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METHODS OF MINIMIZING INTERFERENCE AT RECEIVING INSTALLATIONS

1. General.—In about 20% of the sound broadcast interference complaints investigated it is found that the major cause of interference is an inefficient aerial-earth system; it is probable that the percentage of complaints in which a poor aerial-earth system is a factor contributing to poor reception is even higher. Apart from the legal provisions of the Wireless Telegraphy Act, 1949, there is a moral obligation on the part of a listener or viewer to take all reasonable precautions to minimize interference before an owner of plant causing interference is put to the expense of applying remedial measures. This Instruction explains what the listener or viewer can do to obtain reception with a minimum of interference, particular importance being attached to the need for a good aerial-earth system.

2. Factors determining the severity of interference.—The severity of interference at a receiving installation depends upon the following factors:—

(a) The magnitude of the radio-frequency disturbance at its source

(b) The electrical coupling between the source and the aerial system of the radio receiver

(c) The field strength of transmissions being received

(d) The effective height of the receiving aerial.

3. The coupling between the source and the receiver may be expressed as the ratio of the interference voltage at the input terminals of the receiver to the noise voltage at the terminals of the plant causing the interference. If the noise voltage at the source is represented by v and the coupling by a , then the interference voltage injected into the receiver will be av . Also, if the field strength of a wanted radio or television transmission in the vicinity of the receiving aerial is e and the effective height of the aerial is h , then the signal voltage injected into the receiving aerial will be eh . The signal-to-noise (S/N) ratio at the input to the receiver will, therefore, be eh/av .

4. It is convenient to express these terms logarithmically as follows:—

Noise voltage $V = 20 \log_{10} v$ db. relative to one microvolt

Coupling $A = -20 \log_{10} a$ db.

Field strength of wanted signal $E = 20 \log_{10} e$ db. relative to one microvolt/metre

Effective height of aerial $H = 20 \log_{10} h$ db. relative to one metre

Signal/noise ratio $S/N = E + H - V + A$ db.

5. Factors within the control of the listener or viewer. Usually there is much the listener or viewer can do to improve reception and so make suppression at the source unnecessary, or at least less costly for the plant owner. The first object to be achieved is to make H as great as possible and A as small as possible. If interference is mainly propagated—and this accounts for the bulk of sound broadcasting interference complaints—a complainant having an indoor aerial should be advised to change it for a more efficient outdoor one. The outdoor aerial should have a greater effective height (H) and may have less coupling (A) compared with an indoor aerial, and the S/N ratio would be improved by the increase in the strength of the signal and the decrease in the strength of the interference. When interference is radiated directly from a source within a few yards of the receiving aerial it is often possible to reduce A by altering the position of the aerial, but when the source is some distance from the receiving aerial, altering the position of the aerial seldom results in any appreciable change in A . In the latter event, directional aerial systems and noise limiting circuits in the receiver are about the only means of improving the S/N ratio, and these methods are effective only if conditions for their use are favourable. The second object to be achieved is the attenuation of any noise voltages and currents that may be present in the mains supply. These objectives are dealt with in separate sections of this Instruction for sound broadcasting and television.

SOUND BROADCASTING

6. Basic requirements for good reception.—In designing a radio receiving installation for interference-free reception the main factors to be considered are

(a) the aerial-earth arrangements

(b) the position of the receiver

(c) the condition of the electrical installation, and

(d) the use of mains filters.

These factors are all in some degree within the control of the listener. Selection of the receiving station site—probably the most important factor—is not usually within the control of the average broadcast listener and is therefore not taken into account.

7. Aerial-earth arrangements.—In general, a receiver cannot operate satisfactorily without an efficient aerial-earth system. Local screening may considerably reduce the effective height of a receiving aerial, and thus the effective height of any indoor aerial (particularly one used in a steel-framed building) will be small compared with even a short outdoor aerial erected above the roof of the building.

8. The smaller the aerial the less effective it is at the lower frequencies, and it has to be remembered that a large number of listeners (over 60%, say the B.B.C.) depend on the Droitwich low-frequency (200 kc/s.) transmitter for reception of the "Light" programme. Attempts to increase the effective height of an indoor aerial by increasing its length usually result in a disproportionate increase in the coupling between receiver and interference source and in a decrease in the S/N ratio. For this reason the use of indoor aerials and particularly so-called "mains" aerials is strongly deprecated.

9. Although many modern receivers are capable of reproducing signals with just a short piece of wire attached to the aerial terminal, it is still desirable, for interference-free reception, that as large a signal voltage as possible should be available from the aerial, even though it may be necessary to attenuate some signals at the receiver's input terminals to avoid overloading. An outdoor aerial of reasonable physical height, erected as far as possible from buildings to avoid shielding and coupling to the house wiring, is therefore a necessary pre-requisite to good reception. Descriptions of various aerial systems are given in pars. 16 to 28.

10. The S/N ratio of the receiving installation can be further increased by using an efficient earth-connexion. A really efficient earth-connexion would consist of an insulated stranded-copper cable of about 0.0045 sq. in. section taken from the receiver earth terminal by the shortest available route to the nearest rising water main or to an earth-electrode driven six feet into the ground.

