HANDBOOK ON V.H/F COMMUNICATIONS.

WITH SPECIAL REFERENCE TO MOBILE STATIONS.

CHAPTER 1.

INTRODUCTION.

1. The term "Very High Frequency" (V.H/F) covers the frequency range from 30 to 300 Mc/s, or from 1 metre to 10 metres wavelength. Such frequencies have been used for communication for many years, but they are useful only over rather short distances. Good communication can be kept up between two stations which are within sight of one another ("optical distance"), or about half as far apart again (50% over optical distance). Between ship and shore stations the extreme useful range hardly ever exceeds 100 miles.

2. Communication is made more reliable, or is carried on with relatively small transmitter powers, by using directional aerial systems. By a directional aerial system the power radiated by the transmitter is concentrated in some directions and cut down in others, and similarly power is received by the receiver from some directions rather than from others. Interference with other radio links is also made less, and the risk of interception reduced. This can only be done when it is known that the station with which communication is desired is in a definite direction, and the aerial arrays must be turned so as to radiate and receive in that direction. It must not be supposed that a directional aerial makes communication secret; the usual precautions must be observed.

3. A directional aerial system provides an improvement, or gain, in power radiated in the wanted direction. The gain is measured relative to the half-wave dipole (of which a description is given later) as standard, and is specified in decibels (dB) (10 times log power-ratio, or 20 times log voltage-ratio, in radiated field). A full specification of the performance of an aerial system requires also a polar diagram, showing how much of the power is radiated in different directions, in any plane through the aerial.

4. The choice of different aerial systems depends on the service required, the distance to be covered, the power available, whether the equipment is fixed or mobile, and so on.

CHAPTER 2.

PROPAGATION.

1. V.H/F radiation is propagated through space in exactly the same way as any other electromagnetic radiation. Because of the different wavelength the effect of obstacles is different. Like long and medium waves, these waves are diffracted, or bent round the surface of the earth and other solid objects, but not so strongly. The strength of the field falls off rapidly near the surface of the earth, when the distance much exceeds the optical.

2. The waves are reflected by solid objects, especially conductors, which are large compared with the wavelength; so that hills, large buildings, thick woods, and so on, cast shadows and interfere with the transmission or reception of an aerial which is hidden behind them. Obstacles not greater than a wavelength or so do not have much effect unless the aerial is very close to them.

3. V.H/F waves are not ordinarily reflected from the ionosphere, and so it is not possible to use a sky-wave for communication.

4. The expected range of communication is somewhat increased in normal conditions by the fact that the waves are refracted downwards in the lower atmosphere. Changes in the distribution of temperature and moisture in the atmosphere change the amount of refraction and lead both to fading and also to exceptionally good reception at times.

5. Fading is not usually important for communication at optical distances. Well beyond optical distances it is usually present. The commonest types are (1) short complete fades lasting for about a minute, (2) "flutter fades", in which the signal rises and falls by a few dB every minute or so, for perhaps a quarter of an hour. Neither of these types of fade is usually sufficient to prevent R/T communication. Flutter fades are sometimes more rapid, and may then make the received signals unintelligible. Changes of signal strength at different times of day and different seasons have been observed, but they are not so strongly marked as with H/F sky-waves, and they vary with site and weather.

6. It is not possible to predict exactly the conditions of communication between sites with intervening hills. Experience shows that fairly high hills can be crossed without marked loss of signal strength. Obstacles close to the aerials are by far the most important.

CHAPTER 3.

AERIALS.

1. A V.H/F aerial must be raised well above ground, at least a wavelength high. Otherwise a large proportion of the energy is reflected almost vertically upwards and is lost. To connect the aerials to the transmitter and receiver, feeders are used, which convey the energy without themselves radiating or picking up. They are usually of coaxial cable.

