

RECOMMENDATION ITU-R P.845-3

HF FIELD-STRENGTH MEASUREMENT

(Question ITU-R 223/3)

(1992-1994-1995-1997)

The ITU Radiocommunication Assembly,

considering

- a) that determination of the accuracy of HF field-strength prediction methods requires comparison of predicted field strengths against measured field-strength data of sufficient accuracy;
- b) that accurate HF field-strength measurements are therefore indispensable for the effective use of the HF spectrum,

recommends

- 1 that HF field-strength measurements conforming to Annex 1 should be continued systematically at various locations in the world;
- 2 that, where possible, the standard measurement method described in Annex 2 should be applied to the measurements;
- 3 that the field-strength data obtained from such measurements should be forwarded to the Director, Radiocommunication Bureau (BR) to permit the development of a data base containing uniformly consistent field-strength data.

ANNEX 1

**Measurement of sky-wave signal intensities
at frequencies above 1.6 MHz****1 Introduction**

Measurements of sky-wave signal intensities, if undertaken in a carefully controlled manner, are of value in assessing the accuracy of methods for estimating field strength and transmission loss. Such measurements may also yield an indication of sources of error in existing prediction methods and may be used either to improve these methods or as a basis for developing new methods. Ideally, the requirements are for measurements to be carried out systematically over as wide a range of conditions as possible at a series of frequencies over paths of different lengths in all regions of the world. Measurements are needed at each hour of the day in the separate seasons and for different solar epochs.

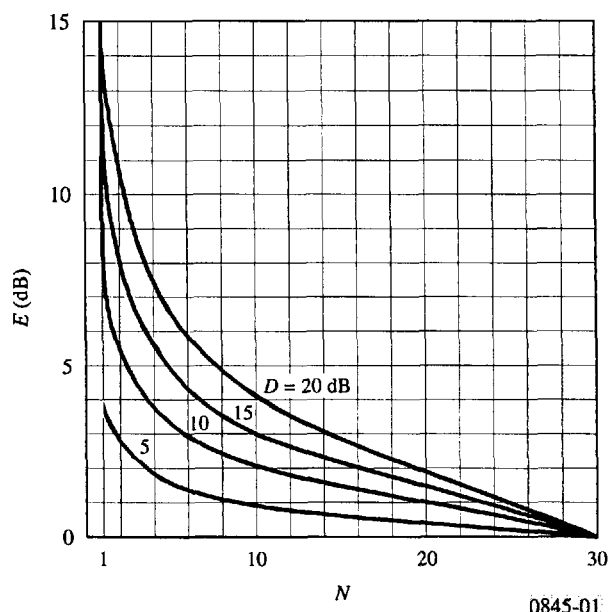
While it is recognized that opportunities to make measurements for particular circuits often arise only incidentally, with transmission schedules and system parameters such as the choice of antennas being determined by operational considerations, nonetheless useful results can be obtained in such cases. However, it is evident that data have their greatest value when measurements are carried out under standardized conditions and when uniform analysis and tabulation procedures are followed. This Annex presents the desirable criteria to be adopted to the extent that other constraints permit.

2 Choice of circuits and periods of operation

Signal-intensity data are required from circuits of different ranges in all geographical regions. Recordings of a given transmission should be made for as many hours as possible every day. The objective should be to derive the median and other percentile values of the day-to-day distribution of signal intensity over all days of the month. Where it is not feasible to carry out measurements every day, uncertainties arise in estimates of these values. Assuming a log-normal law of variation with decile deviation from the median of D (dB), the standard error E in the median based on a sample of N days within a month of 30 days (see Fig. 1) is:

$$E = \frac{D}{1.28} \sqrt{\frac{1}{N} - \frac{1}{30}} \quad \text{dB} \quad (1)$$

FIGURE 1
Standard error in monthly median (E)
as a function of number of days sampled (N) for different
decile deviations from the median (D)



Clearly the standard error increases as the number of days of recording decreases. While there is no limiting sample size giving an abrupt increase in error, as a general rule 10 or more measurements are required for the calculation of the medians, 14 for the quartiles and 18 for the deciles.

It is seldom feasible to embark on a measurement programme extending over a significant part of a solar cycle but to ease data interpretation and to be statistically meaningful, measurements should cover a minimum period of one year at a given fixed frequency. There are particular advantages in attempting to record signals simultaneously over a path at a series of different frequencies, both to aid the understanding of propagation effects and to permit quantitative data to be obtained by night when maximum usable frequencies are low, as well as by day when there is much absorption at the lower frequencies so that signals are masked by background noise.