11. *Position of receiver.*—For satisfactory reception the receiver should be situated as near as possible to the aerial lead-in point, unless an anti-interference aerial is used (see pars. 22 to 28). If reception is required in more than one room it is preferable to use extension loudspeakers rather than to extend the aerial lead. The object of these precautions is to prevent the indoor portion of the aerial from picking-up interference radiated by the mains-wiring in the building.

12. *Condition of the electrical installation.*—Faulty wiring, loose contacts in plugs and socket-outlets, loose fuse fittings, and faulty switch contacts are likely causes of interference; such defects are best avoided by regular inspection and maintenance. Attention should also be given to the efficient bonding and earthing of conduits and lead-sheathed cables, for by this means radiation from the wiring, and its pick-up by the receiving aerial, can be prevented to a certain extent. Intermittent or high-resistance contacts between sections of conduit or lead cable-

sheath, or between them and other metallic bodies such as gas or water pipes, are a frequent source of radio noise and cross-modulation interference. The conduits of the various services should be separated completely or else be bonded together with low-impedance connexions where they lie unavoidably close together.

13. *Mains filters.*—The most effective position in a complainant's premises for fitting a mains filter is at the first convenient point after the mains enter the premises; this is usually at the main double-pole switch, and the earth-connexion for the filter should be made to the metal sheath of the mains feeder-cable. By fitting a suitable radio-frequency filter in this position, the electrical wiring in the premises is freed from interfering currents and voltages, thus reducing the ill effects of the coupling which exists between the receiving aerial system and the house wiring. Design data for LC filters are given in E 0030.

14. The least effective position for a filter is at the mains socket-outlet feeding the receiver. Here, it will be useful only if the rest of the house wiring is well screened and if the main injection of the interference into the aerial-earth system is via the mains lead of the receiver. In this position the earth-connexion for the filter should be made to the earthed conduit or other earth continuity conductor of the house wiring, and not to the receiver earth-connexion.

15. *Limitations of mains filters.*—The efficacy of mains filters at complainant's premises, particularly in blocks of flats and houses which are not detached from other buildings, may be reduced by interference radiated from unscreened and unfiltered mains-wiring in adjacent premises.

16. *Aerial systems.*—The type of aerial to recommend for use in a particular case will depend on local conditions of reception and on the facilities available. Outdoor aerial systems may be grouped as follows:—

- (a) Simple outdoor aerials (see pars. 17 to 21)
- (b) Anti-interference aerials (see pars. 22 to 25)
- (c) Communal aerials (see pars. 26 to 28).

17. *Simple outdoor aerial systems.*—Four typical examples of simple outdoor aerials are shown in Figs. 1 to 4, and are described in pars. 18 to 21. The rod aerials have been classified "A" "B" and "C" by the Radio and Electronic Component Manufacturers' Federation according to dimensions and method of erection (see Figs. 1 to 3); the types of aerials recommended for different field strengths are given in Table 1.

TABLE 1

TYPES OF AERIAL RECOMMENDED BY THE RADIO AND ELECTRONIC COMPONENT MANUFACTURERS' FEDERATION FOR DIFFERENT FIELD STRENGTHS

Wave-band	Field Strength	Class of Aerial
Medium	Greater than 13.3 millivolts per metre	"A" "B" or "C"
	1.3 to 13.3 millivolts per metre	"A" or "B"
	660 microvolts to 1.3 millivolts per metre	"A"
Long	Greater than 40 millivolts per metre	"A" "B" or "C"
	4 to 40 millivolts per metre	"A" or "B"
	1 to 4 millivolts per metre	"A"

18. *Vertical rod aerial above roof*—Class "A" (see Fig. 1). This type consists of a metal rod 10—20 feet in length supported by, and insulated from, a bracket attached to the highest appropriate part of the

in length and is designed for fixing under the eaves of the normal two-storey building or to the gable of a pre-fabricated house.

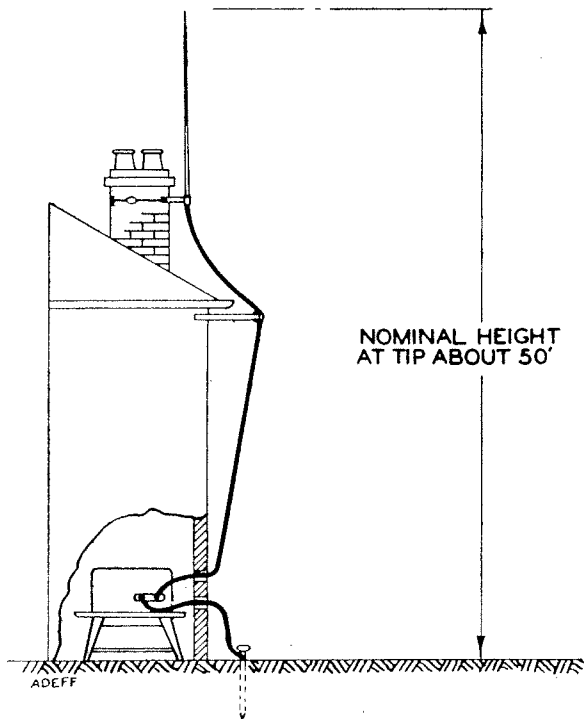


FIG. 1.—VERTICAL ROD AERIAL ABOVE ROOF—CLASS "A"

building—usually the main chimney stack. The insulated wire connecting the aerial to the receiver should be stood-off from roof and walls to minimize coupling to the house wiring, and should be protected from fouling the gutter.

