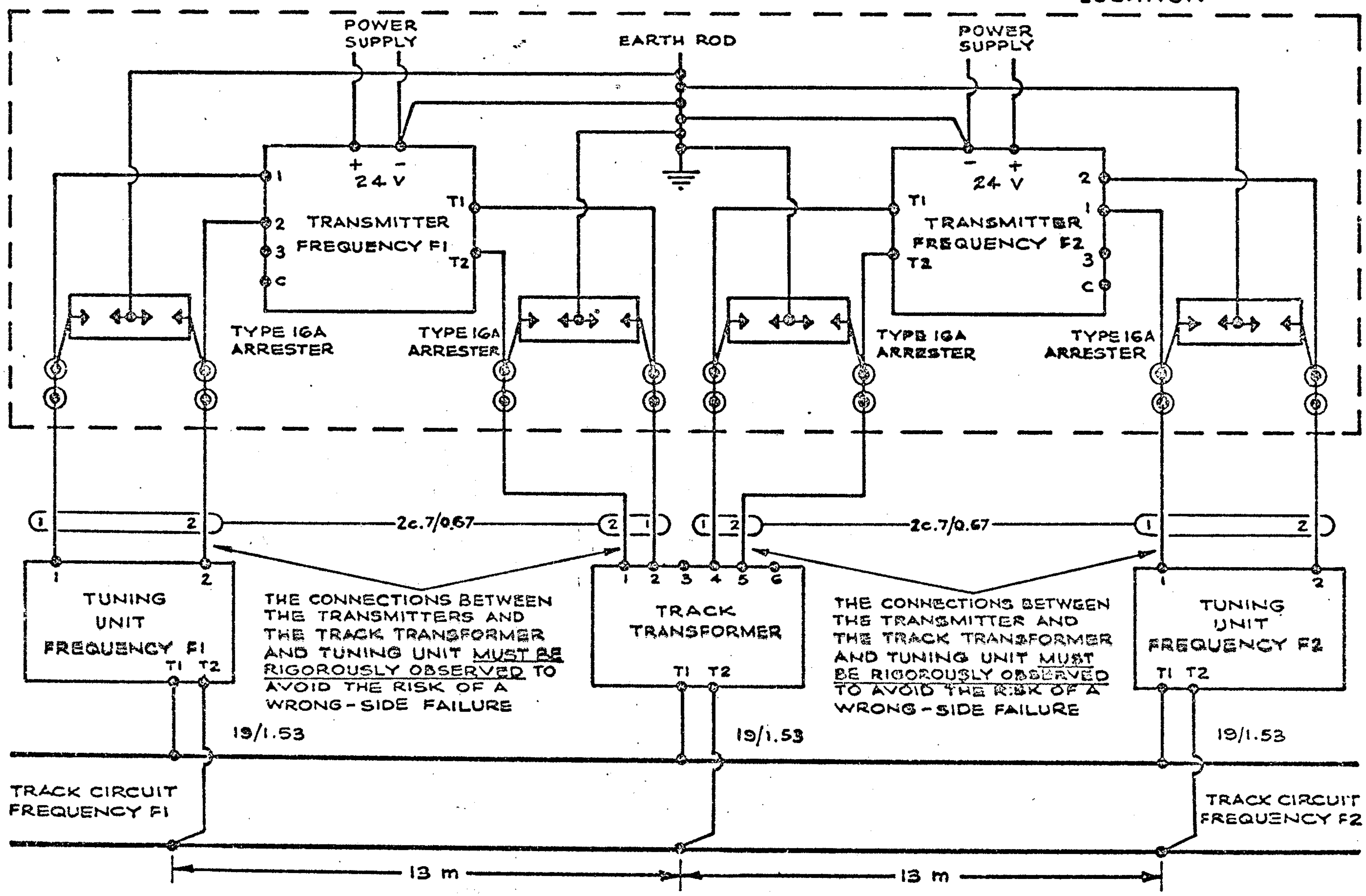


FIG. 8.1

ADJOINING TRANSMITTER AND RECEIVER

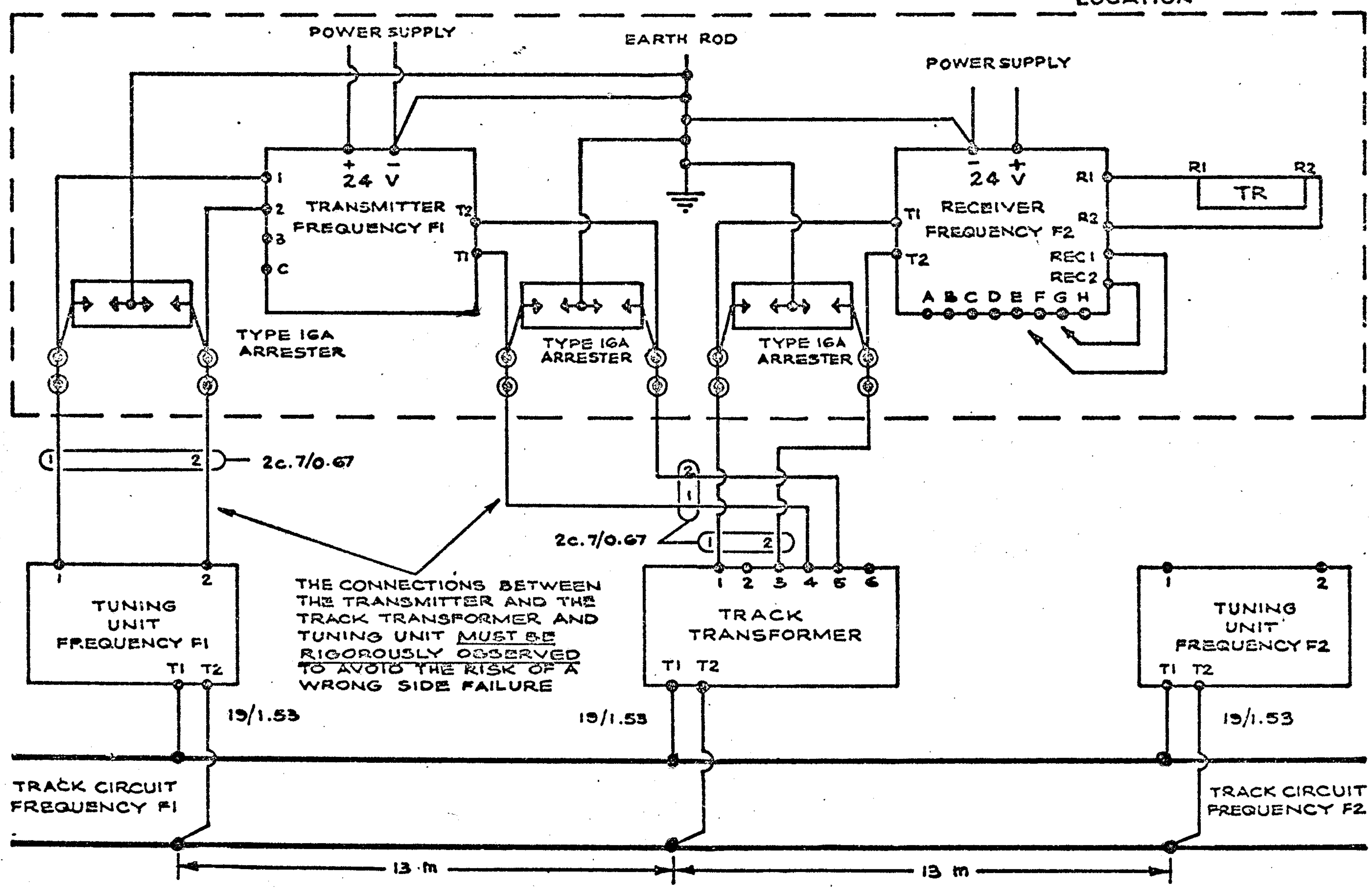


FIG. 8.2

TWO ADJOINING RECEIVERS

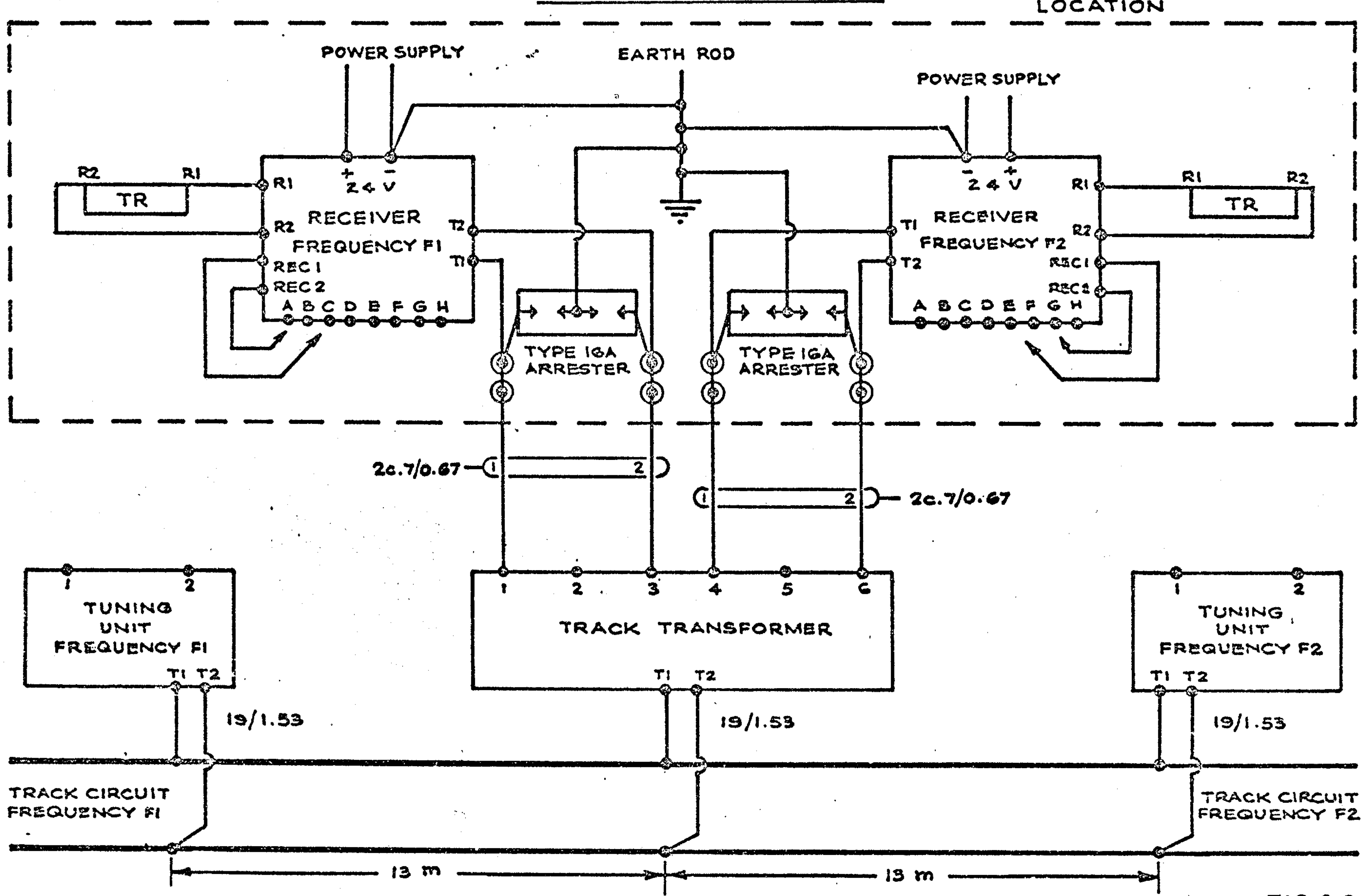


FIG. 8.3

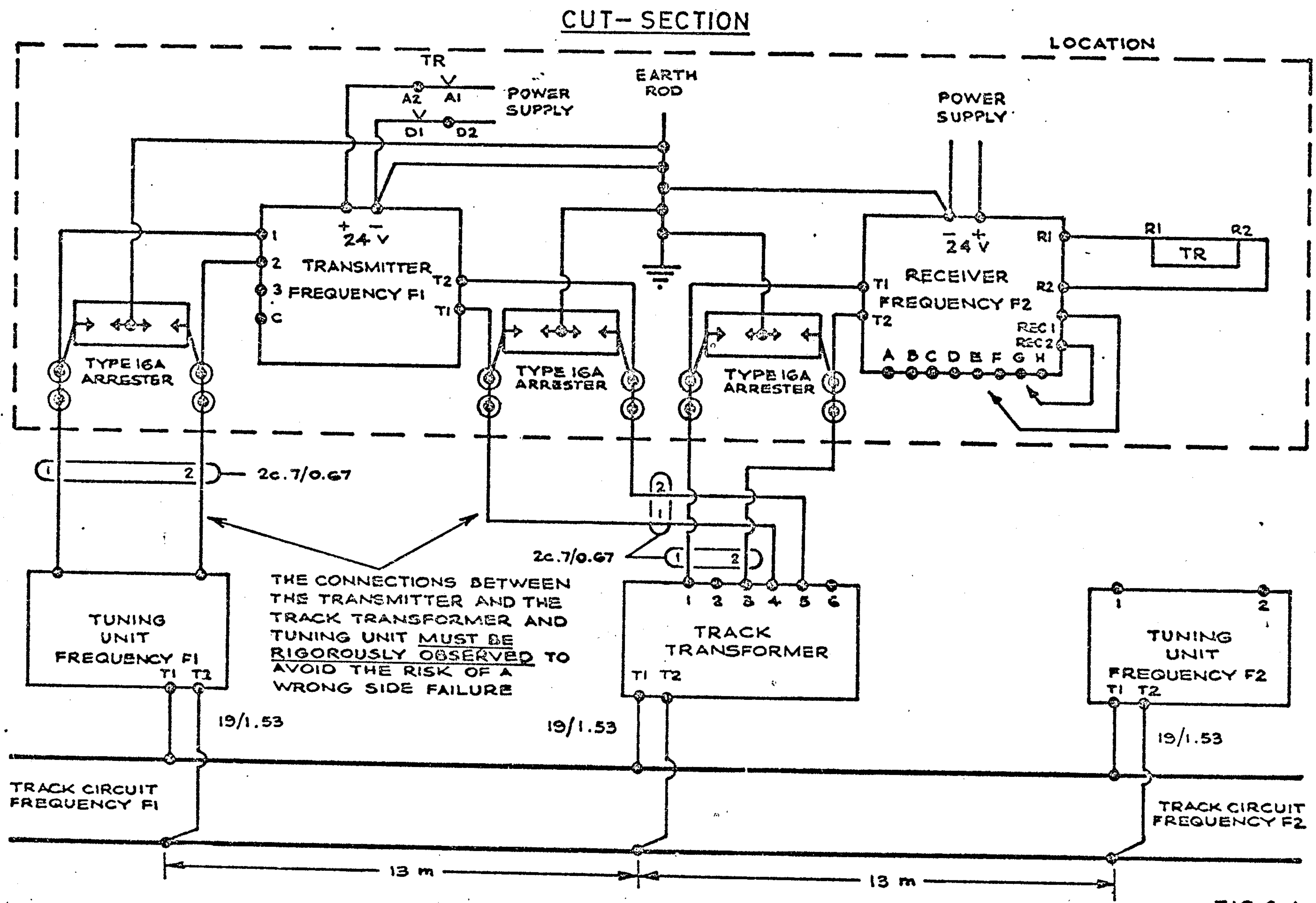

CUT- SECTION
LOCATION
TR
A2 A1
D1 D2
POWER SUPPLY
EARTH ROD
POWER SUPPLY
+ − 24 V
1
2
3
C
TRANSMITTER FREQUENCY F1
T2
T1
− + 24 V
R1
R2
TR
RECEIVER FREQUENCY F2
T1
T2
REC1
REC2
A B C D E F G H
TYPE 16A ARRESTER
TYPE 16A ARRESTER
TYPE 16A ARRESTER
2c.7/0.67
2c.7/0.67
THE CONNECTIONS BETWEEN THE TRANSMITTER AND THE TRACK TRANSFORMER AND TUNING UNIT MUST BE RIGOROUSLY OBSERVED TO AVOID THE RISK OF A WRONG SIDE FAILURE
TUNING UNIT FREQUENCY F1
T1 T2
1 2 3 4 5 6
TRACK TRANSFORMER
T1 T2
TUNING UNIT FREQUENCY F2
T1 T2
19/1.53
19/1.53
19/1.53
TRACK CIRCUIT FREQUENCY F1
TRACK CIRCUIT FREQUENCY F2
13 m
13 m

