

THE NATURE, ORIGIN AND PROPAGATION OF INTERFERENCE

1. General.—In this Instruction, the term 'interference' means any disturbance or signal that mars the reception of a wanted signal or program. For the purpose of explaining the nature and origin of interference, interference is classified under two main types, as follows:—

(a) *Impulsive interference* is interference caused by sudden changes in electric potentials or currents such as occur during the normal operation of certain kinds of domestic and industrial electrical appliances and some types of gas discharge lighting. Atmospheric are another example of impulsive-type interference.

(b) *Continuous-wave interference* is interference arising from radio transmitters, receivers and industrial and medical radio frequency equipment, all of which generate radio-frequency continuous-wave energy for their normal functioning, and vacuum-type filament lamps in which the generation of interference is an incidental and undesired feature.

IMPULSIVE INTERFERENCE

2. Generation of impulsive interference in electrical appliances.—Impulsive noise at radio frequencies usually arises from transient effects produced by the making and breaking of a current. The values of the r.f. noise currents, over the frequency spectrum, will depend on the wave-form and magnitude of the transient, and the impedances of the circuit.

3. The generation of current changes in a simple electrical circuit is illustrated in Figs. 1 and 2. In Fig.

1, A and B are the terminals of an appliance which is represented by a resistive load R in series with a switch Xa Xb. The circuit is typical of an electric heater having a thermostatic control. When the switch in Fig. 1 is open, there is a capacitance Cx between the switch contacts, and capacitances Cxa and Cxb between the contacts and earth. The self-capacitance of the resistive load has not been shown, but its effect is to reduce greatly the load impedance at radio frequencies, and this impedance decreases as the frequency increases. When the switch contacts are closed, the point Xb at potential Vb is connected to the point Xa at potential Va. This sudden change in electrical conditions is equivalent to the injection of a voltage step V, where $V = Va \sim Vb$. By application of the Fourier integral energy theorem to a unit step function, it will be found that the energy contained in this voltage step V is distributed over the whole frequency spectrum, and varies inversely as the square of the frequency.

4. Fig. 2 shows the appliance with the switch capacitors replaced by their equivalent impedances Z. The power supply leads have distributed impedance between them, and between each line and earth, represented in Fig. 2 by Zm, Za and Zb respectively. In the example chosen, the appliance is connected to the public electricity supply, but the same principles would apply to a battery or locally generated source of supply. The instantaneous radio frequency currents that are circulating in the various branches of the circuit are represented by i_1, i_2 , etc. The asymmetric and symmetric currents flowing in the power supply leads are of particular importance, and they are constituted as follows:—

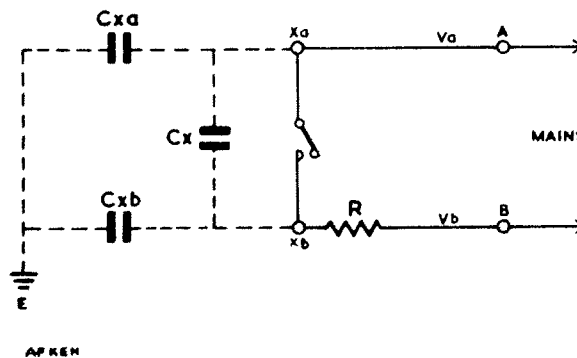


FIG. 1. GENERATION OF INTERFERENCE

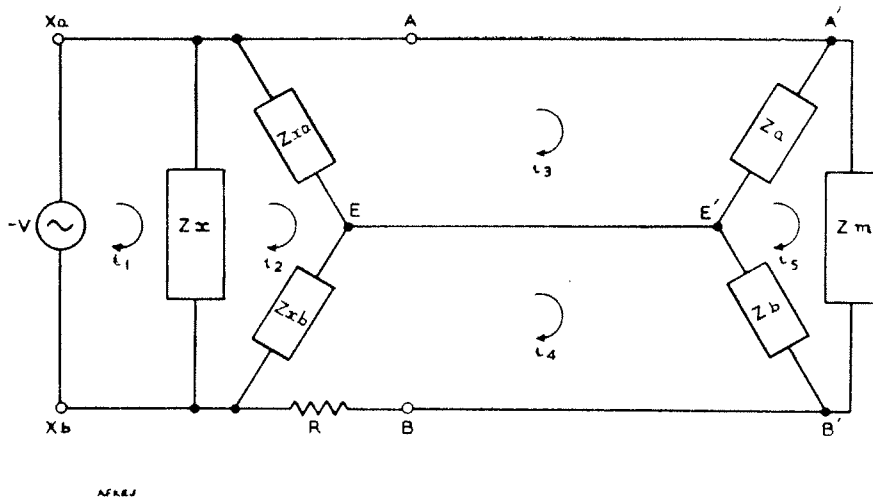


FIG. 2. NETWORK SHOWING EQUIVALENT IMPEDANCES OF APPLIANCE AND MAINS

(a) Asymmetric currents flow along AA' and BB' and return via the earth line EE' . They are represented by i_3 and i_4 , and their magnitudes will depend largely on the impedances Z_{xa} and Z_{xb} of the appliance, and the impedances Z_a and Z_b of the mains.