19. *Vertical rod aerial at eaves level*—Class "B" (see Fig. 2). This aerial is usually less than 15 feet

20. *Window-sill rod aerial*—Class "C" (see Fig. 3) This is a rod aerial usually not more than 10 feet in length, inclined at an angle of about 30 degrees from the vertical to avoid projections from the building and to reduce screening. It is particularly useful in blocks of flats, and though less effective than Class "A" or "B" aerials, it is usually superior to an indoor aerial.

21. *Inverted "L" aerial* (see Fig. 4). This type usually consists of a horizontal wire with a lead-in from the near-end direct to the receiver, the whole forming roughly an inverted letter "L." The height above ground should be at least 20 feet and could with advantage be more, and the length of the horizontal portion should be at least equal to the height. On the long wave band this type has a better performance than the other types illustrated. The physical dimensions and methods of erection of horizontal aerials vary within wide limits according to the site facilities, and it is therefore not practicable to classify them.

22. *Anti-interference aerial systems*.—Anti-interference aerials work on the principle that the signal pick-up portion of the aerial is placed outside the interference field and in a position favourable to the reception of the required transmissions; the aerial is then connected to the receiver by a screened down-lead with or without impedance-matching transformers. Simple screening of the down-lead alone removes the electric component of the interference field, leaving the magnetic component. It reduces the efficiency of the aerial to an extent depending on the length and characteristics of the screened lead; but if the length is not greatly in excess of 20 feet, and the capacitance not greater than about 20 pF. per foot, the interference will generally be attenuated

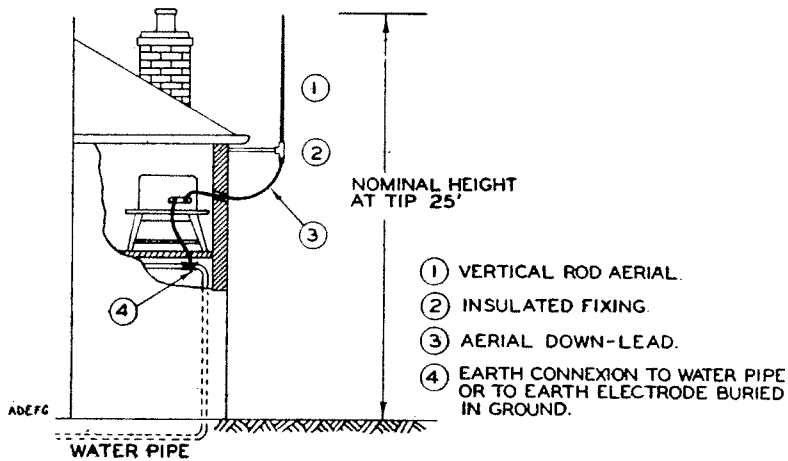


FIG. 2.—VERTICAL AERIAL AT EAVES LEVEL—CLASS "B"

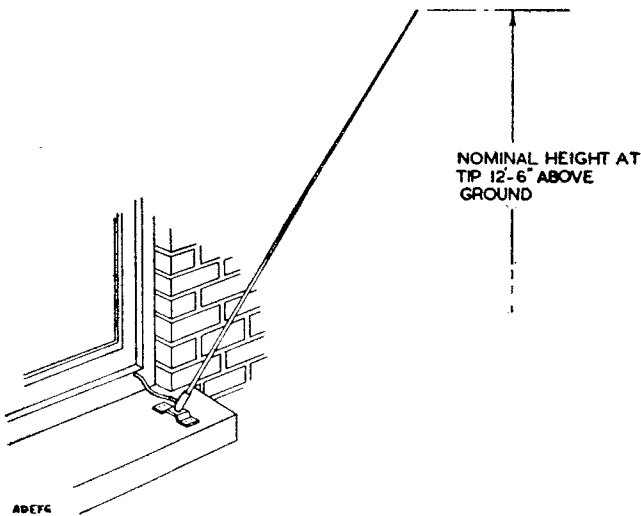


FIG. 3.—WINDOW-SILL ROD AERIAL—CLASS "C"