FIG. 8.4

CENTRE FED TRANSMITTER
1·7 kHz OR 2·0 kHz

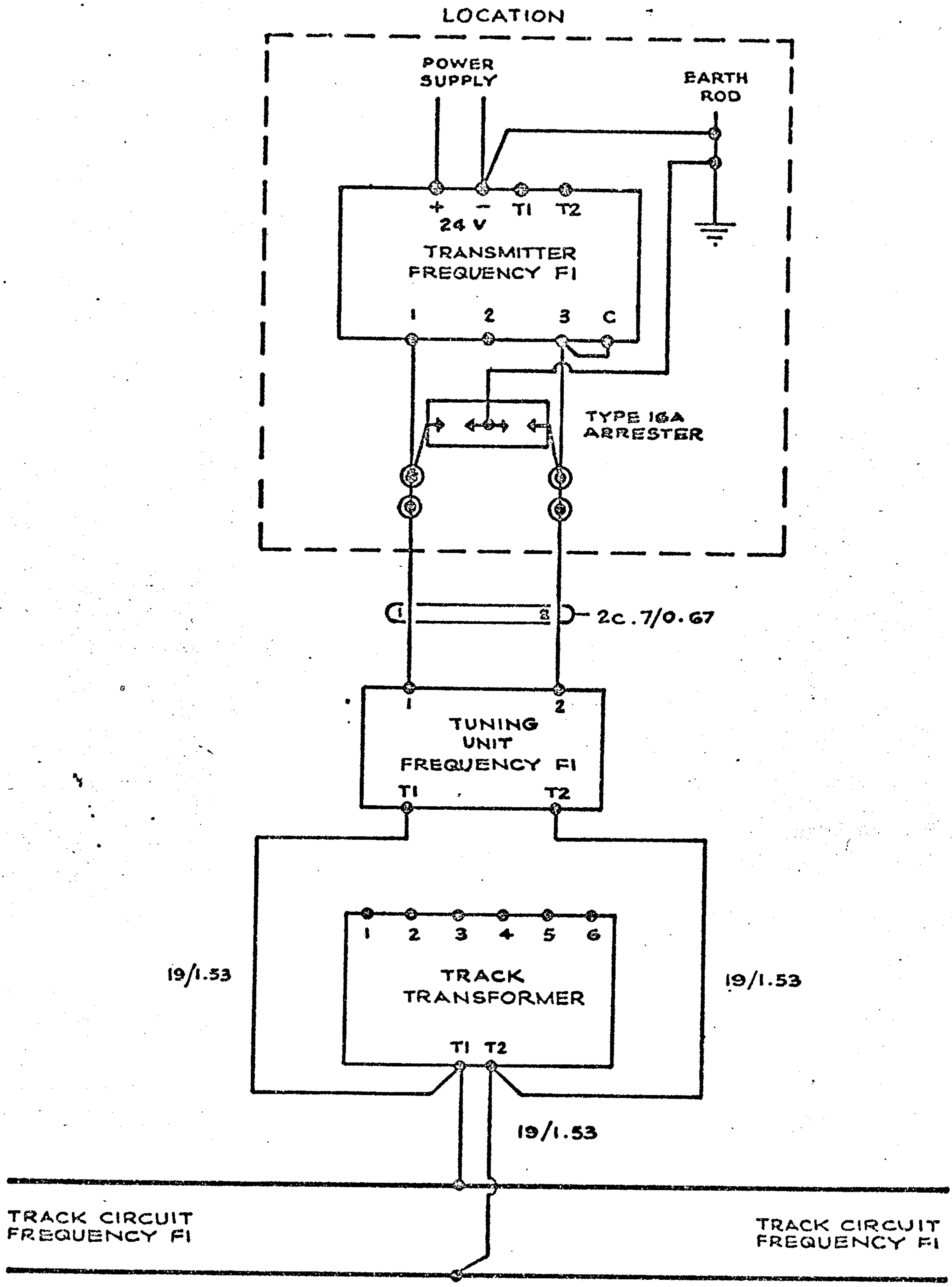


FIG. 8.5

CENTRE FED TRANSMITTER
2.3 kHz OR 2.6 kHz

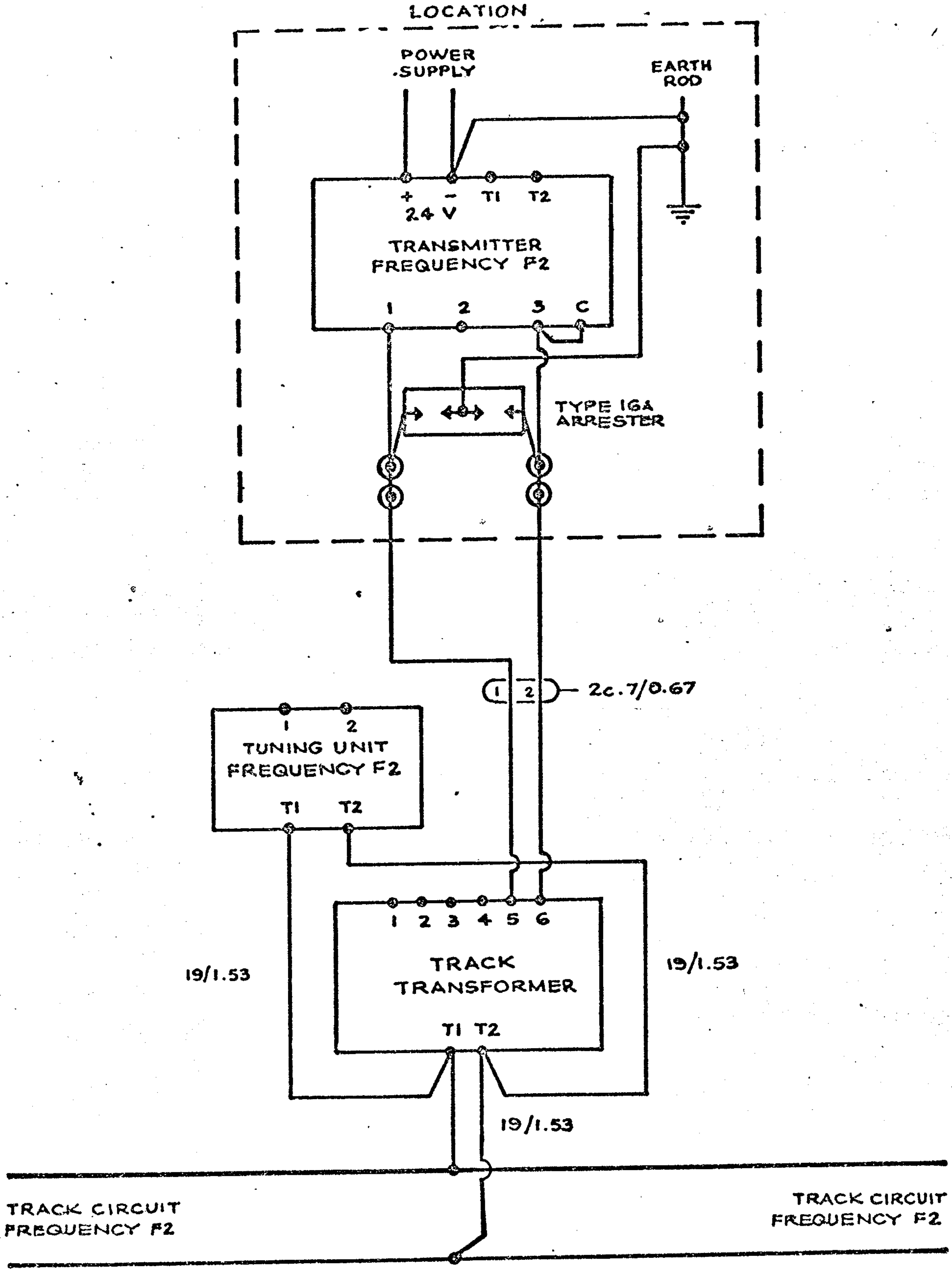


FIG. 8.6

TRANSMITTER ABUTTING CONVENTIONAL TRACK CIRCUIT

1·7 kHz OR 2·0 kHz