(b) The symmetric current circulates in AA' BB' , linked by the impedance Z_m of the mains. It is represented by i_5 , and its magnitude will depend largely on the impedance Z_x of the appliance and the impedance Z_m of the mains.

5. In general, asymmetric currents cause more interference than symmetric currents because:—

(a) symmetric currents usually flow in circuits forming only small loops which couple loosely to a receiving aerial.

(b) asymmetric currents as a rule flow in circuits forming rather large loops and coupling to a receiving aerial is much tighter on that account.

6. The sudden changes in current in the circuit of an electrical appliance and its power supply wiring are capable of exciting a response in the circuits of a receiver which may be tuned to any frequency within a fairly large range. The response of a receiver to impulsive-type interference is too big a subject to be dealt with in this Instruction, but brief reference to it is made in par. 16, subjective annoyance is mentioned in par. 17, and the paths by which noise currents find their way from a source of interference to a receiving installation are described in pars. 39 to 45.

7. Common sources of asymmetrically radiated impulsive noise are high voltage overhead power lines, which generate step voltages of a nature referred to earlier, by reason of discharges which occur under

certain weather conditions across overstressed air-gaps in the system, such as between conductors and insulators and between surfaces of associated metal-work which are nominally in contact.

8. Impulsive-type interference caused by lightning discharges.—The source of all atmospheric noise, excepting precipitation static, is the natural lightning discharge associated with thunderstorms, and all thunderstorms within a thousand miles or more of a receiving station may contribute to the general noise reproduced by a receiver tuned to a weak station in the low or medium frequency sound broadcasting bands.

9. In a storm cloud, a positive charge accumulates near the cloud top and a negative charge collects in the cloud underneath the positive charge. The generation and separation of these charges occurs in the ice region and it is possible that strong ascending currents of air cause ice particles to collide. The collisions charge the ice negatively and the air positively and it is the settling of the ice particles relative to the air which separates the positive and negative charges. Below the main negative charges there are sometimes regions in the lower half of the cloud containing positive charges. The temperature in these regions is usually above freezing point and it is probable that the positive charges are generated by the breaking of rain drops in ascending currents of air.

10. Lightning flashes are initiated when the intensity of the electric field at some point exceeds the disruptive strength of the dielectric medium. Flashes may occur between the positively and negatively charged regions within a cloud, from the upper part of the cloud to the upper atmosphere and from the

base of the cloud to earth. A lightning flash can be regarded as a pulse generator having energy components distributed throughout the frequency spectrum.

11. Apart from local storms which may cause total interruption of sound broadcasting and television reception for short periods, distant storms may cause continuous interference for long periods, particularly late in the day in summertime. Although continuous atmospheric interference is of more concern to the listener to distant foreign stations, it also mars reception of B.B.C. programs in areas of low field strength and it is sometimes erroneously taken to be interference caused by electrical plant.

12. Precipitation static is the interference generated by rain, hail, snow and dust storms in the vicinity of a receiving aerial. Its characteristics are varied and the audio output from a receiver may be either a crackle or a tone of varying pitch.

13. One theory to account for this phenomena involves the corona discharge which occurs from sharp points of an aerial when the potential gradient exceeds the dielectric strength of air. This corona discharge consists of very short duration pulses with a high recurrence frequency and consequently a relatively intense radio frequency content.

14. High vertical rod aerials are often affected by this form of interference but the effect can be lessened by eliminating sharp points from the aerial and its surroundings, and by providing suitable means of dissipating the charge which builds up on the aerial during stormy electrical conditions.

15. The effect of impulsive noise on a receiver. If a sharp pulse is applied to the input of a receiver, the output, prior to detection, consists of damped oscillations at the natural frequency of the tuned circuits in the receiver. The peak and r.m.s. values of the response at the detector produced by unit pulse at the input to the receiver are proportional respectively to the bandwidth and the square-root of the bandwidth. The most rapidly varying portion of the wave-form of a pulse determines the essence of its radio-frequency spectrum; a sharp pulse has a greater radio-frequency content than a rounded one of the same height and duration. Each single pulse of noise is reproduced by the loudspeaker (after detection and amplification) as a click. If the noise source generates a rapid succession of pulses the sound emitted by the loudspeaker is more or less continuous. Commutator motors working with a constant load produce a continuous noise; some of the very-high-speed machines produce an almost musical note. Interference caused by neon signs and fluorescent lighting is characterized by a strong 100-cycle modulation because discontinuities occur in their wave-forms twice per cycle of the supply frequency. Interference caused by thermostatically controlled

appliances may take the form of a long drawn out rasping sound, or a short sharp plop, according to the type of thermostat concerned.