2. Every feeder has a characteristic impedance, and it will only act properly as a conveyor of energy if it is matched, that is, terminated at each end with an impedance equal to its own characteristic impedance. Coaxial feeders have characteristic impedances ranging from 40 to 100 ohms. With some transmitters it is possible to adjust the impedance so as to suit the whole of this range. When this is not possible the feeder is chosen to have a characteristic impedance close to that for which the transmitter is designed.

3. Different aerials have different impedances, and the impedance also depends on the points to which connection is made. It is usually necessary to have some sort of transformer to match the aerial impedance to the characteristic impedance of the feeder.

4. Many aerials are balanced; that is, they are symmetrical structures in which the voltages in the two halves are, at any moment, equal and opposite. A coaxial feeder is essentially unbalanced. A balancing sheath, or other device, is necessary (in addition to or combined with the matching transformer) to change over from one to the other.

5. When the matching and balancing are both properly done, there are no standing waves inside the coaxial feeder, and its outside is "dead".

6. The half-wave dipole is shown in the vertical position in Fig. 1. It is a straight conductor, approximately half a wavelength long, fed so as to have equal and opposite voltages at its two ends. The actual length in practice is less than a true half-wave because of the effects of capacity and resistance. At V.H/F the reduction in length is about 6%.

7. The dipole is often fed at the centre. The impedance here is about 73 ohms, and feeders of approximately this characteristic impedance are available. No matching transformer is needed at the aerial end of the feeder. Also the input and output impedances of receivers and transmitters respectively are often made to be of about the same impedance, so that the feeder is matched at the set end too.

8. The unbalance of the feeder must be corrected at the aerial end. The simplest way of doing this is with a quarter-wave sheath. It is a conducting tube which surrounds the feeder, is open-ended at the aerial end, and shorted at its other end to the outer conductor of the feeder. The feeder and sheath are kept two or three inches away from the aerial itself, so that there is not too much capacity between them. Connection is made from the two halves of the dipole to the inner and outer conductors of the feeder by short lengths of braid.

9. The aerial itself is supported on insulating materials. If it is vertical, the top section of the supporting mast is usually of wood. The balancing sheath and feeder leave the aerial at right angles, and if it is necessary to bring the feeder round the supporting mast, this is done some distance below the aerial.

10. The vertical dipole radiates equally all round in the horizontal plane. Its polar diagram in this plane is thus a circle (Fig. 2a).

11. The dipole is also used horizontally. This simplifies the constructional arrangements, as the feeder and balancing sheath lie straight down the mast. The mast can be of metal throughout, provided that the aerial is supported a short distance off it.

12. The polar diagram of the horizontal dipole is shown in Fig. 2b. The radiation is greatest in the broadside-on directions and least in the direction of the dipole itself.

13. A dipole produces a wave which is polarised in the direction of its own length. This means that the electric force is in this direction. Thus a vertical dipole produces a vertically polarised wave. For V.H/F it cannot be said that either vertically polarised waves or horizontally polarised waves are better for propagation; the differences vary with site and terrain. But a vertically polarised wave is best received on an aerial which is placed vertically, and a horizontally polarised wave on one which is placed horizontally.

14. If the feeder unbalance is not corrected, or if it is placed too close or parallel to the aerial, the polar diagram of the aerial is upset. The polarisation is also disturbed. In addition the impedance of the aerial is changed, and this means that there is a mismatch. A mismatch, whatever its cause, means that power is not fed from the transmitter to the aerial, and that the output stage of the transmitter is improperly loaded, leading to a breakdown. At the receiving end, it means that the signal fed to the receiver is reduced.

15. The horizontal dipole is directional to some extent, but the radiation is equally backwards and forwards. A really useful directional aerial has the radiation concentrated in the forward direction. This leads to a gain of power in the forward direction, as mentioned above. The directivity may be measured by the front-to-back ratio. This is the ratio of the power sent directly forward to that sent at 180°, and is given in dB.

16. Simple directional aerial arrays are made by placing reflectors or directors, or both, parallel to a half-wave dipole. In these the reflector is a conductor usually rather longer than the dipole and about a tenth of a wavelength behind it. A director is rather shorter than the dipole and a similar distance in front of it. An aerial consisting of a dipole and reflector, placed a quarter-wave behind it, is used instead of the ARS aerial (described below) in Station YY and the Handcart stations, when the ARS aerial is not available.