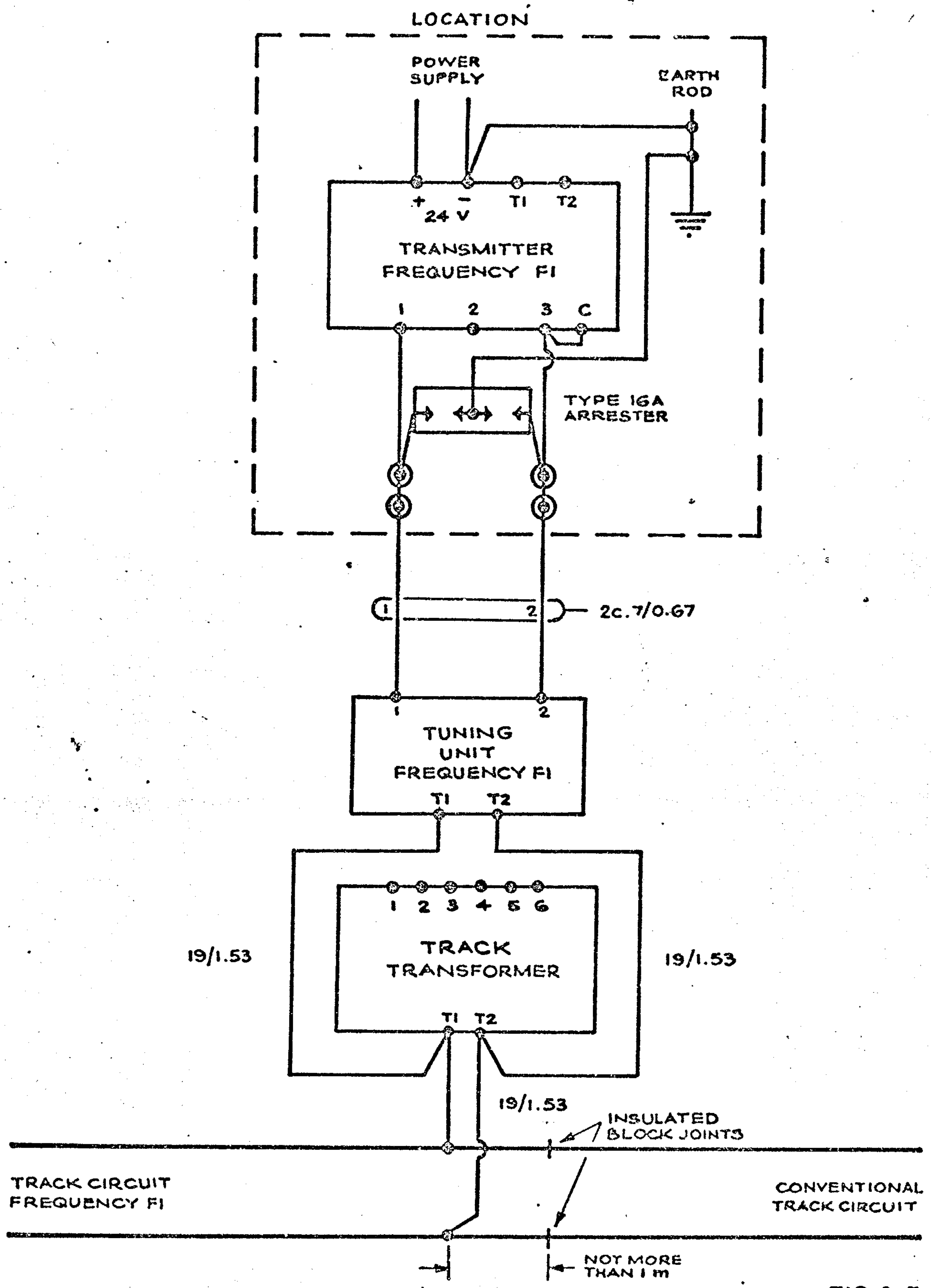


FIG. 8. 7

TRANSMITTER ABUTTING CONVENTIONAL TRACK CIRCUIT
2·3 kHz OR 2·6 kHz

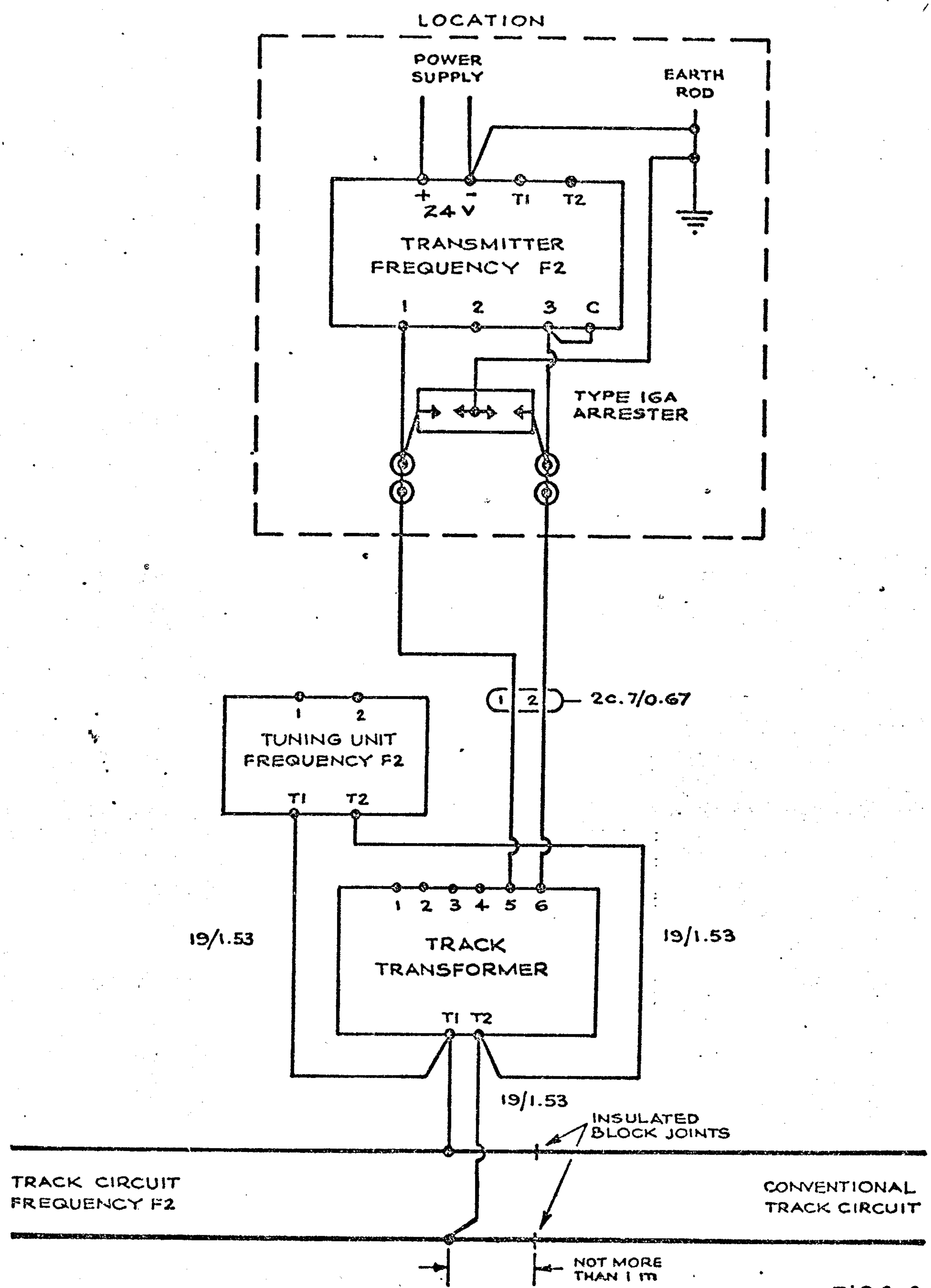


FIG.8.8

RECEIVER ABUTTING CONVENTIONAL TRACK CIRCUIT

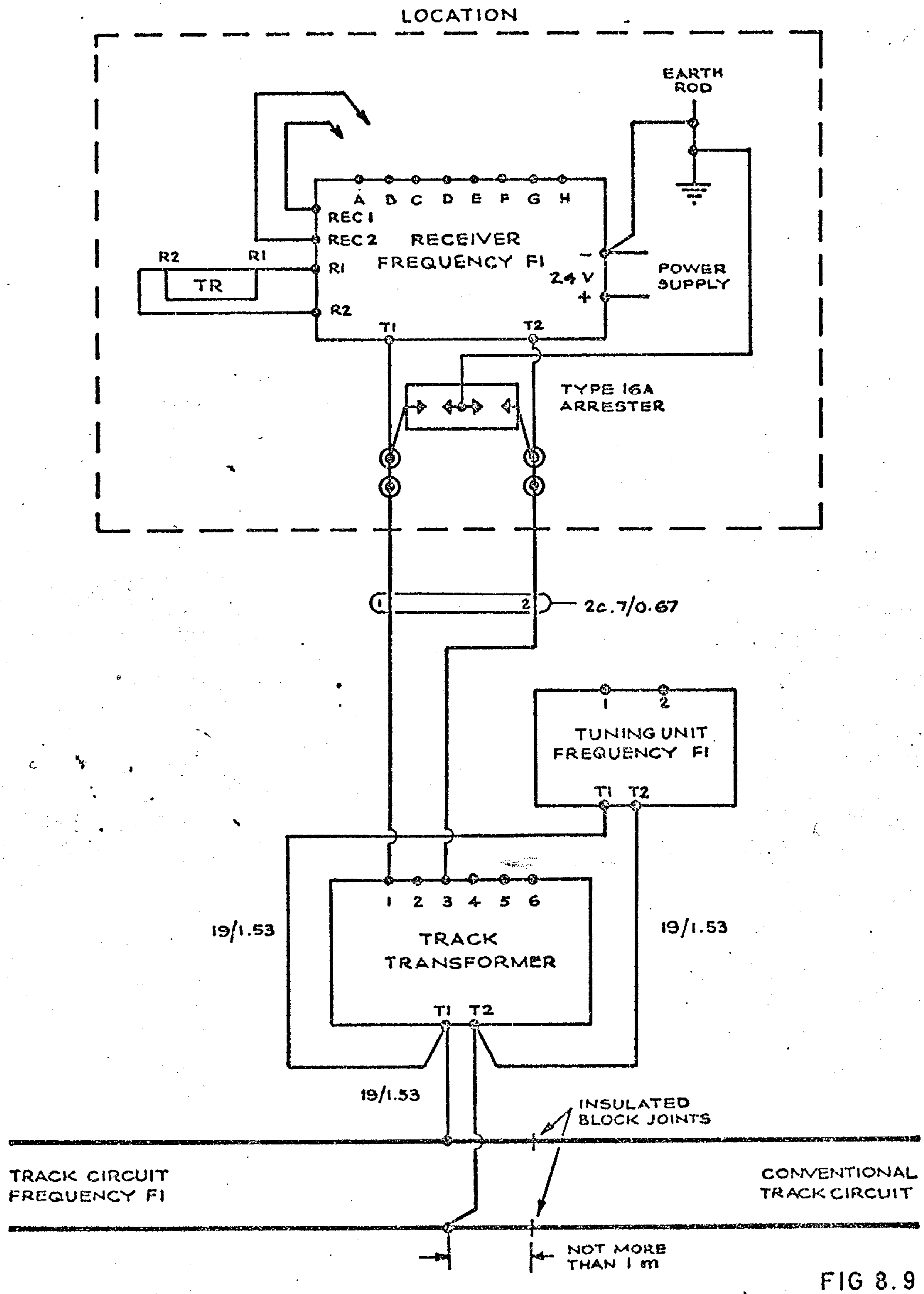


FIG 8.9