16. The response of a receiver to the impulsive type of noise which is generated by most classes of domestic and industrial appliances is dependent on the statistical distribution of the peak values of pulses and also on the duration and spacing of the separate pulses. It is the relation between these time parameters and the reciprocal of a receiver's bandwidth which determines the nature of the receiver's response.

17. The subjective annoyance value of interference cannot be expressed by any one parameter; if the peaks occur infrequently the general level of interference determines the annoyance value, but if the peaks are predominant, the disturbing effect is determined largely by the magnitude of the peaks, their relative duration, and their average rate of recurrence.

18. Most radio receivers have automatic gain control of the type which allows the amplification to be greatest when no signal is being received. If a receiver is tuned to a signal the amplification is automatically reduced to an amount depending on the strength of the signal, so that for a given setting of the manual volume control the loudness of the loudspeaker output is substantially independent of the strength of the received carrier wave. With such receivers interference may sound very strong if the carrier wave of a broadcasting station is not accurately tuned in, but negligible if the receiver is correctly tuned. Observations of interference should, therefore, be made when the receiver is accurately tuned to the wanted signal.

19. 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 (see C 0007) and it disturbs the operation of the line time-base, causing lateral displacement of the lines. Also, strong pulses of interference may cause the picture to flick upwards or downwards momentarily.

CONTINUOUS-WAVE INTERFERENCE

20. Definition.—Continuous-wave interference is, in the main, interference taking the form of undamped radio-frequency oscillations which may be unmodulated, or pulse, frequency, or amplitude modulated. With few exceptions, the production of radio-frequency energy is an essential feature of the equipment concerned. Typical sources of continuous-wave interference are listed in Table 1, and the way in which the various modes of interference affect a receiver is given in Table 2.

21. The origin of continuous-wave-type interference.—The basic source of this kind of interference is the thermionic valve oscillator. The

TABLE 1. TYPICAL SOURCES OF CONTINUOUS-WAVE INTERFERENCE

Basic source	Sub-divisions	Mode of interference
Industrial and medical r.f. equipment	R.F. dielectric heaters for non-metals (industrial) R.F. eddy current heaters for metals (industrial) Diathermy equipment (medical)	Co-channel, adjacent channel, harmonics, blocking and cross-modulation, shock-excitation, parasitic oscillation, and break through at image frequency or i.f.
Radio transmitters	Amateur transmitting stations Foreign broadcasting " " Home " " (including television) Commercial transmitting stations Government " " (including the fighting services) Private mobile radio stations (e.g. business radio)	
Radio and television receivers	Time-base circuits of television receivers Beating oscillators of super-heterodyne receivers R.F. oscillators for cathode-ray tube e.h.t. supply Self oscillation in audio stages	Co-channel, harmonics
Filament-type electric lamps	Tungsten-filament vacuum lamps	Amplitude and frequency modulated pulses of interference covering sometimes a narrow band and sometimes a wide band of frequencies

TABLE 2. RESPONSE OF RECEIVER TO VARIOUS MODES OF INTERFERENCE

Mode of interference	Effect on receiving set	Remarks
Co-channel	Wanted and unwanted signals transmitted on approximately the same frequency are reproduced with little discrimination	As some stations in different countries or localities share the same frequencies, radio propagation conditions may have an important bearing on co-channel and adjacent channel interference
Adjacent channel	Heterodyne whistle (or pattern), sideband splash	
Harmonic	Similar to co-channel and adjacent channel interference	An integral multiple of the fundamental frequency of an unwanted transmission
Blocking and cross-modulation	Energy from a strong unwanted signal on an adjacent channel may cause a reduction in the level of the wanted signal (blocking) and the modulation of the interfering carrier may be superimposed on the wanted carrier (cross-modulation)	
External cross-modulation	When two powerful local broadcasting stations are involved, whichever station is tuned in the program of the other station is heard in the background. Both stations may be heard together at practically equal volume at certain other frequencies	This interference occurs only in districts having a very high field from one or more local stations (see pars. 34-37)

TABLE 2 (contd.)