3 Transmitter and transmitting antenna

The transmitter should be unambiguously identifiable so as to be sure that what is recorded is the wanted transmission and not co-channel signals, adjacent channel signals, or interfering noise. It is useful if the signals are interrupted at some periodic rate, say for 5 min once every hour, both as an aid to transmitter identification and to determine received background levels as confirmation that there is no significant signal contamination. The transmitter should operate

preferably for 24 h per day. It must be stable in both frequency and radiated power, and these two parameters must be known accurately. For reception over short paths it should desirably have a radiated power in excess of 1 kW and over medium distance and long paths a power of 10 kW or more. Where a special transmitter is operated, this would normally radiate continuous waves, although other waveforms may be used to study the characteristics of individual propagation modes. If use is made of commercial transmitters carrying modulated signals, it is important that the type of modulation should be constant and the mean percentage modulation should not vary. Narrow-band transmissions (approximately 1 kHz bandwidth or less) or a narrow-band component of a composite signal are most appropriate to record. Wider bandwidth signals are liable to interference contamination. Standard-frequency transmissions have been employed in the past, but in many receiver locations there is now serious interference between signals from different transmitters operating this service and sharing the same frequency. Nevertheless, interference can be avoided to some extent by means of a narrow-band receiver capable of resolving the different audio modulation frequencies of each co-channel transmitter. Transmitters for point-to-point telephony or telegraphy services offer the advantages of providing channels which are relatively free from interference, and a detailed log of transmission schedules is usually available. On the other hand, these transmitters often employ high-gain antennas, which tends to be a disadvantage.

A suitable category of transmitters meeting nearly all of the above criteria is weather-chart (FAX) transmitters using frequency shift-keying (± 400 Hz). As there are numbers of receivers (ships) with unknown position, these transmitters use omnidirectional antennas and transmit mostly for 24 h per day. Receiving systems should be very sensitive especially when recordings are made for very long paths.

Inspection of the International Frequency List maintained by the BR is of value in the selection of suitable transmitters to monitor. In particular, this usually gives information concerning transmitter radiated power, form of modulation and period of the day of operation. Sometimes it also yields details of the antenna type and orientation. The International Frequency List is useful additionally in providing a list of co-channel and adjacent-channel transmitters which should be considered further to assess the likelihood of possible interference. However, before embarking on a programme of systematic measurements it is recommended that after selecting a potentially suitable transmitter in this way, firstly a series of monitoring measurements should be carried out at various times over a period of about a month to determine the order of signal intensities encountered, the time coverage over which such signals can be detected, and the amounts of interference experienced. Then, a direct approach should be made to the organization operating the transmitter to verify the International Frequency List entries, to supply such additional details as are required – for example, concerning the type of antenna used and the associated ground properties. In particular, it should be checked that the radiated power is maintained constant, that different antennas are not used by night and day, and that the transmitter is not part of a network of transmitters operating at the same frequency from geographically separated sites – a procedure adopted in the HF broadcasting services in some countries. It is important to confirm also that it is proposed that the transmitter will remain operational throughout the whole period for which it is intended to make measurements. Only then should a decision be reached to carry out systematic recordings of the transmissions. Whilst ideally it would be desirable to receive details of the transmitter log, noting in particular any malfunctions or temporary changes in technical characteristics which might influence the measurements, it is rarely feasible to obtain such data and to apply variable corrections to results in retrospect. Instead, every effort should be taken at the outset to avoid the monitoring of transmitters whose characteristics are known to fluctuate.

For a particular transmitter to be suitable for signal-intensity measurements, the performance of its transmitting antenna needs to be known accurately. Transmitters coupled to antennas with little directivity have advantages over those with highly-directional antennas because radiation patterns usually approximate more closely to theory, because the relative strengths at the receiving site of signals travelling via different modes are then determined mainly by propagation effects, and because valid deductions may be made with a single allowance for transmitting-antenna gain in the absence of a knowledge of wave launch directions. Unfortunately though, low-gain transmitting antennas are seldom used for other applications. Most point-to-point HF land-fixed communication circuits employ high-gain rhombic or log-periodic antennas; for sky-wave broadcasting, arrays of horizontal dipoles, also with significant directivity, are popular. The exception is with standard-time transmitters which aim to provide all-round azimuthal coverage by means of vertical half-wavelength dipoles. These transmissions are particularly suitable for monitoring purposes. Radiation patterns for a vertical-dipole antenna may be estimated fairly accurately, except at low elevation angles where the particular ground constants control signal intensities. However, even at low angles the performance is known more accurately than for most other types of antenna. If no such transmitter is conveniently positioned for use, then before monitoring transmissions from a directional antenna it should be checked that the great-circle path to the receiver does not involve

reception of side-lobe signals. If propagation is over medium or long distances, ideally the antenna vertical polar diagram for elevation angles less than 20° should approximate that of a reference short vertical radiator sited over average ground (see Fig. 2a)).