TRANSMITTER ABUTTING NON-TRACK CIRCUITED LINE

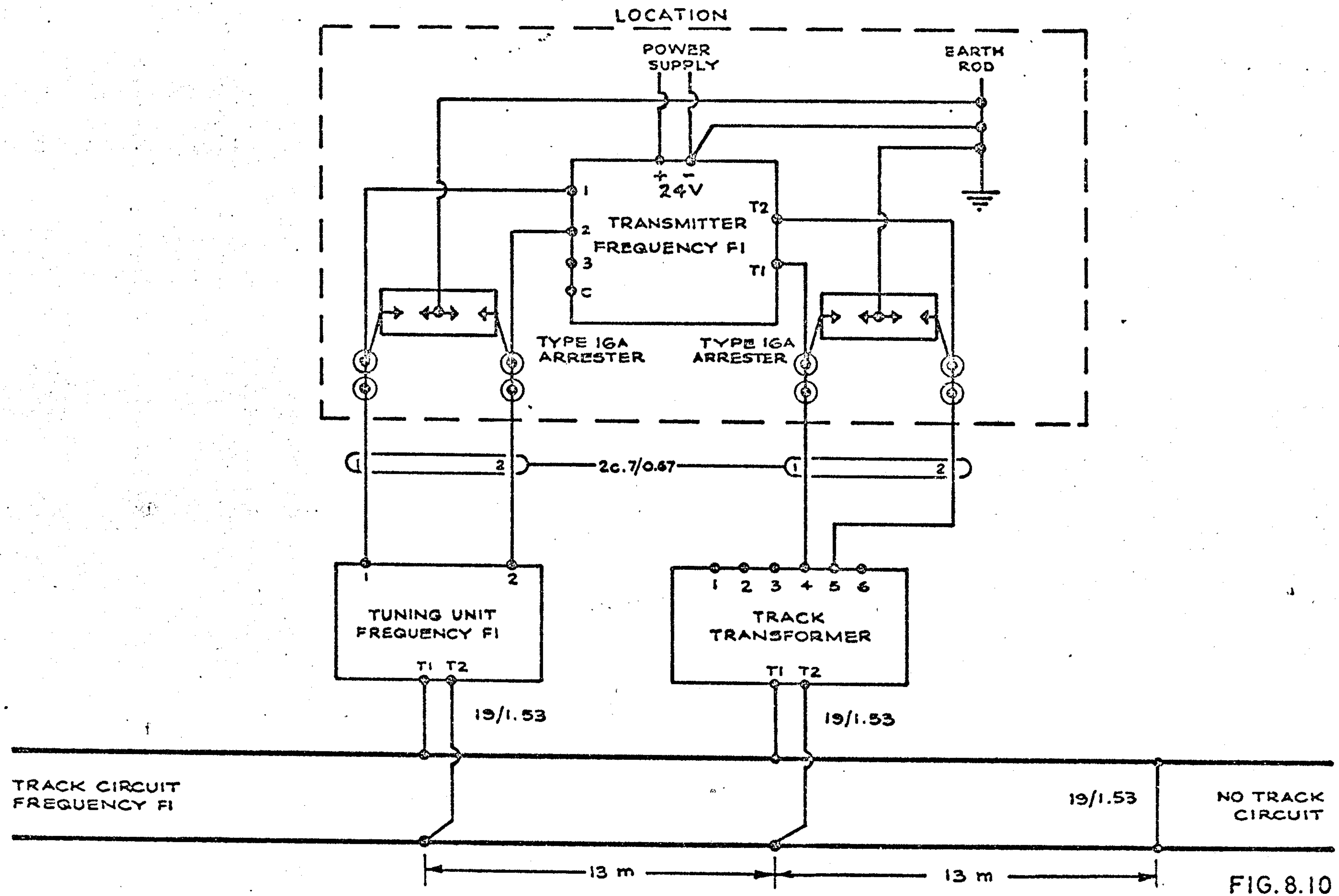


FIG. 8.10

RECEIVER ABUTTING NON-TRACK CIRCUITED LINE

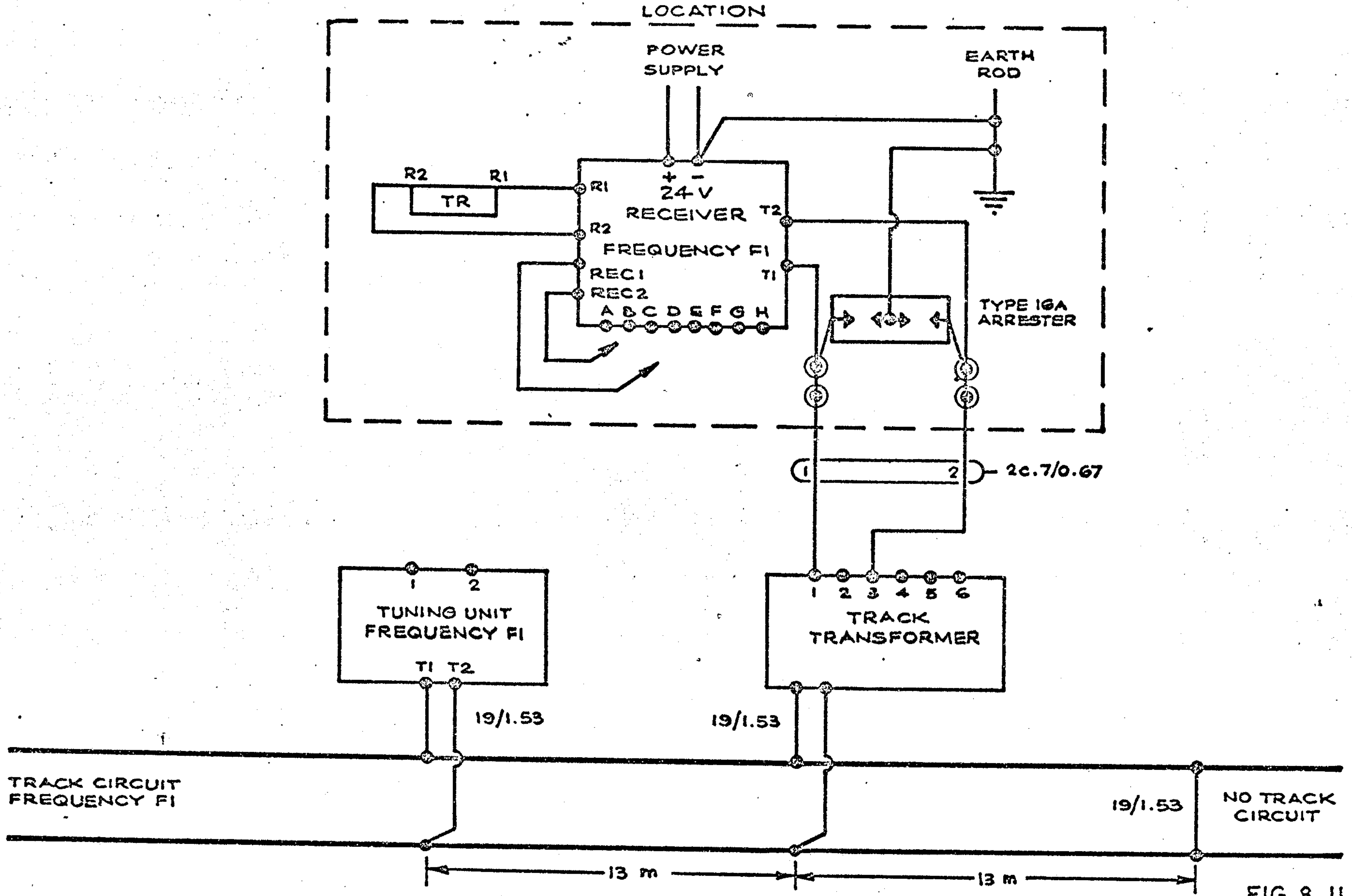
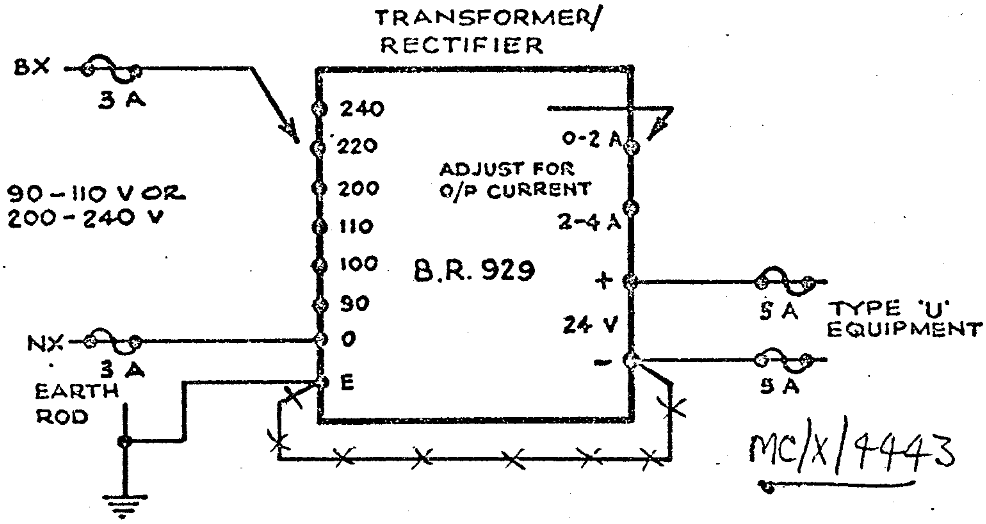
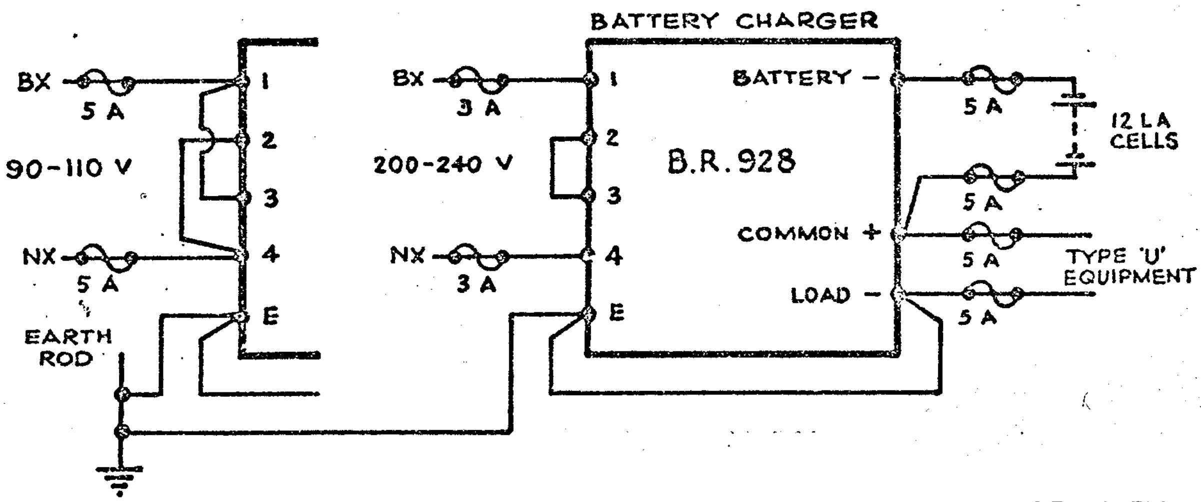