Mode of interference	Effect on receiving set	Remarks
Shock-excitation	Excitation of natural oscillations in a tuned circuit caused by a sudden acquisition of energy from an external source	The frequency of the external source may be vastly different from the frequency to which the receiver is tuned
I.F. break-through	If energy is transmitted on a frequency corresponding closely to a receiver's i.f. or a harmonic of it, that energy may be picked up by, or be conducted to, the i.f. circuits and appear in the receiver output as an unwanted signal	This effect is independent of the frequency to which a receiver may be tuned
Spurious	A super-heterodyne receiver responds not only to the frequency to which it is tuned (i.e. the desired frequency), but also to another frequency differing from the desired frequency by twice the i.f., or by twice the beating oscillator frequency, whichever is the lower. The oscillator frequency is usually arranged to be higher than the wanted signal frequency so the unwanted or image frequency is usually higher than the frequency of the wanted signal	Receivers with poor signal frequency selectivity may have other spurious responses which are calculable as follows:— $2a-b$, $2a+b$, $3a-b$, $3a+b$, etc. where a is the oscillator frequency and b is the intermediate frequency

thermionic valve as a generator of oscillations is explained in General. B 1009 and the basic principles of valve transmitters are dealt with in General. B 1010. Many books are available for further reading on the subject of oscillators and transmitters, but little has been written about interference from tungsten-filament vacuum lamps, interference from television time-base circuits and external cross-modulation interference. For this reason these subjects are singled out for special mention.

22. The nature of interference caused by filament-type lamps.—Electric lamps which are on the point of breakdown have long been known as sources of short lived interference, the cause being a spark bridging a minute gap in the filament. Interference from lamps in good working order only came into prominence with the development of very high frequencies for communication purposes, particularly for television. Electric lamp interference is known to spread over a band of frequencies up to 10 Mc/s wide, and to occur somewhere within the range of roughly 30 to 130 Mc/s. If the electricity supply is d.c. obtained from rotary machines or mercury-arc rectifiers, the oscillations may be modulated at the a.c. component ripple frequency; on a.c. supplies the modulation appears to be well over 100% at twice the supply frequency.

23. On a television screen, interference from an a.c. operated lamp appears as one or two horizontal bars covering from about four to sixty lines of the

visible picture, corresponding to interference pulses of roughly 0.4 to 6 ms duration. The wider bars show beat-pattern striations somewhat similar to the pattern caused by valve diathermy apparatus of the type which has raw a.c. applied to the valve anode. On a tunable v.h.f. receiver for 'sound' reception, the interference is usually found to be markedly asymmetrical about the peak intensity point, the cut-off on the higher frequency side of the peak being very sharp.

24. Origin of interference caused by filament-type lamps.—The type of lamp responsible for most of the early complaints had a straight tungsten-wire filament which was folded several times over supports at the base and top in zigzag fashion. The 'double-wreath' rough service lamp now appears to be the most common offender. Only vacuum-type lamps cause this kind of interference. They are inefficient sources of light but stand up to very rough usage. Coiled-filament lamps have been reported as sources of interference but usually these lamps are either gas-filled lamps on the point of burn out (see par. 22) or an early type of vacuum lamp having the appearance of the modern gas-filled coiled-filament lamp.

25. Several unconfirmed theories have been put forward to account for electric lamp interference but the true explanation remains somewhat obscure. One theory which has much to support it postulates that a vacuum lamp may under certain conditions operate in a similar manner to the Barkhausen-Kurz

oscillator. The principles upon which the Barkhausen-Kurz oscillator works, and the applicability of these principles to the phenomena observed with oscillating vacuum lamps, are discussed in pars. 46-51.

26. It has been established that for a given lamp the frequency of oscillation increases as the applied voltage is increased. It is therefore reasonable to assume that the frequency swings during each half cycle of applied a.c. voltage; this, and the discontinuities which occur twice per cycle, probably account for the broadness of band over which interference occurs.

27. **The nature of time-base interference.**—Time-base interference takes the form of an un-interrupted continuous wave signal modulated with very low audio frequencies. The pitch of the interfering signal depends on the difference between the frequencies of the carrier of the wanted station and that harmonic of the line time-base oscillator which happens to be nearest in frequency to the wanted carrier. When listening to some broadcasting stations, the frequency difference may be so small or so great that only the rough modulation of the interfering signal is heard. In the U.K., the interference occurs at intervals of 10·125 kc/s and spreads beyond the low and medium frequency broadcasting bands with an intensity that decreases as the harmonic order increases.

28. Time-base interference to television reception is observed on a television screen as a vertical white bar of between $\frac{1}{4}$ in. and 2 in. wide, the full height of the screen, which may be stationary or moving slowly to and fro across the screen. The movement described in the latter case has earned this type of interference the title of 'windscreen wiping' interference.