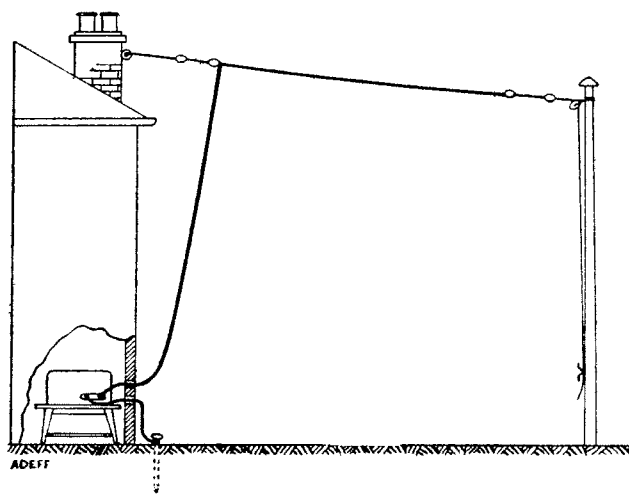


FIG. 4.—INVERTED "L" AERIAL

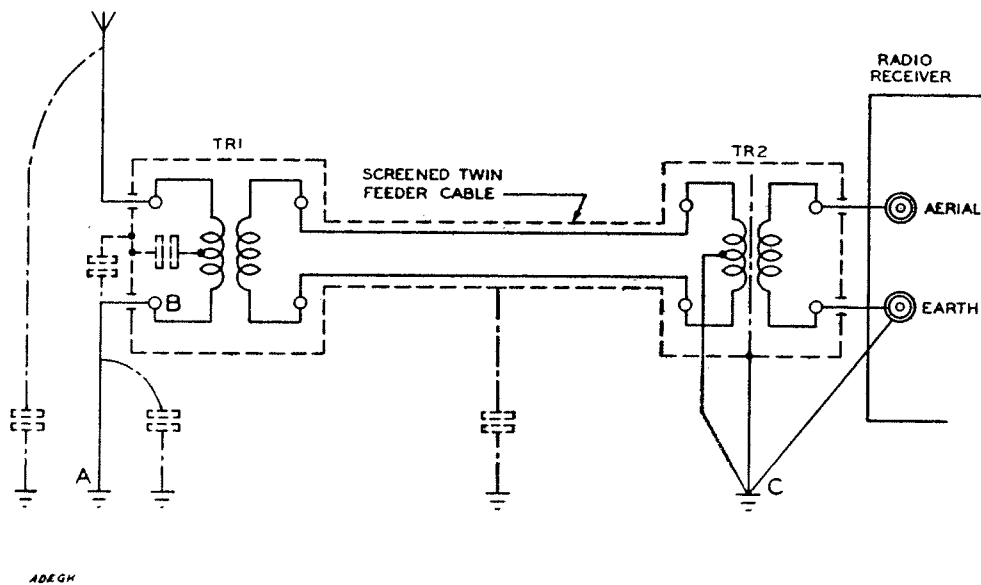


FIG. 5.—ANTI-INTERFERENCE AERIAL—CIRCUIT DETAILS

to a greater extent than the wanted signal, thus improving the S/N ratio. To compensate for any signal loss in the system the active portion of the aerial should be of adequate length ; this requirement rules out the use of *short* vertical rod aerials.

23. An anti-interference aerial of the type which uses a low-impedance screened twin-wire feeder cable and matching transformers is shown diagrammatically in Fig. 5, and Fig. 6 shows a well laid-out practical installation ; rejection of interference is effected as follows :—

If the 'pick-up' portion of the aerial, the aerial-matching transformer, and the earth lead A—B are

placed outside the interference field no interference will be picked up on this part of the system. Interference voltages will however be developed on the screen of the feeder cable because it passes through the interference field radiated from the house wiring. Interference currents circulate along the screen of the cable returning to earth via the capacitance of the cable to the windings of TR1 and the earth lead A—B. Interference currents are thus induced into the two conductors of the feeder cable. But, if the feeder circuit is electrically balanced with respect to earth, interference currents induced into the two conductors of the feeder cable will be of equal value and in phase ; the currents in the two halves of the primary winding of TR2 will therefore oppose each other and