17. The impedance of an array with reflectors and directors is considerably lower (10 - 20 ohms) than that of the simple dipole.

18. A transformer is necessary from the feeder to the aerial. One type of transformer is a quarter-wave section of line, whose impedance is the geometric mean of those of the feeder and aerial, placed in series between them.

19. The ARS aerial array (Fig. 3) has one director and one reflector. The array is mounted on a wooden frame and supported on wooden struts. It is designed to be taken down and erected rapidly, and so is suitable for mobile equipment. The matching transformer and balancing sheath are formed of concentric tubes, and the feeder is fixed in permanently with water-tight glands. The array is not adjustable for frequency and covers only a range of about 2 Mc/s.

20. The array has a front-to-back ratio of 25 dB, and a gain of about 5 dB. When the frequency departs by more than about 1 Mc/s from the design frequency, the gain is not greatly altered, but there is much more backward radiation.

21. The array is designed to be placed either horizontally or vertically. Although the gain and directivity are about the same in either case, the shape of the polar diagram is different. The polar diagram for the horizontal array is shown in Fig. 4a, and that for the vertical in Fig. 4b.

22. The ARR or Windmill Array is an array of four "full wave dipoles", each with a reflector. A full wave dipole is really a pair of half-wave dipoles placed end to end and fed at the adjacent ends. In the Windmill the dipoles are vertical and making them full-wave concentrates the energy to some extent towards the horizontal plane. the four full-wave dipoles are placed side by side approximately a half-wave apart, and are connected together by pairs of conductors ("Phasing sections") in such a way as to concentrate the energy from the sides into the backward and forward directions (Fig. 5). The row of reflectors, about a fifth wavelength behind, reflects most of the radiation from the backward to the forward direction.

23. The impedance at the end of a half-wave dipole is high (about 2,000 ohms). At the centre-point of the phasing sections, which is a quarter-wave from the nearest dipoles, the impedance is low. In the Windmill array the feeder is matched into this point by a transformer consisting of a quarter-wave section of two-wire line. The tapping point from the feeder to the transformer is adjustable.

24. The Windmill array is practically a "spot frequency aerial. It is mounted on a wooden frame and supported by ropes from a collar free to rotate about the mast. It can thus be directed as required.

25. The Rhombic Aerial (Fig. 6) is a directional aerial constructed on a different principle. It consists of a rhombus or diamond-shaped conductor, which is preferably several wavelengths long. This is usually made of stranded wire, supported horizontally on four masts, one at each corner, at a height of two to three wavelengths. It is fed at one of the acute angles of the diamond. The impedance at this point is for a small rhombic about 600 ohms, and for a large rhombic about 800 ohms. The feeder is usually matched through a quarter-wave section of two-wire line. The aerial is balanced and the unbalance of the feeder may be corrected by a balancing sheath as described above.

26. The rhombic is terminated at the corner opposite to the feeding point, by a resistance equal to its own impedance. This is often made in the form of two carbon resistors of 300 or 400 ohms each, one placed at the end of each wire at the corner, and connected in series.

27. The rhombic aerial has considerable directivity. It radiates chiefly in the direction from the feeder to the termination and receives from the same direction.

28. The radiation is strictly horizontal, but is directed upwards at an elevation of five degrees or so. This is an advantage for communication at any distance, because of atmospheric refraction.

29. The aerial is untuned, that is to say, it does not have to be of any exact length compared with a wavelength. The matching and balancing transformers are usually of a design dependent on frequency, but not very strongly so. This makes the whole system flexible, as the same aerial can be used for a considerable range of frequencies.

30. In spite of its size, the rhombic is simple and robust. It can

be rapidly set up and taken down by a trained team. It is suitable for mobile stations.