29. When television receivers work in close proximity, and are tuned to the same transmitting station, the interference set up by an offending receiver will cause the white bar to appear on the left-hand side of the screen of the affected receivers. If reception in an area is possible from two transmitting stations which have their synchronizing signals locked to a common source, the interference set up by a receiver tuned to one transmitting station will appear on the screen of an affected receiver tuned to the other transmitting station as a stationary white bar, the position of which will depend on the difference in time taken for the two signals to arrive at the receiving point from their common source. This occurs generally in or near fringe reception areas of two or more transmitting stations. In areas which are served by two transmitting stations, the synchronizing signals of which are not locked to a common source, the interference set up by one receiver tuned to one transmitting station will appear on the screen of an affected receiver tuned to the other transmitting station as a white bar moving to and fro across the screen. In the U.K. this is characteristic of areas

that are served by both B.B.C. and I.T.A. transmissions.

30. **The origin of time-base interference.**—The interference is generated in the line time-base oscillator of a television receiver. This oscillator is designed to work at 10·125 kc/s and has an output of saw-tooth wave-form which is inherently productive of harmonics. Although many forms of oscillator circuit are used for line time-bases, such as blocking oscillator, transitron, thyatron and multi-vibrator, all have similar output wave-forms and are equally capable of causing this particular type of interference.

31. The interference is greatly intensified in the highly inductive anode circuit of the line time-base amplifier where the rapid changes in the wave-form are responsible for pulses of voltage rising to several kilovolts. Receivers which derive their high voltage supply for the final anode of the C.R.T. from a boosted line fly-back voltage usually generate a higher level of interference than receivers which use a mains transformer or r.f. oscillator for this purpose. Radiation of the interference occurs mainly from the deflexion coils and their connecting wires.

32. The interference to television reception is caused by oscillation, or harmonics of such oscillation, which are radiated at v.h.f. by the line time-base circuit. The switching effect of the booster diode may be of sufficient amplitude, even at the high order of harmonic required, to cause this type of interference.

33. The greatly varying conditions that exist in the line time-base circuit during a cycle of its oscillation may be responsible for originating unwanted oscillation at much higher frequencies. At low anode voltage and low anode current, there may be regions of negative resistance in the I_a/V_a characteristic of the line output valve which, immediately following the flyback pulse when the valve begins to conduct, produces conditions suitable for dynatron oscillation. Barkhausen-Kurz oscillation may be generated in the valve, during the period following the flyback pulse, if the conditions are such that the anode voltage is negative relative to the grid.

34. **The nature of external cross-modulation interference.**—This interference may be experienced in the neighbourhood of two or more powerful transmitting stations where fields greater than about 0·1 volt per metre are set up. The more usual case involves two local transmitting stations, e.g. the Home and Light program transmitters at Brookmans Park. If a receiver working within a few miles radius of the transmitter is tuned to the medium-wave Light program, the Home program may be heard in the background, and vice versa if the receiver is tuned to the Home program. The effect is most noticeable during light passages or intervals in the wanted program. At certain other frequencies both programs may be heard together in complete confusion.

35. External cross-modulation interference may be heard on a receiver in one house but not on the same receiver when it is tested on the next door neighbour's aerial. On the other hand all the receivers in a row of houses or a block of flats may be affected. External cross-modulation interference affects any type of broadcast receiver, the selective and the unselective alike. It may vary in intensity or cease altogether at times.

36. **The origin of external cross-modulation interference.**—In its more common form cross-modulation interference arises from the mixing of two modulated carrier waves in a circuit containing a non-linear element, and the radiation of energy containing both sets of modulation frequencies together. Electrical conduits, hot water pipes, gas pipes, drain pipes, metal roofs, wire fences and other conducting materials found in and around a house are capable of picking up radio signals. Where there are poor joints in these conductors, or where they are in light contact one with another, there sometimes exists what is in effect a very inefficient rectifier. Rectification is improved if oxides have formed on the surfaces of the conductors at their points of contact; the contact pressure is usually critical.

37. When the conduits, pipes, etc. pick up the carrier waves of the powerful local transmitters and pass them through a rectifier, a series of new frequencies is generated. These new frequencies bear the following relationship to the frequencies of the induced carrier waves:— $a+b$, $a-b$, $2a$, $2b$, $2a+b$, $2a-b$, $2b+a$, $2b-a$, $3a$, $3b$, etc., where a and b are the frequencies of the local transmitting stations. An effect also takes place whereby the modulation components of both stations are impressed on the carriers of the fundamental frequencies and the new frequencies.

For a theoretical discussion of these phenomena, see par. 52.

38. An effect due to a similar cause may be experienced when there is only one powerful transmitting station in the locality, but in this case it would be a contradiction of terms to refer to it as cross-modulation. With only one strong carrier wave present, the new frequencies created by the action of the non-linear element are all multiples of the fundamental frequency of the carrier, e.g. $2a$, $3a$. That this effect has nothing to do with the radiation of harmonics by the transmitting station can be proved by short-circuiting or removing the non-linear element.