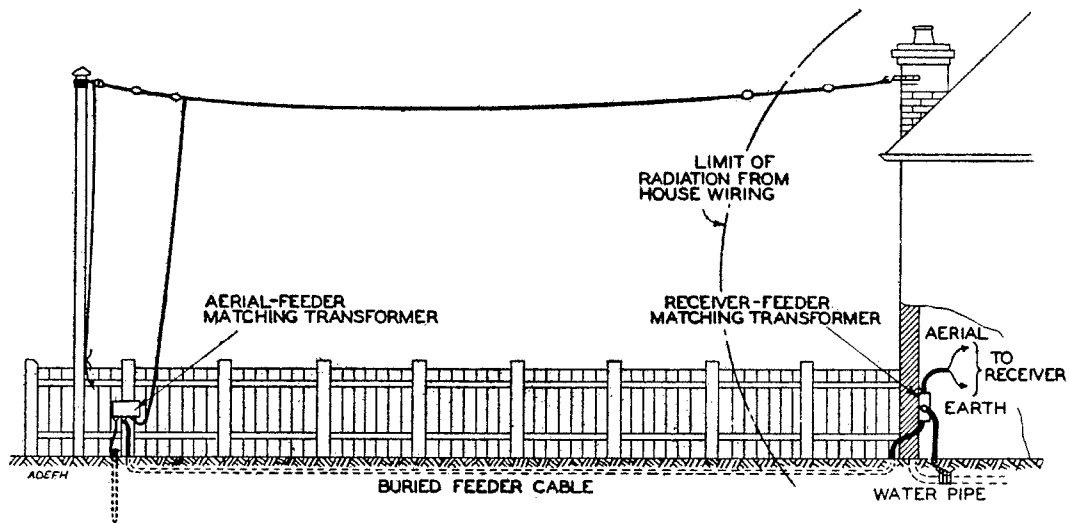


FIG. 6.—ANTI-INTERFERENCE AERIAL—IDEAL ARRANGEMENT

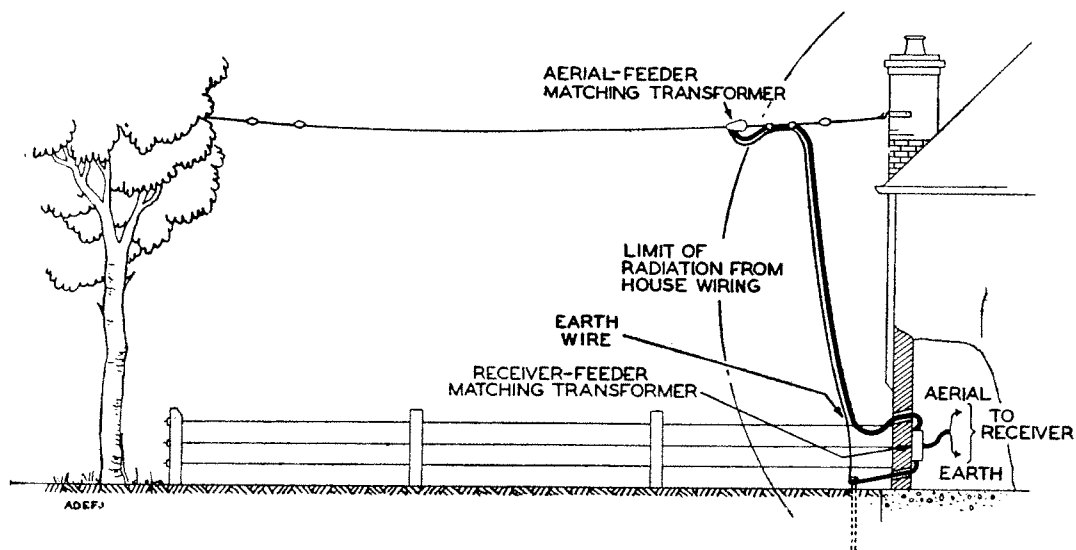


FIG. 7.—ANTI-INTERFERENCE AERIAL—ALTERNATIVE ARRANGEMENT

will be neutralized, and no interference voltages will be developed across the input terminals of the receiver.

24. A high degree of balance in the feeder system is essential; an electrostatic screen between the primary and secondary windings of TR2 helps in preventing the transfer of interference voltages through inter-winding capacitance. The screens around TR1, the feeder, and TR2 are bonded together and earthed at one point only, preferably at C. The primary of TR1 and the earth-lead A-B are insulated from the screen of TR1; if they were not, a loop A-B-C would be formed and pick-up of the magnetic component of the interference field would be greatly increased.

to the receiver transformer and interference voltages are thus applied to the receiver input. Although the layout shown in Fig. 7 does not make the best use of the aerial equipment—it would nevertheless give a better S/N ratio than a plain aerial.

26. **Communal aerial systems.**—A communal aerial system enables a number of receivers to be worked from one aerial. There are two types of communal aerial :—

(a) A non-amplifier system for small installations (see Fig. 8)

(b) An amplifier system for large installations (see Fig. 9).

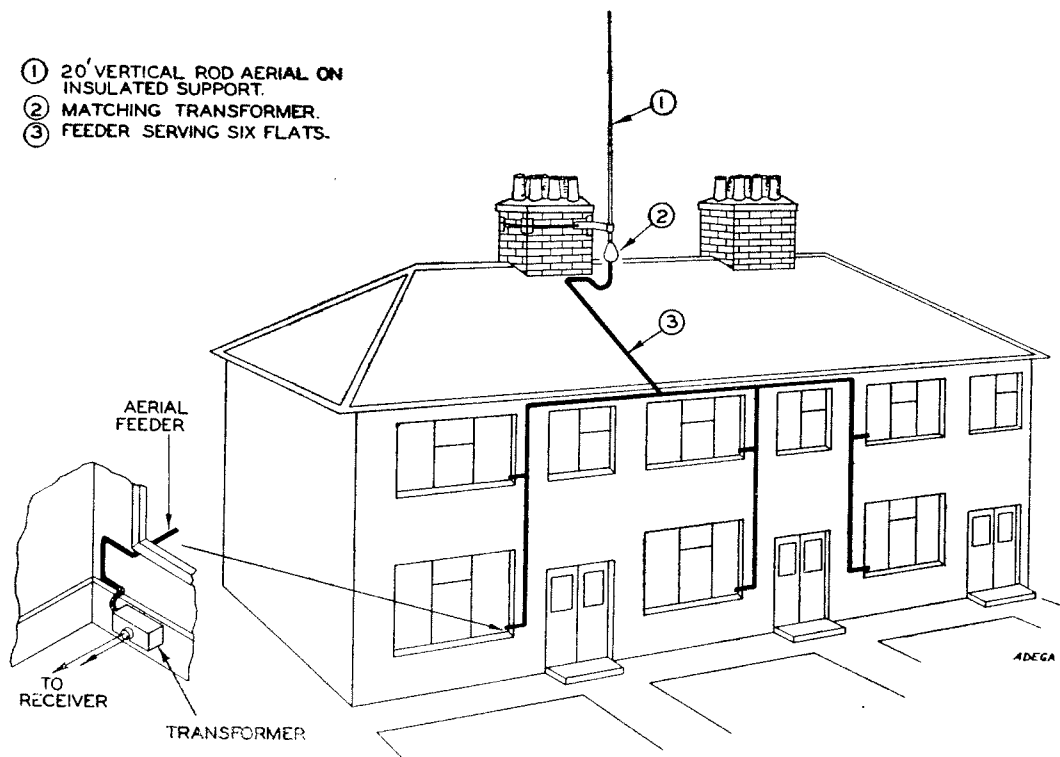


FIG. 8.—NON-AMPLIFIER COMMUNAL AERIAL SYSTEM

25. In Fig. 6 it will be seen that the most vulnerable parts of the aerial system are almost entirely outside the interference field and the earth lead from the aerial transformer is very short. The installation shown in Fig. 7 is poor by comparison, though such arrangements are often seen. Fig. 7 shows the earth lead from the aerial matching transformer well within the interference field; it is long, and possesses a fairly appreciable impedance. Interference voltages developed across this impedance will cause some currents to pass through the primary of the aerial matching transformer returning to earth via the aerial-earth capacitance. Any currents through the primary of the aerial transformer will be transferred