FIG. 8.11

POWER SUPPLY UNITS
WIRING DIAGRAMS



MC/X/4443 3/10/77



NX FUSES ONLY FITTED IF LOCAL PRACTICE REQUIRES THEM

IF IN ANY OF THE ABOVE ARRANGEMENTS THE AC POWER SUPPLY COMES FROM EITHER OPEN LINES OR AERIAL CABLE ON A POLE ROUTE THEN SURGE ARRESTERS ARE TO BE FITTED AS SHOWN HERE

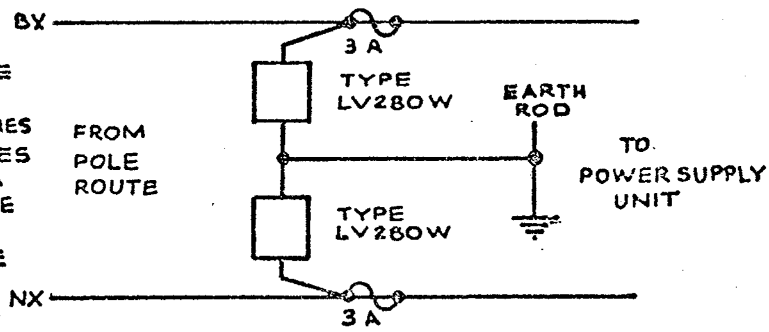
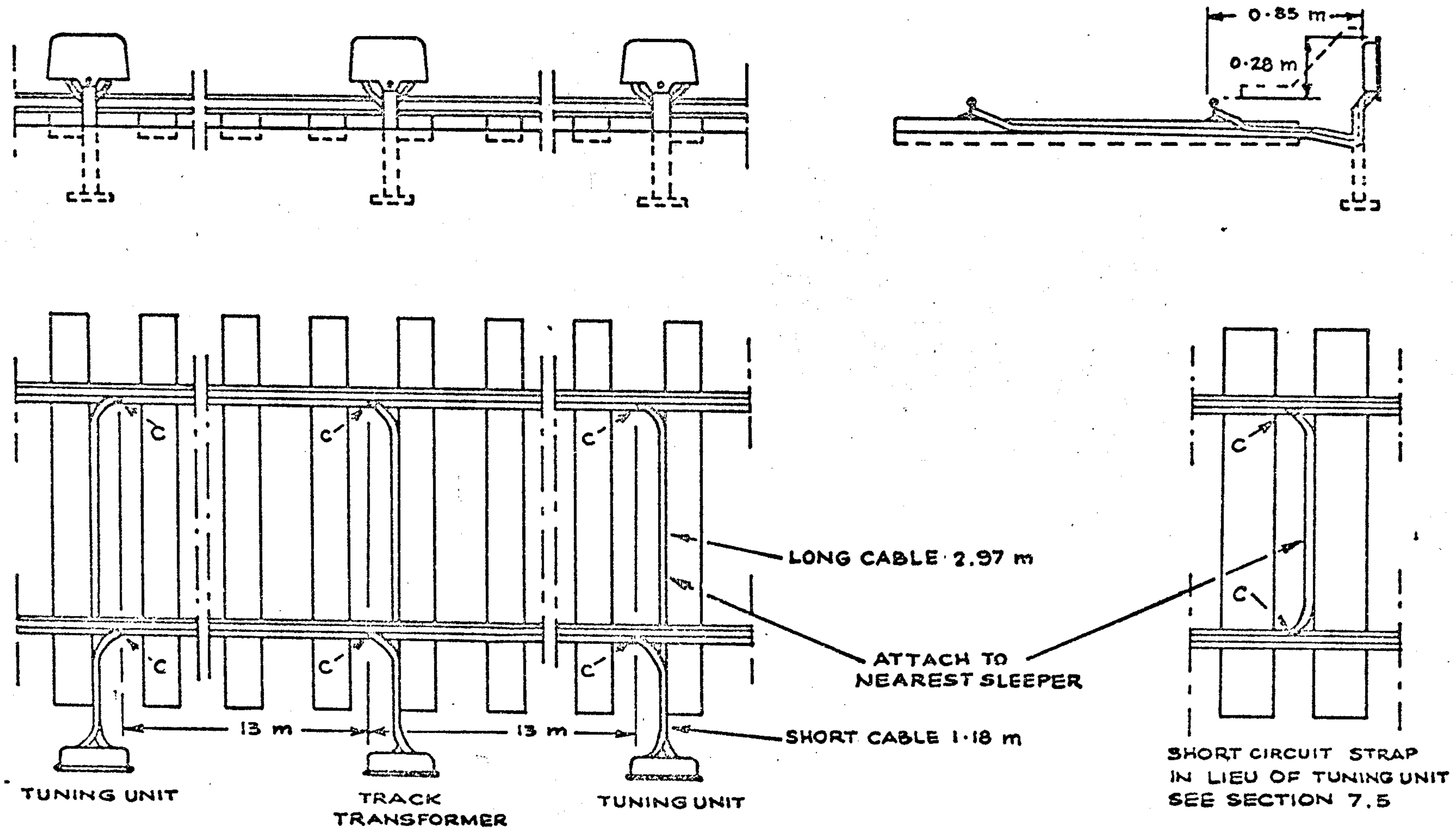


FIG. 8.12

INSTALLATION DIAGRAMS
STANDARD CONFIGURATION
JOINT (GENERAL CASE)
TRANSMITTER. RECEIVER AND AUXILIARY UNITS LOCATED ADJACENT