PROPAGATION OF INTERFERENCE

39. **Manner of propagation.**—The radio-frequency energy generated in the manner described in the previous sections is propagated in one, or a combination of, the following ways:—

(a) By radiation directly from the interference source and any wiring associated with it

(b) By conduction along the cables of the public electricity supply mains from which the source draws its power

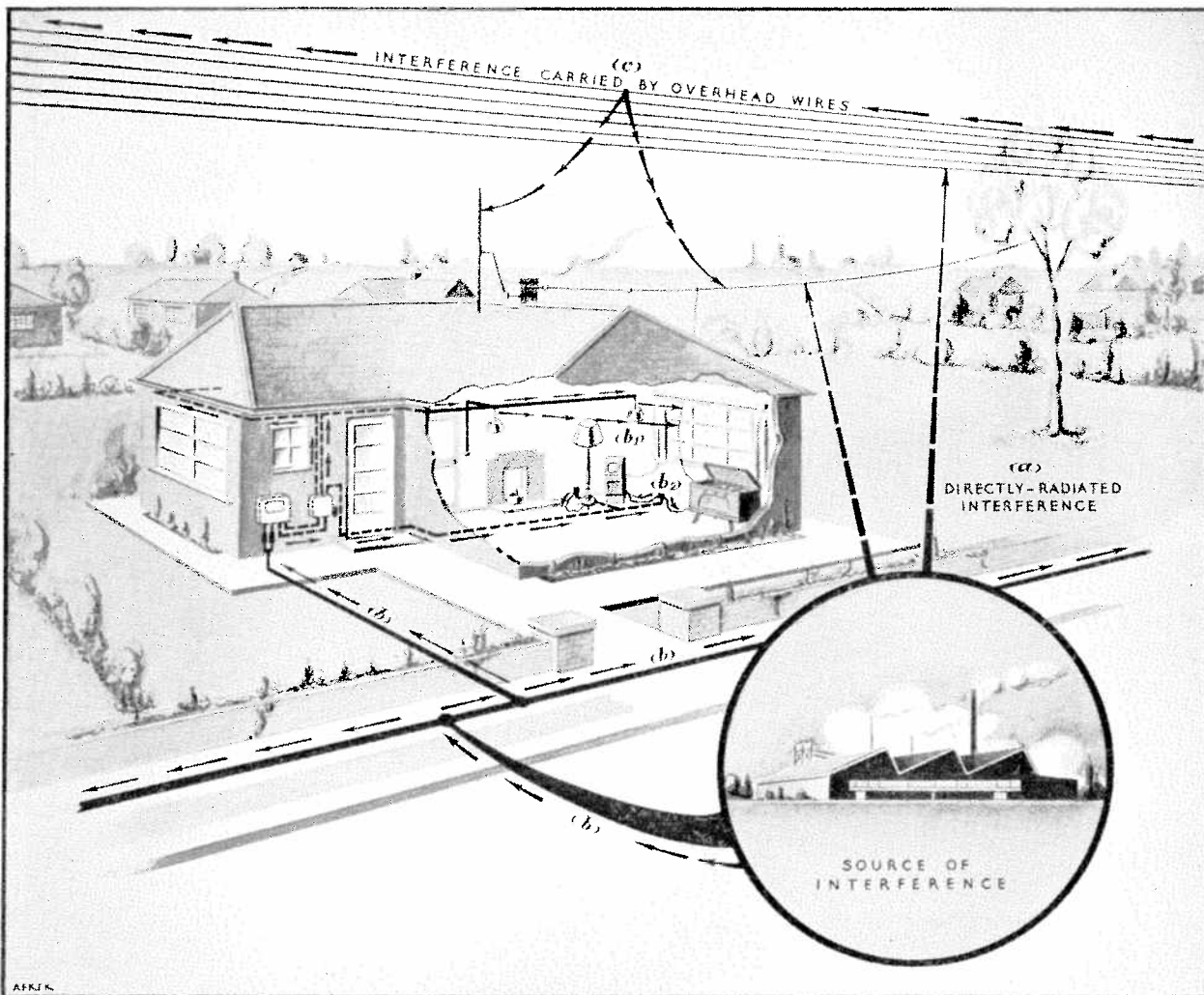
(c) By conduction along wires, etc., not directly connected to the source or its power supply, but closely coupled to them.

These propagation paths are illustrated in Fig. 3.