27. *Non-amplifier system.* This consists of

- (a) an efficient outdoor aerial
- (b) an impedance-matching transformer at the junction of the aerial and feeder cable
- (c) a low-impedance screened feeder, preferably of the twin-wire balanced type, connecting the aerial to the receiving points
- (d) an impedance-matching transformer and attenuator at each receiving point; the attenuator is required to limit energy passing from the receiver back to the feeder.

The non-amplifier system can supply up to about ten

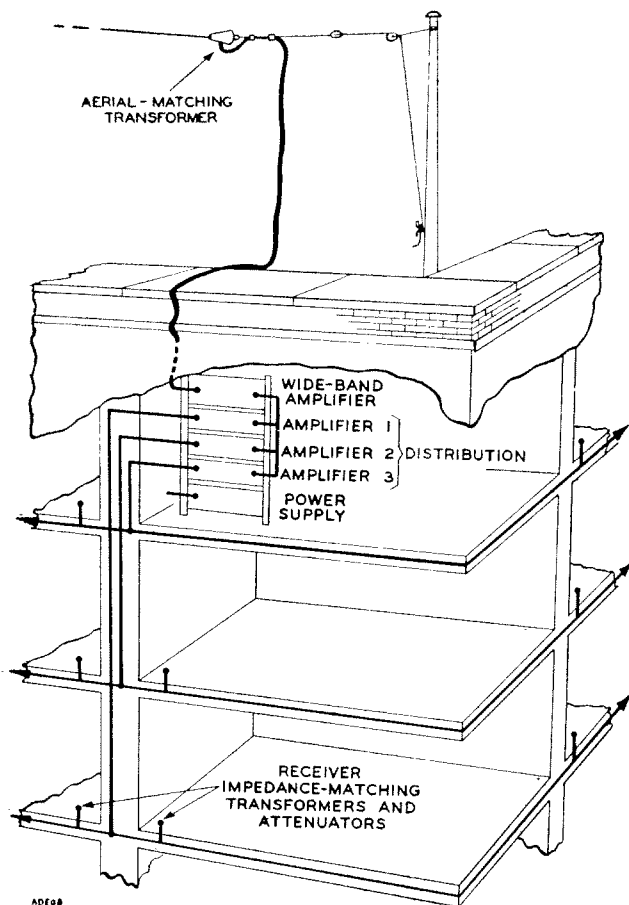


FIG. 9.—COMMUNAL AERIAL SYSTEM—AMPLIFIER TYPE

receivers, depending on the aerial and the length of feeder cable used. A larger number of receivers can be sub-divided into groups, each group having a separate aerial installation.

28. Amplifier system.—A system using one or more amplifiers is necessary if a large number of receivers is to be operated from a single aerial. Such an installation would consist of

- (a) an efficient outdoor aerial
- (b) a wide-band amplifier ; the aerial is connected to the input of the amplifier, which has one or more output stages feeding the distribution network. Several amplifiers may be required for very large installations.
- (c) a balanced and screened twin-wire distribution system to feed the receiving points, each point having a matching transformer and attenuator.

TELEVISION

29. General.—At the very high frequencies (V.H.F.) used for television broadcasting, noise voltages and

currents are not propagated along power supply conductors to the same extent as at the much lower frequencies used for ordinary sound broadcasting, but the directly-radiated noise field extends further, and it is generally found that interference is picked up by the viewer's aerial directly from the source. V.H.F. television transmissions suffer much attenuation in passing over the earth's surface and the range at which satisfactory reception can be obtained is less than with low-frequency and medium-frequency sound transmissions. Therefore, to obtain good television signals with a minimum of interference, an aerial system of suitable design and positioning is of the utmost importance.

30. Interference has two effects on the reproduction of a television picture ; it causes brightness modulation of the picture field—the form depending on the character of the interference—and it disturbs the operation of the line time-base, causing lateral displacement of the lines. A television receiving installation is susceptible to interference in the following ways :—

- (a) Pick-up by the aerial system
- (b) Pick-up by the receiver circuits
- (c) The injection of mains-propagated interference into the receiver via the mains lead.

31. Pick-up by the aerial system.—At V.H.F., noise voltages and currents generated in electrical equipment are severely attenuated on passing into the power supply network, and, with a well designed receiver, (b) and (c) of par. 30 are likely to make only a small contribution to the total interference pick-up. In general, interference is caused by radiation from the equipment or appliance concerned and the first few feet of its mains wiring, and this radiation is picked-up by the viewer's aerial and feeder cable. In such an event it is desirable to use an aerial possessing directional properties to discriminate against interference pick-up. It is also desirable to ensure that the type of feeder-cable used is appropriate to the receiver, i.e. twin cable for a receiver having a balanced input or coaxial cable for a receiver having one pole of the input earthy.