C = 'CADWELDED' RAIL CONNECTIONS

FIG.8.13

INSTALLATION DIAGRAMS
CENTRE – FED CONFIGURATION
TRANSMITTER AND AUXILIARY UNITS LOCATED ADJACENT

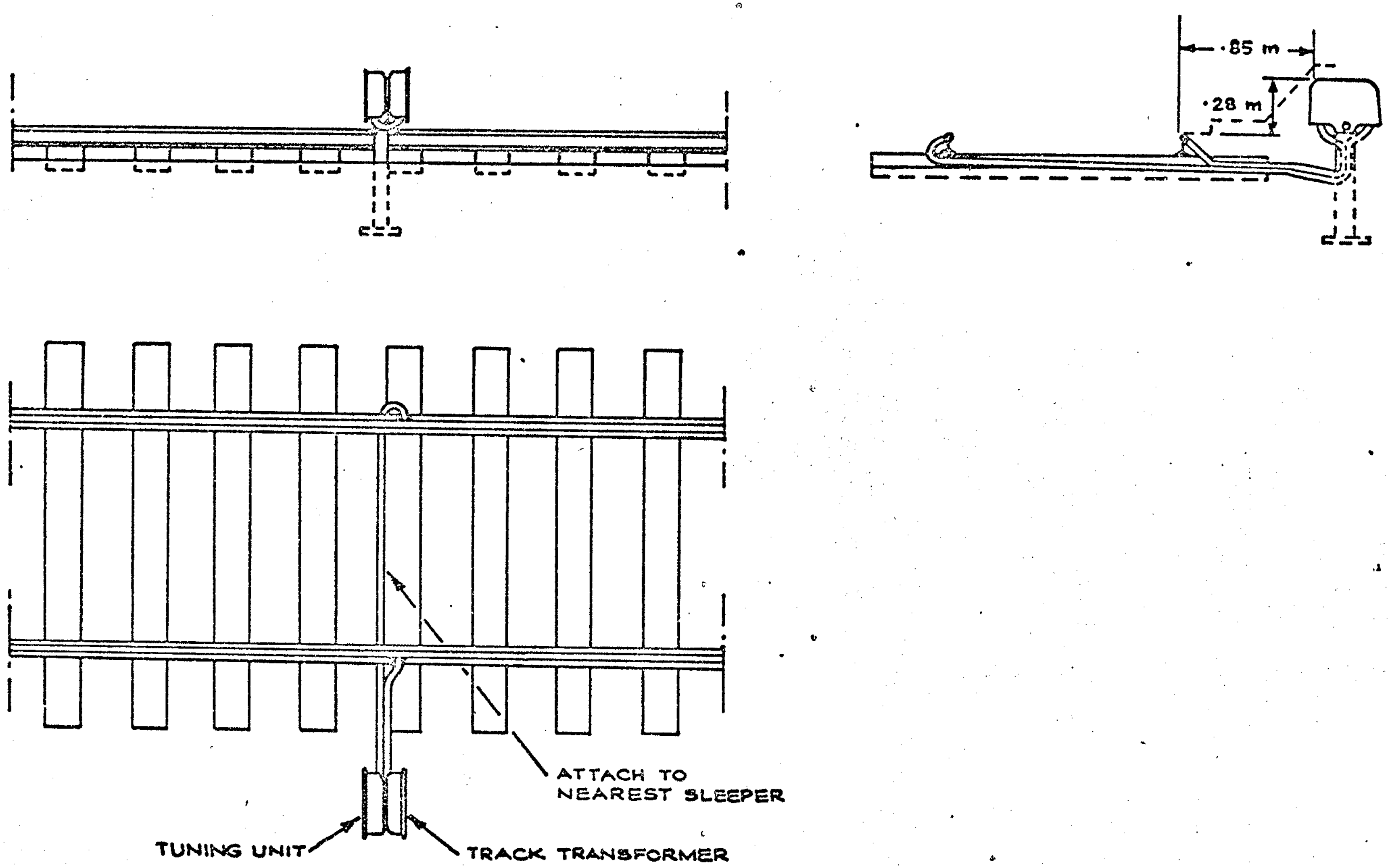


FIG. 8.14

9. ADJUSTMENT

9.1 Power Supply

The battery charger (to B.R. Specification No. 928) is provided with two input ranges either 90 - 110 V or 200 - 240 V and the wiring (Fig. 8.10) should be checked before switching on. There is an output voltage control which should be used to set the output voltage to 27.6 V with both the load and battery connected. If the battery charging current is about 100 mA then it should be capable of providing standby when required. The battery voltage should be checked within a few days of being set in work and the voltage control may need resetting if the battery was previously discharged.

The transformer/rectifier (to B.R. Specification No. 929) is provided with input tappings and the wiring (Fig. 8.10) should be checked before switching on to ensure that the right tap has been chosen. There is a choice of two output tappings depending on the load connected. If the total load (see table in section 7.10) is under 2 A then one tapping is used; if it is over 2 A the other is used. The output voltage should then be checked to see that it lies in the permitted range, 22.5 V to 29.5 V.

9.2 Transmitter

There is no means of adjustment of the transmitter output. If the supply voltage lies within the permitted range 22.5 V to 29.5 V then the rail voltage measured across the tuning unit to which the transmitter is connected should lie within the following limits:-

Track Circuit Length - Metres	Rail Voltage at Tuning Unit	
	Minimum	Maximum
50	1.6	2.7
1 000	2.5	5.3

When the track circuit is first installed the serial number of each Aster unit should be recorded together with:-

i) Supply voltage and current.

ii) Rail voltage across tuning unit.

iii) State of the ballast, dry or wet.

iv) Voltage between terminals T1 and T2 on the transmitter (for standard configuration track circuits only).

9.2 Transmitter (contd)

These readings are only required as a basis for comparison should a fault occur. They should only be taken again if an Aster unit is changed for any reason.

9.3 Receiver

The overall gain of the receiver may be adjusted by varying the turns ratio of the input transformer to the receiver. The wiring of this is shown in Fig. 5.0.1. The 49 steps of gain are obtained by connecting the terminals as shown in the table. The track circuit lengths are quoted as a guide only and the ratio required should be chosen to suit the conditions of the individual track circuit.

TABLE OF RECEIVER GAIN CONNECTIONS

Gain	Nominal length m	Rec. 1	Rec. 2	Strap
1		A	B	-
2	50	C	D	-
3		A	D	BC
4	100	D	E	-
5		A	E	BD
6		C	E	-
7		A	E	BC
8	200	E	G	CF
9		E	G	AF BD
10		E	G	DF
11		D	G	AF BC
12	300	D	G	CF
13		B	G	AF
14		F	G	-
15		A	G	BF
16	400	C	G	DF
17		A	G	BC DF
18		D	G	EF
19		A	G	BD EF
20	500	C	G	EF
21		A	G	BC EF
22		E	H	CG
23		E	H	AG BD
24	600	E	H	DG
25		D	H	AG BC

contd/....

9.3 Receiver (contd)

TABLE OF RECEIVER GAIN CONNECTIONS (CONTD)

Gain	Nominal Length m	Rec. 1	Rec. 2	Strap
26		D	H	CG
27		B	H	AG
28	700	G	H	–
29		A	H	BG
30		C	H	DG
31		A	H	BC DG
32	800	D	H	EG
33		A	H	BD EG
34		C	H	EG
35		A	H	BC EG
36	900	E	H	CF
37		E	H	AF BD
38		E	H	DF
39		D	H	AF BC
40	1 000	D	H	CF
41		B	H	AF
42		F	H	–
43		A	H	BF
44		C	H	DF
45		A	H	BC DF
46		D	H	EF
47		A	H	BD EF
48		C	H	EF
49		A	H	BC EF
–		–	–	–

9.3 Receiver (contd)

The rail voltage measured across the tuning unit can vary over a wide range but for a normal track circuit should lie within the following limits:-

Track Circuit Length - Metres	Rail Voltage at Tuning Unit	
	Minimum	Maximum
50	1.7	2.8
1 000	0.25	0.80

The power supply should first be checked that it lies in the permitted range 22.5 V to 29.5 V. The gain should then be chosen to give a track circuit with a drop-away shunt, taken across the rails at the tuning unit, between 0.5 ohm and 1.0 ohms. The relay voltage should lie between 28 V and 32 V.

When the track circuit is first installed the serial number of each Aster unit should be recorded together with:-

i) Supply voltage and current.

ii) Rail voltage across tuning unit.

iii) Train shunt (drop-away)

iv) State of the ballast, dry or wet.

v) Relay voltage.

vi) Voltage between terminals T1 and T2 on the receiver.

The Train shunt and relay voltage should be taken at the standard intervals laid down by regional instructions. The other figures need not be taken again but are required simply as a basis for comparison should a fault occur.

N.B. 1) The train shunt must never be taken direct across the relay coil as this would result in damage to the receiver.

2) When readings are being taken on the rails, track transformer, tuning unit, transmitter or receiver, voltages will be present from both Aster track circuits where two adjoin.

To avoid false readings the transmitter of the adjacent track circuit must be disconnected unless a frequency-selective voltmeter is being used.

10. FAULT CLEARANCE

10.1 General

10.1.1 The voltages recorded in accordance with sections 9.2 and 9.3 are required as a standard of comparison for fault finding.

10.1.2 When two adjoining track circuits fail simultaneously it is most probable that the fault is at the junction of the two track circuits, in the power supply, tuning units, or associated connections.

10.1.3 In the case of an individual track circuit failure, testing may commence at either the feed or relay end, as convenient.

10.2 FEED END (See Fig. 10.2)

10.2.1 If the transmitter is not emitting its characteristic "singing" note, then either the power supply or the transmitter has failed.

10.2.2 Check that the supply voltage to the transmitter is in the range 22.5V to 29.5V and adjust if necessary.

10.2.3 Check the rail voltage at the transmitter tuning unit. If this voltage is correct, go to the relay end and carry out the procedure of section 10.3, if not carry on as follows.

If the voltage has fallen by more than approximately one third of the initial value recorded, then check the transmitter as follows:-

Connect a shunt box set to 10 ohms to the transmitter side of the links in the leads connected to terminals 1 and 2 or 3 of the transmitter, and then open the links. If terminal C of the transmitter is linked to terminal 3, disconnect C.

The voltage across the terminals of the shunt box should be not less than the appropriate value in the following table:-

Transmitter Frequency	Minimum Voltage
1.7 kHz	3.1
2.0 kHz	3.2
2.3 kHz	4.0
2.6 kHz	4.0

If a shunt box is not conveniently available, the links should not be opened; instead the supply current should be checked. If this differs by more than approximately one third of the recorded value, then the transmitter is probably at fault and should be changed.

(Cont'd.)

10.2.4 If the transmitter is functioning correctly check all the connections to the tuning units and track transformer.

10.2.5 Where two Aster track circuits adjoin, measure the rail voltage at the transmitter tuning unit when the rail terminals of the tuning unit of the other track circuit are short-circuited. If this produces an increase in rail voltage, replace the tuning unit of the other track circuit.

N.B. This test will shunt the adjoining track circuit.

10.2.6 If none of the preceding tests has cleared the fault, replace the transmitter tuning unit.

If this does not clear the fault, replace the air-cored transformer, and then the transmitter.