40. **Propagation by direct radiation.**—The term direct radiation is used to denote the process whereby electromagnetic energy generated by a source of interference is transferred to free space from whence a portion of the energy can be abstracted by a receiving aerial. Radiation from electrical equipment occurs from the equipment itself, from the flexible cable (if any) and from the first few feet of the fixed power supply wiring which acts as a transmitting aerial. For a transmitting aerial to act as an efficient radiator of energy it must be closely coupled to free space, a condition which obtains when the length of the aerial becomes significant compared with the wavelength of the radiated wave. The length of the radiating portion of most domestic and industrial appliances is extremely small compared to the wavelengths corresponding to the lowest frequencies used in sound broadcasting, consequently direct radiation is reduced to a harmless level within a few feet of the source. At medium frequencies, conditions for radiation are little better but as the frequency of the radiated wave increases to the high and very high frequency ranges so noise fields extend further and further from the source. At television frequencies, the wavelengths become comparable with the length of mains cord attached to many kinds of electrical appliances, particularly portable ones, and conditions for radiation are close to the optimum. Some typical sources of interference in which propagation is wholly or partly directly radiated are listed in Table 3.

41. **Propagation by conduction along power supply cables.**—If a source of interference is connected to the public power supply, it is almost certain that radio-frequency noise currents will be injected into the power supply cable and from thence into the wiring of the premises that are supplied from the cable for some distance along its route on either side of the point of injection. This is shown as propagation type (b) in Fig. 3. The noise currents are attenuated as they pass along the power mains; attenuation increases as the frequency increases and at very high frequencies the attenuation is so great that very little interference reaches a receiving installation by this medium.

42. The noise currents that are conducted into the electrical wiring of houses set up potentials between the wiring and earth and each house may thus be regarded as having its own separate noise field. These



- (a) Interference radiated directly from the source
- (b) " " injected into the electricity supply mains
- (b₁) Mains propagated interference radiated from house wiring
- (b₂) " " " " conducted into receivers
- (c) Interference carried by overhead wires

FIG. 3. PROPAGATION OF INTERFERENCE

fields do not as a rule extend much beyond the confines of the houses, but weak as the fields may be, an aerial, or any part of an aerial situated within one of the houses, may pick-up interference because of the tight coupling between the aerial and the house wiring. This is shown as propagation type (b₁) in Fig. 3.

43. Noise currents may also be induced into a receiver by its own mains cords. This is shown as propagation type (b₂) in Fig. 3. Usually this kind of

interference injection occurs where the aerial lead and the mains cord come close together as they enter the receiver.

44. Propagation by conduction along wires coupled to, but not directly connected to a source of interference.—Noise currents may be set up in conductors, e.g. telephone wires, if they pass through a strong radio-interference field. These noise currents may then be carried for considerable distances along the conductors; this is shown as propagation type (c)

TABLE 3

Source (including radiation from connecting wires)	Frequencies affected	Distance from source
Industrial and medical radio-frequency apparatus Neon signs Petrol-engine ignition systems	H.F. and V.H.F. (occasionally M.F.) L.F., M.F., and V.H.F. H.F. and V.H.F.	One mile or more at V.H.F., much less at lower frequencies Usually less than 75 yds. Up to half a mile at V.H.F., less at lower frequencies
Power lines Radio transmitters Tungsten-filament vacuum lamps	L.F., M.F., H.F. and V.H.F. L.F., M.F., H.F. and V.H.F. V.H.F.	Up to 300 yds. — Up to 300 yds.

in Fig. 3. If a receiving aerial is placed near these conductors, and particularly if it is placed parallel with them, it will pick-up interference from the noise field radiating from the conductors. Tramway and trolley-bus systems, and certain classes of industrial and medical radio-frequency equipment, are sources of interference most likely to be concerned in this type of propagation.

45. It should also be mentioned that lengthy pieces of metalwork such as steel girders, gas and water pipes, and even gutters, which are not all points at radio-frequency earth potential sometimes carry noise currents from one part of a building to another.

BARKHAUSEN-KURZ THEORY APPLIED TO THE TUNGSTEN-FILAMENT VACUUM LAMP OSCILLATOR

46. In the Barkhausen-Kurz oscillator, the grid of a triode valve is given a high positive potential and the anode is usually slightly more negative than the cathode. In the tungsten-filament lamp, the filament can be regarded as being both cathode and grid and it is assumed that the anode is the glass bulb upon which sufficient electrons have collected to give it a negative charge; it is also possible that the bulb has deposits of minute particles of metal or semi-conducting material on its inner surface. It has been reported that some new lamps do not become oscillators until they have been in use for a few hours. This may be because it takes some time for the 'anode' to form.