Where a special transmitter is operated, a short vertical antenna is to be preferred. Alternatively, for short paths a horizontal dipole aligned for broadside radiation along the great-circle direction may be used. For greater ranges corresponding to low elevation angles, the direct and ground-reflected components of the sky wave nearly cancel one another so that a horizontal antenna is very inefficient unless elevated to a great height and should be avoided.

Transmitting-antenna gain (like receiving-antenna gain) is best determined from near-site measurements in the far-field region, but it is recognized that these rarely form part of the normal programme of work at a transmitting installation and that it is not generally possible to be able to arrange for such measurements to be carried out at a remote location, not under the control of the receiving organization. Accordingly, transmitting-antenna gain must usually be calculated from theoretical relationships in terms of the known antenna geometry, and by making certain assumptions concerning the type of ground involved.

4 Receiving antenna, receiver and recording techniques

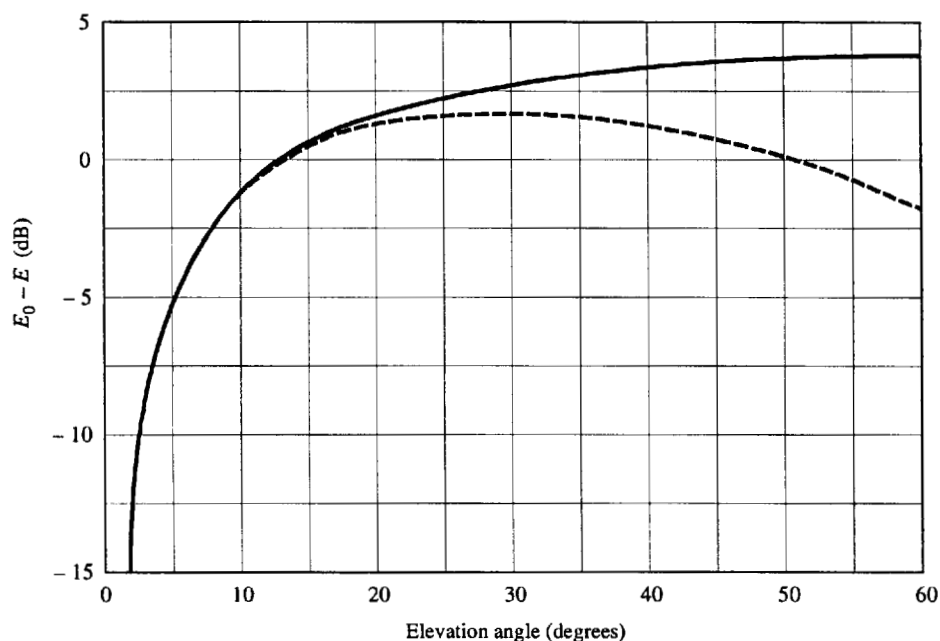
Since existing methods of prediction of signal intensities do not take account of field distortion effects due to local features at the receiving site such as undulating ground, obstacles like buildings and foliage and adjacent antennas which act as re-radiating structures, it is important to site the receiving antenna so that these effects are kept to a minimum. The ground should have a slope not exceeding 2° out to a distance of five wavelengths and no obstacles should subtend an angle from the horizontal at the centre of the antenna in excess of 5° . The separation from other antennas should be not less than ten times the antenna length.

It is more important that the receiving-antenna performance should be known accurately than that it should have high gain. Except at the lower frequencies during the daytime when there is much ionospheric absorption, threshold levels for signal detection will normally be determined by external noise intensities whatever receiving antenna is used. In general, the greater the antenna gain, the more likely the possibility of error in assessing its performance. Accordingly, a short vertical active antenna or a grounded vertical monopole antenna not exceeding a quarter wavelength high or a small loop antenna are most appropriate to employ. The loop antenna would normally be aligned in a vertical plane containing the great-circle direction to the transmitter. For long-distance paths where off-great circle propagation is likely to be important, the vertical-monopole antenna is preferable since this provides omnidirectional azimuthal pick-up. If several transmissions from different azimuths are recorded with one antenna, only a vertical antenna should be used. Some organizations use vertical monopoles for signal measurements but standardize results by means of calibration data involving comparisons for selected sample signals with the pick-up indicated by a portable "field-strength" meter incorporating an integral loop-receiving antenna.