31. The gain, directivity, and angle of elevation of the principal radiation depend on the size, shape and height of the rhombic, and on the wavelength. Up to a considerable length (several hundred feet on V.H/F), the gain is increased by the increase of size. The angle of elevation of the radiation is <u>decreased</u> by lifting the aerial higher above ground.

32. A full-size rhombic aerial has a gain of 10-15 dB. A small rhombic may have a gain of 5 dB or more.

33. <u>Choice of Aerials for Different Services</u> :-

(a) For V.H/F communication from ships, all round reception and radiation are usually required. A vertical half-wave dipole is the simplest way of achieving this. A gain of about $1\frac{1}{2}$ dB, is obtained with a full-wave dipole, the next simplest system. One or other of these is normally used for communication from ship to ship or ship to shore.

(b) <u>For shore to ship communications</u>, dipoles can be used if the distance to be covered is not large (say up to 20 miles) and a good site is available. For longer distances more gain is needed. A vertical array is required, and the ARR is designed for this purpose. It must be turned to follow the motion of the ship.

(c) <u>For short links from shore to shore</u>, or overland, either an ARS or a small rhombic is used. Distances up to 30 or 40 miles can be covered from good sites.

(d) <u>For long links from shore to shore</u>, or overland, a large rhombic is the most practical array. It should be properly laid out in a compass bearing. (Making allowance for magnetic variation). With a rhombic at each end, distances up to 80 miles can be covered with relatively small transmitter powers.

34. <u>Sites.</u>

The choice of sites for V.H/F aerials is of the greatest importance for reliable communication. The range and scope of the system is largely dependent on this.

35. <u>Height.</u> Communication between points within optical range is almost cast-iron. For this reason, if a given distance is to be covered, the aerials are, if possible, raised to such a height that they are within sight of one another. To determine the heights required, the distances of the horizon from a given height must be known. If h is the height in feet and D the distance in nautical miles, then $D = 1{\cdot}06/h$. The following table shows some examples :

Height (ft.)	Distance to Horizon (nautical miles).
25	5·3
50	7·5
100	11
200	15
400	21
700	28
1000	34

36. To find the optical distances between two stations both above sea-level, the distances from each to the horizon are added.

37. In practice, atmospheric refraction makes a considerable difference to this. For heights up to a few hundred feet the range of good communication is increased beyond the figures given. At greater heights it appears that the effects of refraction are less, or even unfavourable, so that not much is gained by going higher. In all cases, a good height above the surrounding ground is certainly useful. If the transmission is from shore over sea, it is an advantage to be at the top of a cliff not too far from the sea.

38. Position. The vertical dipoles on a ship are placed as high above the main structure, and as far from interfering metal objects, particularly vertical masts, as possible. They are also placed as far as possible from one another.

39. On shore, all aerials are given as much clear space as possible. It is important that an array such as the ARS should be placed so as to have a clear view in the forward direction; if possible with a clearance of several feet over the tops of trees and buildings in the neighbourhood.

40. A rhombic aerial is erected on a clear piece of ground as flat as possible. The ground in front should be flat for a distance half as great again as the length of the rhombic. It is important that the ground should not rise markedly in front of the rhombic for a mile or so.

41. A few rows of trees act as a good screen for vertically polarised waves, while horizontally polarised waves penetrate them more easily. On the other hand, horizontal conductors, such as overhead telephone lines, disturb the propagation of horizontally polarised waves but do not much affect vertically polarised waves. Thus a site which is near one or other of these special types of obstacle may be satisfactory for one type of polarisation; but not for the other.

42. Layout. The vans, buildings, etc., on a shore station are treated just like any other obstacle. Thus the vans are not placed in front of a directional aerial. Also, the different aerials at a site with several links are kept away from one another as far as possible, and, in particular, one is not placed in front of another. If two aerials are transmitting to or receiving from the same direction, they are placed side by side, with as much spacing between as possible. This leads to a layout in which the vans, generators, etc., of the station occupy a central position, with the aerials disposed around, each directed outwards in the appropriate direction.