47. Electrons emitted from the cathode (negative end of the filament) are accelerated towards the grid (positive end of the filament) and most of them pass through the open grid wires towards the anode (glass bulb). But the electrons are subjected to the reverse pull of the grid and they slow down before reaching the anode, stop and then accelerate back towards the grid. Again most of them pass through the grid, slowing down and stopping before they get to the cathode, then reverse direction once more and the whole process is repeated. But if the grid potential

were to oscillate above and below the steady h.t. potential at a frequency corresponding to the transit time of electrons passing from the cathode to the anode, then the electrons that leave the cathode just as the grid is becoming more positive are subjected to greater acceleration than they would be if the grid potential were not varying. Because of the synchronization of frequency, by the time the electrons have gone just beyond the grid the grid potential would have become less positive and so the electrons would be retarded less than they would if the grid potential were steady. These electrons would impinge upon the anode (glass bulb) and would be prevented from any further circulation. This extra acceleration towards the anode represents energy abstracted from the superimposed oscillation on the grid.

48. Electrons that start from the cathode just as the grid is becoming less positive are accelerated less than with the h.t. steady, and by the time they get beyond the grid, the grid potential has increased and so they are retarded more and soon return towards the grid, passing through the grid many times before finally being caught by it. These electrons always work against the oscillating voltage assumed to be superimposed on the d.c. grid voltage and they deliver energy to the grid oscillation.

Electrons that deliver energy to the grid oscillation travel backwards and forwards through the grid more times than do those electrons that abstract energy from the grid oscillation. There is thus a surplus of energy to sustain the oscillations.

49. In the true Barkhausen-Kurz oscillator, the frequency of the electron oscillation is determined primarily by the spacing between cathode and anode and by the voltage applied to the grid in accordance with the formula

$$\lambda = \frac{670d}{E}$$

where λ is the wavelength in cm
d is the diameter of the anode in cm
E is the voltage applied to the grid

This formula is based on the assumption that the spacing between cathode and grid and grid and anode is equal.

The higher the frequency to be generated the greater must be the grid potential and the smaller the spacing between cathode and anode. An external tuned circuit has little effect on the frequency generated.

50. There is ample proof that the only factor controlling the frequency generated by a given tungsten-filament vacuum lamp is the applied voltage and that external circuits have little effect on the frequency. It is a difficult matter to check the relationship between electrode spacing and frequency in the case of the vacuum lamp, but research workers in this country and in the U.S.A. claim to have done so and confirm that it has the same bearing on frequency as in the case of the Barkhausen-Kurz oscillator.

51. When a vacuum lamp is connected to an a.c. supply further complications are introduced. It is possible that as the voltage varies over each half cycle of the supply a range of frequencies is generated; or it may be that the spacing of the electrodes is such that oscillation only occurs at the peak of the voltage cycle. These possibilities may account for the fact that with some lamps the interference occurs over a wide band of frequencies and with other lamps over a comparatively narrow band.

RECTIFIER OR NON-LINEAR ELEMENT CHARACTERISTIC

52. A rectifier or non-linear element has a characteristic which may be expressed by a power series expansion:—

References:—C 0007
(WP2/3) General, B 1009, B 1010
Instruction cancelled:—General, C 0301

$$\frac{i}{k} = a + be + ce^2 + de^3 + \dots \quad (1)$$

where i is the output current of the rectifier
 k is the rectification constant
 a, b, c, d are coefficients of the rectification characteristic
 e is the applied voltage and

$$e = E_1 \cos x + E_2 \cos y \dots \quad (2)$$

where E_1 is the amplitude of signal with frequency x
 E_2 is the amplitude of signal with frequency y

E_1 and E_2 vary at modulation frequency.

Substituting (2) in (1), the resultant output of the rectifier becomes:—

$$\begin{aligned} \frac{i}{k} = & a + bE_1 \cos x + bE_2 \cos y + \frac{c}{2} E_1^2 + \frac{c}{2} E_1^2 \\ & \cos 2x + \frac{c}{2} E_2^2 + \frac{c}{2} E_2^2 \cos 2y + cE_1 E_2 \cos \\ & (x+y) + cE_1 E_2 \cos (x-y) + \frac{3d}{4} E_1^3 \cos x + \\ & \frac{d}{4} E_1^3 \cos 3x + \frac{3d}{4} E_2^3 \cos y + \frac{d}{4} E_2^3 \cos 3y \\ & + \frac{3d}{2} E_1 E_2^2 \cos x + \frac{3d}{4} E_1 E_2^2 \cos (2y + x) \\ & + \frac{3d}{4} E_1 E_2^2 \cos (2y-x) + \frac{3d}{2} E_1^2 E_2 \cos y + \\ & \frac{3d}{4} E_1^2 E_2 \cos (2x+y) + \frac{3d}{4} E_1^2 E_2 \cos (2x-y) \\ & \dots \dots \dots (3) \end{aligned}$$

This expression shows the large number of resultant frequencies and their relative magnitudes. The second order term results in new frequencies carrying the modulation of one or both of the signals. The third order term introduces additional new frequencies also carrying the modulation of one or both of the signals.

E N D