32. Pick-up by the receiver circuits.—The shielding of most commercially available television receivers is usually sufficient to reduce direct pick-up by the receiver circuits to negligible proportions ; but interference can be experienced if noise currents are induced in the outer conductor of a coaxial feeder cable which is not effectively bonded to the receiver chassis at the aerial input socket. In an A.C./D.C. receiver the chassis is usually connected to one side of the mains supply, and an isolating capacitor is connected between the chassis and the outer conductor of the coaxial feeder. Unless the impedance of the capacitor path is negligible the noise currents

in the feeder sheath may produce voltages across the receiver input circuit. With a receiver designed for use with a two-wire balanced feeder the voltage across the receiver input due to feeder pick-up is proportional to the balance/unbalance ratio, and a high degree of balance is therefore desirable.

33. Injection of mains propagated interference into the receiver via the mains lead.—Although noise currents are heavily attenuated in passing into the mains network, residual noise from a strong source of interference (or one very close to the receiver) can prove troublesome—especially when the wanted signal field is weak—if the mains lead is run close to the receiver input circuit. The use of a mains aerial is deprecated because it is likely to give a poorer signal-to-noise ratio than any other type of aerial.

34. Multiple-path reception.—Multiple images ('ghosts') are caused by the vision-signal arriving at the receiving aerial by more than one path. The transmitted wave may be reflected from a large metal structure or from a hill and arrive at the receiving aerial a fraction of a second later than the direct ray. The displaced image may be positive or negative according to whether the direct and reflected rays arrive in phase or in anti-phase. The actual distance between the receiving aerial and the point at which the reflexion occurs is not deducible, but the difference in the lengths of the two paths is given to a close approximation by $D = 15.5 \frac{S}{W}$, where D is the difference in miles of the paths of the direct and reflected rays, S is the space in inches between true and displaced images, and W is the width in inches of the visible picture. Aeroplanes in flight in the neighbourhood of the receiver may cause flutter of the sound and picture with sometimes a fleeting glimpse of a 'ghost.'

35. Careful experiment with highly directional aerial arrays may be necessary to bring about the elimination of persistent 'ghosts'. All the aerials shown in Table 2 (see par. 38) possess some degree of directivity, but the double "H" and horizontal slot

aerials are particularly useful in difficult cases of multiple path reception.

36. Television aerial systems.—Aerials which resonate at the frequency to be received increase the signal input to the receiver. For television frequencies such aerials are of practical dimensions and are generally used. Although the sound and vision components of the television service are transmitted on carrier frequencies that differ by 3.5 Mc/s., both can be satisfactorily received on the same aerial without serious loss. Different frequencies are, however, used by television transmitting stations in various parts of the country, and it is important for a viewer to use an aerial which is designed for, and correctly placed to receive from, the particular transmitting station giving the best service in the area concerned. Receiving aerials should also be mounted in the vertical or horizontal plane according to the polarization of the transmissions it is desired to receive.

37. The requirements of a television receiving aerial to give maximum discrimination against interference pick-up are a narrow acceptance angle with a high front-to-back ratio; additionally, good forward gain and adequate bandwidth are desirable features. It should, perhaps, be mentioned that bandwidth depends on the construction of the aerial, the feeder and the method used to terminate it, and on the input arrangements of the receiver.

38. A representative selection of television aerials is shown in Table 2; the polar diagrams and information about the different types are based on data published by manufacturers. There are many variations of each type of aerial both in the spacing, and the number of elements used. The horizontal polar diagram of each type is shown but this may in practice be distorted by nearby metal objects.

39. It should not be overlooked that an increase in the height of a simple aerial could bring about a signal gain far greater than might be obtained by changing to an aerial of more elaborate design without increasing its height.