FEED END

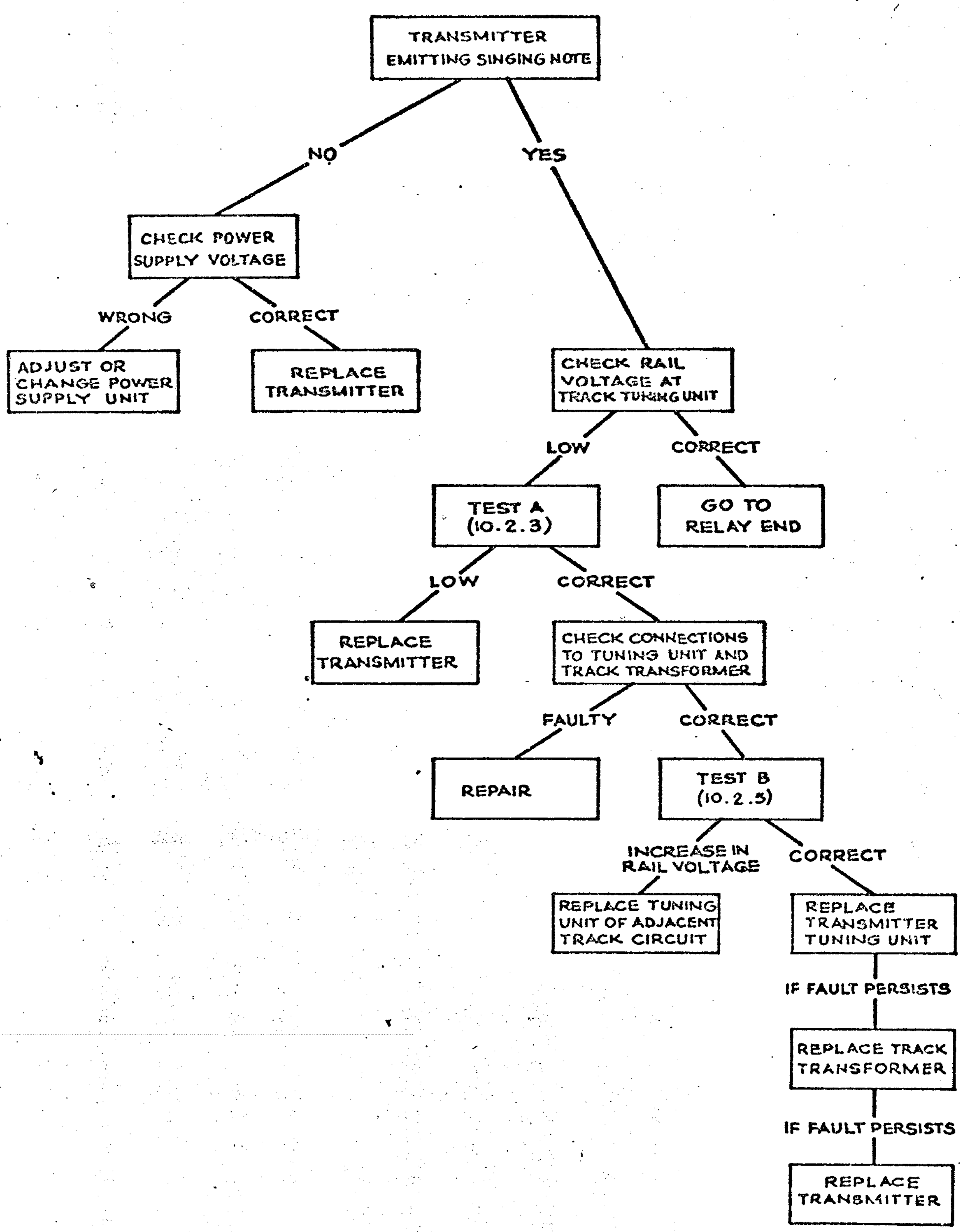


FIG. 10. 2

10.3 RELAY END (See Fig. 10.3)

10.3.1 Check the rail voltage across the receiver tuning unit. If this has fallen by more than approximately one third of the initial value recorded, go to the transmitter and follow through the procedure of section 10.2.

10.3.2 If the transmitter is working correctly, and the rail voltage across the receiver tuning unit is low, proceed as follows:-

(a) Check all tuning unit, track transformer, and receiver connections;

(b) Where the relay end adjoins another Aster track circuit, measure the rail voltage across the receiver tuning unit with the rail terminals of the tuning unit of the adjacent track circuit short-circuited. If the rail voltage is now correct, change the tuning unit of the adjacent track circuit;

N.B. This test will shunt the adjacent track circuit.

(c) Inspect the track for insulation faults;

(d) Change the receiver tuning unit;

(e) Change the track transformer;

10.3.3 If the rail voltage is correct check that the supply voltage to the receiver is in the range 22.5 V to 29.5 V and adjust if necessary

10.3.4 Check the connections to the receiver.

10.3.5 Check the relay voltage on terminals R1 and R2 of the receiver. If this is greater than 19 V with the relay de-energised, then the relay or wiring is faulty.

10.3.6 If the relay voltage is less than 19 V measure the voltage at terminals T1 and T2 of the receiver.

N.B. Where the relay end adjoins another Aster track circuit this voltage should be measured with a frequency selective voltmeter, or else the transmitter of the adjacent track circuit must be disconnected while the measurement is taken.

If the voltage is not less than two thirds of the original value recorded, the receiver should be changed.

If the voltage is less than two thirds of the original value recorded, check the connections to the track transformer and tuning unit, and, if necessary, change the track transformer, then the tuning unit, then the receiver.

RELAY END

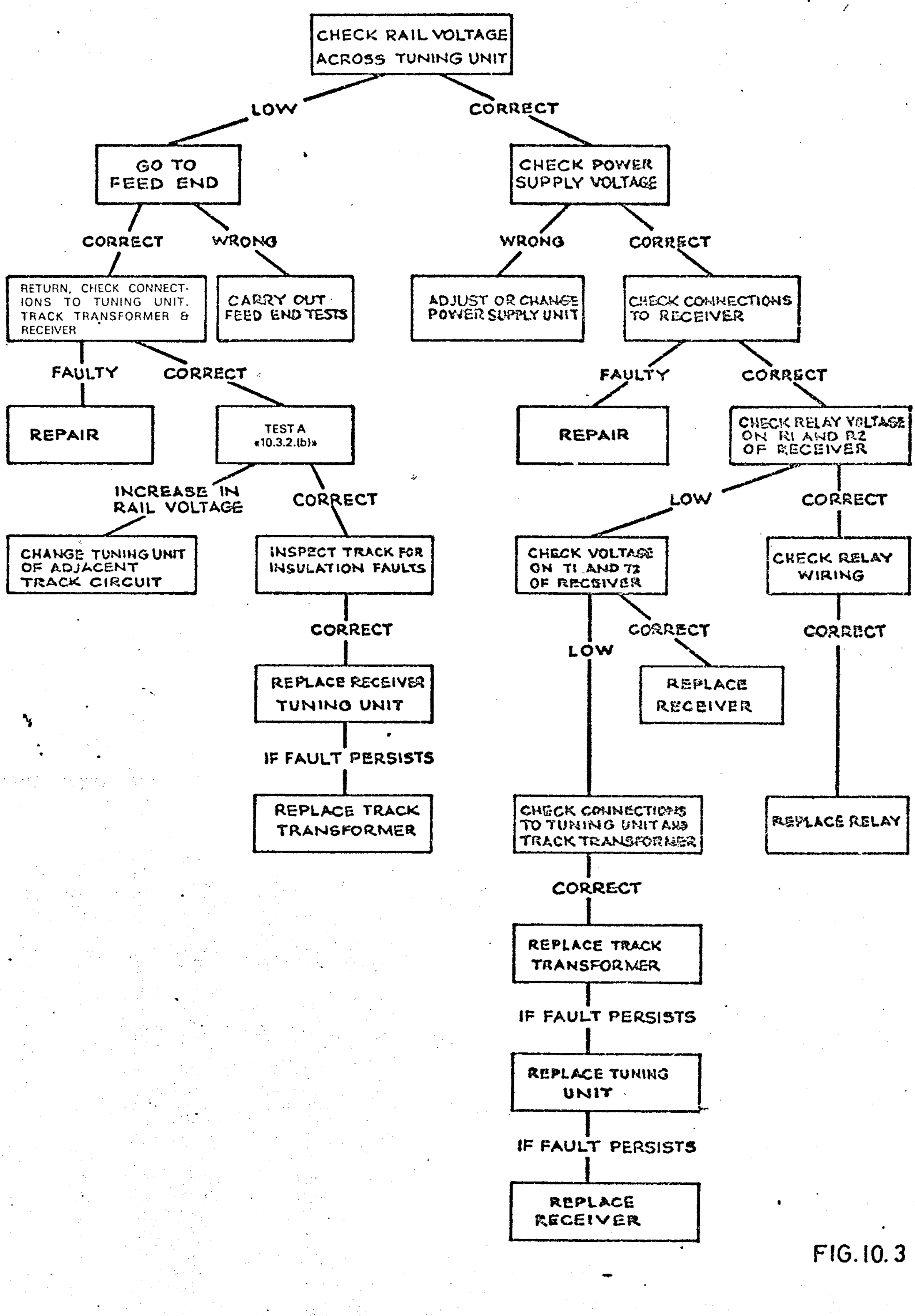


FIG. 10.3

11. COMPATABILITY WITH 1 WATT ASTERS

11.1 Adjoining Track Circuits

11.1.1 It is not necessary to provide conventional track circuits with insulated block joints between an Aster 1 watt installation and and an Aster 'U' type installation, provided that appropriate frequency track circuits abut.

A hybrid track circuit of not longer than 500 m must link the two installations and only the 11 arrangements shown in the table below are to be used. NO OTHER ARRANGEMENT IS TO BE ATTEMPTED.

In three of the permitted arrangements, special units are required, which are available on request. The remaining arrangements use no equipment other than standard Aster components of the appropriate type.

11.1.2 In arrangement A1-A4 (See figure 11.1.2) the link track circuit is of the 1 watt type, feeding through the Z-bond in the normal manner and being received by 'U' type equipment. A 14 μF padder capacitance retunes the 1.7 kHz tuning units to 1.62 kHz in arrangement A1. A 14 μF padder retunes each tuning unit (2.6 kHz and 2.0 kHz) for 1.86 kHz to be received in arrangement A2.

2.34 kHz and 2.58 kHz are received through 2.3 kHz and 2.6 kHz tuning unit without modification.

It is essential in arrangements A1-A4 that the link track circuit should abut the receiver end of the 'U' type circuit.

11.1.3 In arrangement B5-B8 (See Fig. 11.1.3), the link track circuit is of the 'U' type being received through the Z-bond. 1.7 kHz, 2.3 kHz, and 2.6 kHz may be received respectively through the 1 watt 1.62 kHz, 2.34 kHz, and 2.58 kHz receiver tuning units but a special 1.86 kHz 'U' type transmitter must be used in arrangement B6 together with 14 μF padders re-tuning the 'U' type 2.0 kHz and 2.6 kHz tuning units, and a 1 watt style receiver.

11.1.4 Arrangement C9-C11 (See Fig. 11.1.4) are similar to arrangement B, but the link track circuit is in one half of a centre-fed 'U' type. 1.7 kHz, 2.3 kHz, and 2.6 kHz are again received through 1 watt tuning units but a 2.0 kHz 'U' type must not be used in this arrangement.

11.2 Parallel Track Circuits

Where jointless track circuits are installed on adjacent lines, the difference in frequency between the track circuits must not be less than 200 Hz.

COMPATABILITY WITH 1 WATT ASTERS

	Combination	1 watt	Link			'U' Type
Arrangement A		(Relay end)	(Feed end)		(Relay end)	(Relay end)
	1	2.1 kHz	(1 watt)	1.62 kHz	(1 watt)	2.3 kHz (Mod)
	2	2.34 kHz	(1 watt)	1.86 kHz	(1 watt)	2.6 kHz (Mod)
	3	2.82 kHz	(1 watt)	2.34 kHz	(1 watt)	1.7 kHz
	4	1.62 kHz	(1 watt)	2.58 kHz	(1 watt)	2.0 kHz
Arrangement B		(Feed end)	(Relay end)		(Feed end)	(Relay end)
	5	2.58 kHz	('U' type)	1.7 kHz	('U' type)	2.3 kHz
	6	2.82 kHz	(1 watt)	1.86 kHz	('U' type) (special)	2.6 kHz (Mod)
	7	1.86 kHz	('U' type)	2.3 kHz	('U' type)	1.7 kHz
	8	2.1 kHz	('U' type)	2.6 kHz	('U' type)	2.0 kHz
Arrangement C		(Feed end)	(Relay end)		(Centre fed)	
	9	2.58 kHz	('U' type)	1.7 kHz	('U' type) 1.7 kHz	
	10	1.86 kHz	('U' type)	2.3 kHz	('U' type) 2.3 kHz	
	11	2.1 kHz	('U' type)	2.6 kHz	('U' type) 2.6 kHz	

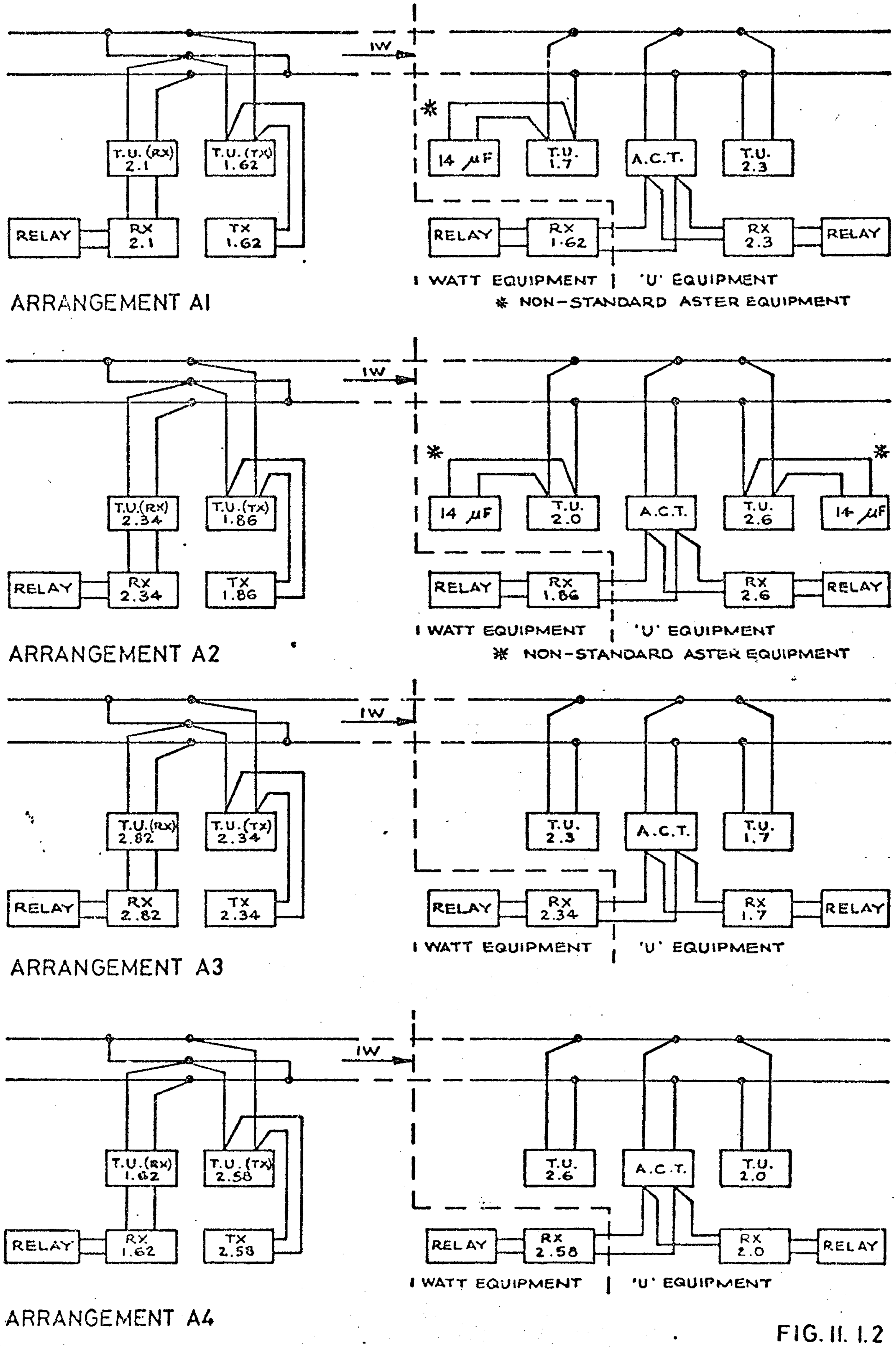
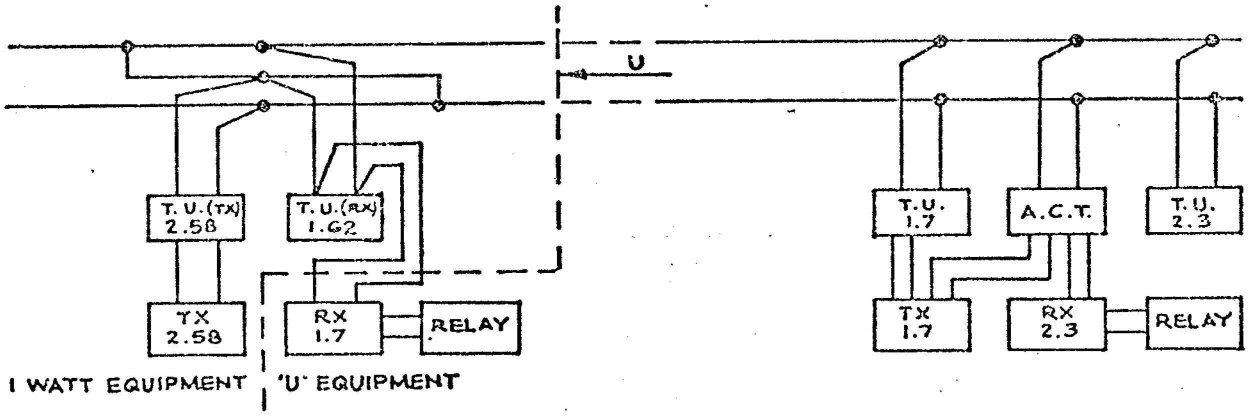
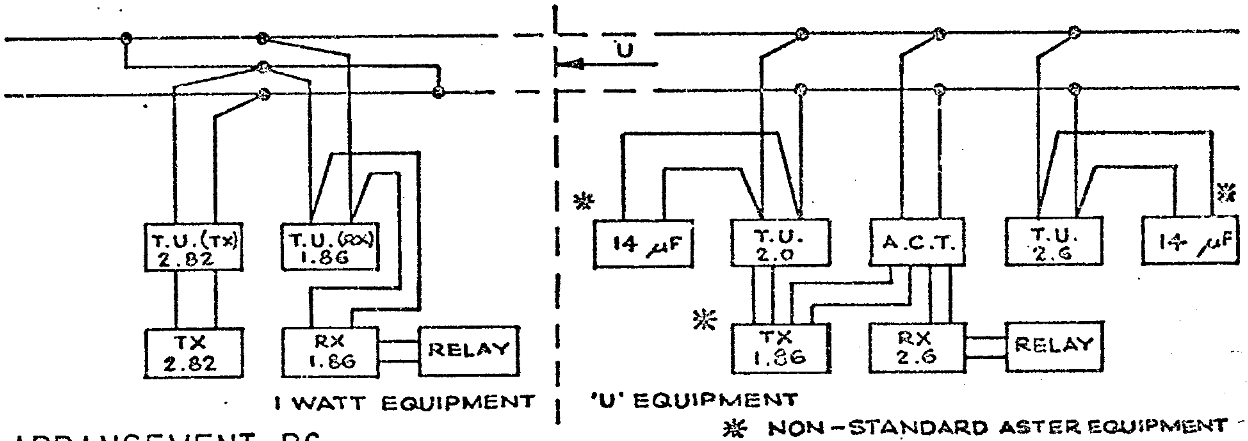


FIG. II. 1.2

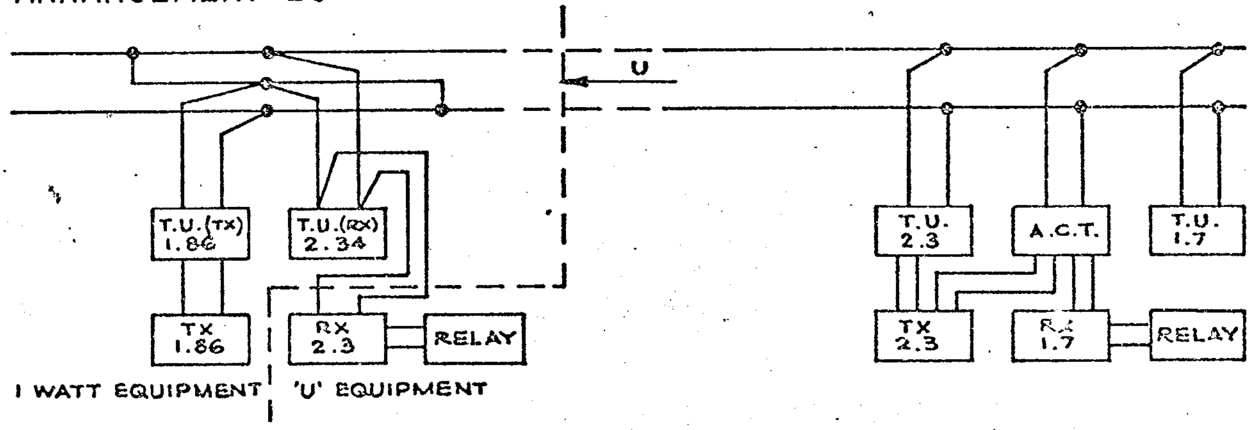
 (Amended November 1977)



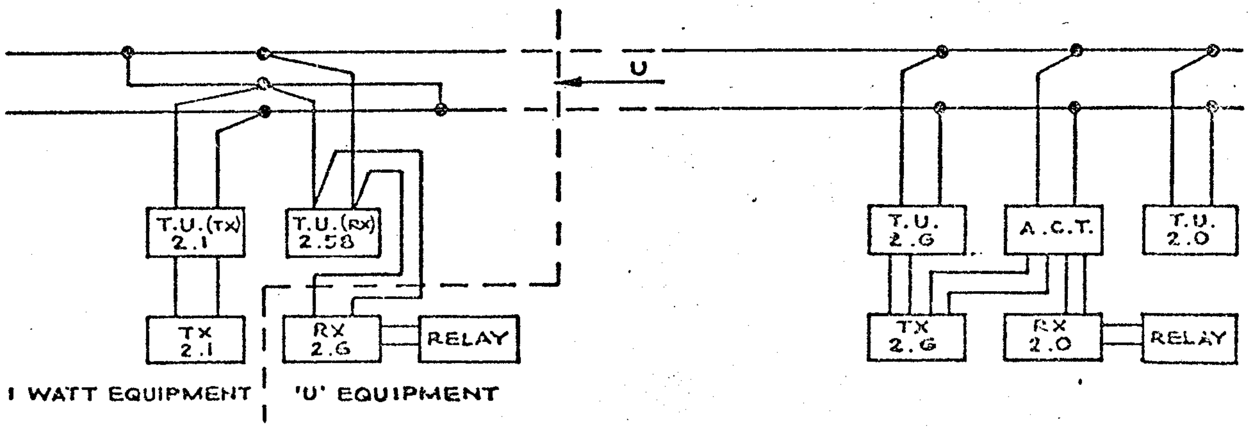
ARRANGEMENT B5



ARRANGEMENT B6



ARRANGEMENT B7



ARRANGEMENT B8

FIG. II. 1.3