TABLE 2—TELEVISION AERIALS

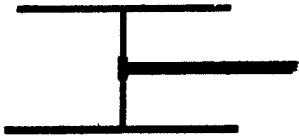
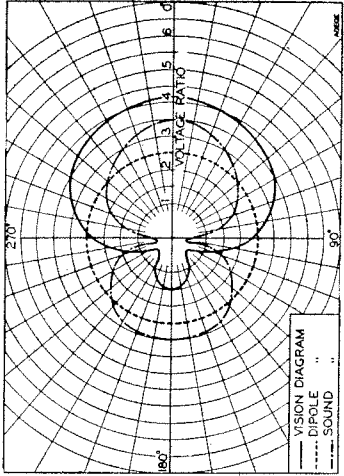
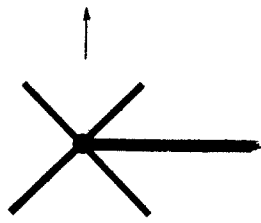
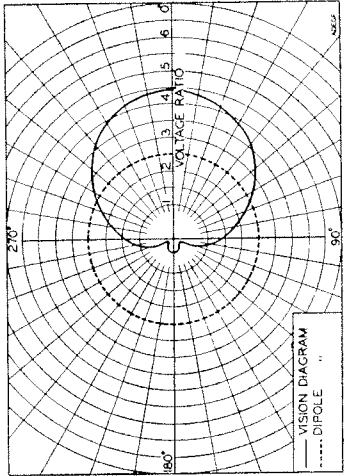
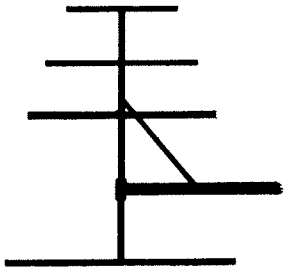
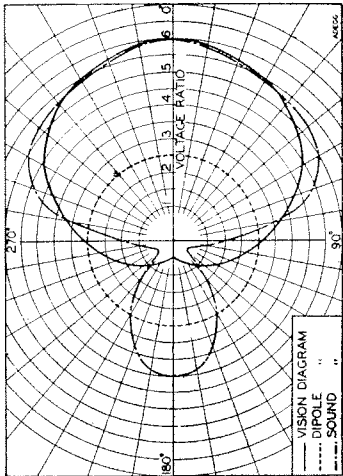
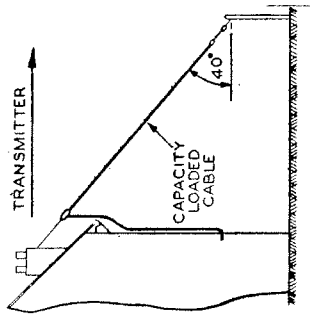
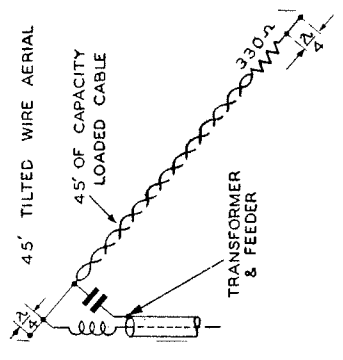
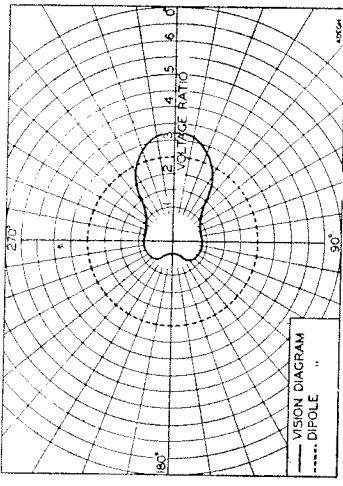
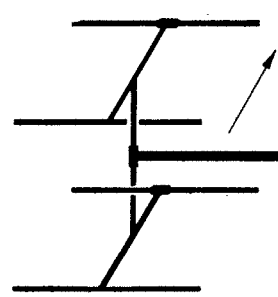
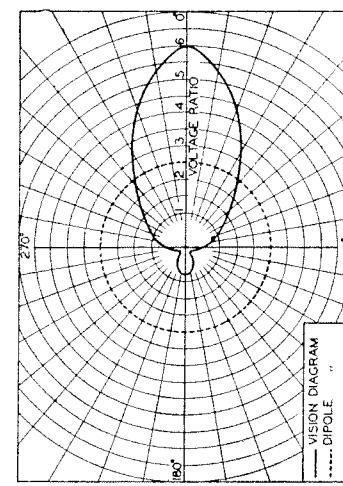
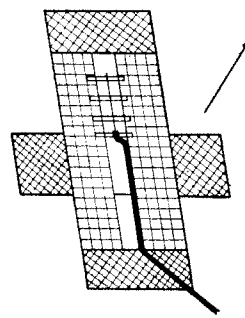
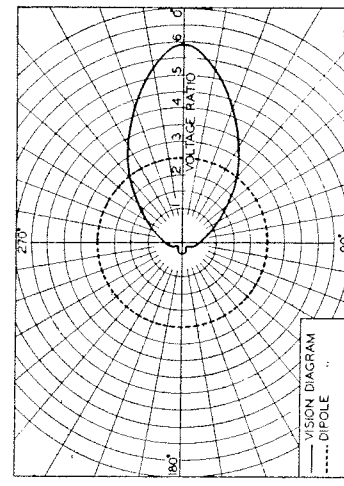
Aerial outline	Description	At vision frequency		Polar diagram (horizontal plane)
		Forward gain relative to dipole (db.)	Front-to-back ratio (db.)	
	"H" AERIAL DIPOLE AND REFLECTOR SPACED $\frac{1}{4}$	5	9	
	"X" AERIAL STRAPPED AS SHOWN	5	22	
	4-ELEMENT ARRAY $\frac{1}{2}$ " H AERIAL WITH 2 DIRECTORS SPACED $\frac{1}{2}$ AND MATCHING TO TRANSFORMER	8	24	

TABLE 2 (contd.)

Aerial outline	Description	At vision frequency		Polar diagram (horizontal plane)
		Forward gain relative to dipole (db.)	Front-to-back ratio (db.)	
		2 to 3	18	
	<p>DOUBLE "H" AERIAL TWO $\frac{1}{4}$ "H" AERIALS SPACED $\frac{\lambda}{2}$ APART</p>	8	26	
	<p>HORIZONTAL SLOT AERIAL WITH VERTICAL REFLECTOR SPACED $\frac{\lambda}{4}$ AND $\frac{\lambda}{4}$ MATCHING SECTION</p>	8	26	

References :—E 0030
(WP 2/3)

Instructions cancelled :—F 0050, General C 0313

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