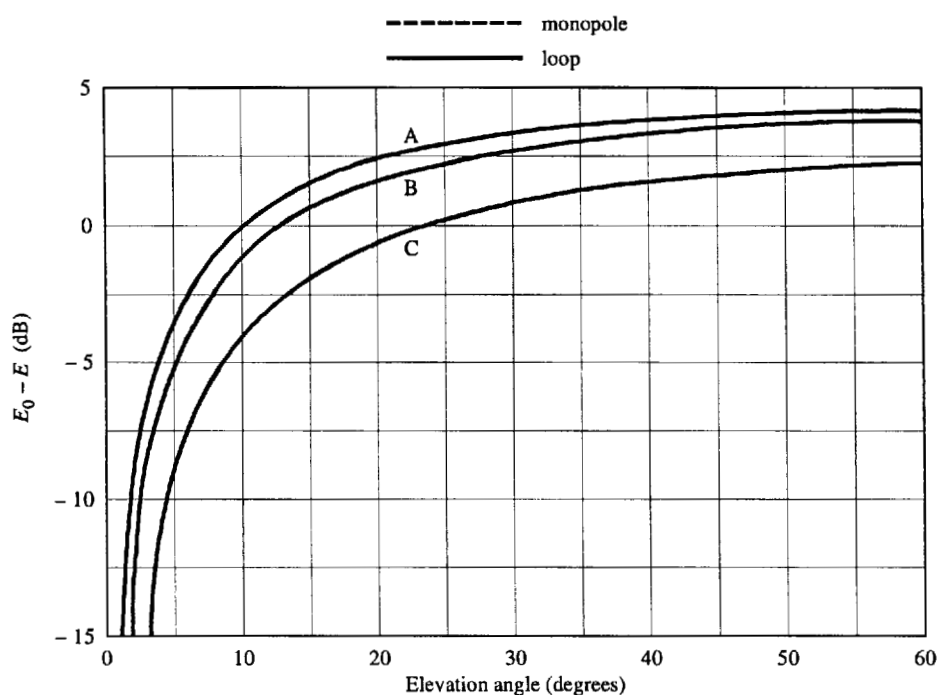
Figure 2a) shows the variation with elevation angle of the term $E_0 - E$ (a measure of the signal pick-up resulting from a downcoming sky-wave of constant intensity and its associated ground-reflected wave, defined in § 6.2) for a short vertical grounded monopole and a loop antenna, both situated over average ground. For elevation angles below about 30° the monopole and loop antennas have very similar polar diagrams but at higher elevation angles the loop-antenna pattern is preferable since the pick-up is relatively insensitive to angle. Figure 2b) shows the effect of antenna siting over ground of different properties. Signal pick-up for wet ground exceeds that for very dry ground by some 2-6 dB with the largest differences occurring at low elevation angles. The marked dependence of the pick-up on the ground constants and on the elevation angle when this is low, which has been discussed already with regard to the transmitting antenna, leads to particular data interpretation difficulties for long paths where elevation angles are not known accurately. In principle, the use of an artificial ground screen would lead to a receiving system performance less dependent on weather conditions which affect ground water content. The screen would improve the ground constants and so increase the signal pick-up, but to be effective in this role it would need to have dimensions of the order of tens of wavelengths and this is rarely practicable. On the other hand, short screens of length up to about five wavelengths can be implemented and are of value in stabilizing antenna impedances to improve circuit matching. If a screen is used, it is desirable to assess its effect by carrying out near-site calibration measurements with signals radiated in the far-field region from an airborne transmitter.

FIGURE 2

Difference between r.m.s. equivalent-incident field strength, E_0 , and r.m.s. sky-wave field strength, E , for short vertical monopole and for loop antenna at a height of 1 m. Frequency: 15 MHz



a) Monopole and loop sited over average ground of conductivity $\sigma = 0.01$ S/m, relative dielectric constant $\epsilon = 15$



b) Loop sited over wet, average and very dry ground

Curves A: wet ground $\sigma = 0.02$ S/m, $\epsilon = 20$
 B: average ground $\sigma = 0.01$ S/m, $\epsilon = 15$
 C: very dry ground $\sigma = 0.002$ S/m, $\epsilon = 5$

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Horizontal half-wave dipoles for single-frequency operation or terminated dipoles for multiple-frequency measurements are sometimes suitable for reception of signals on short paths. In particular, pick-up is not strongly dependent on the ground constants. However, for medium distance and long paths when elevation angles are low, these antennas provide

only limited pick-up, again markedly dependent on elevation angle, unless they are elevated to great heights. They should not be used for these paths because of calibration difficulties.

Some organizations are equipped to make measurements using special antenna systems, such as rhombic arrays, designed for specific circuits to improve signal/noise ratios and to enable measurements to be made under conditions where a simple antenna would be unusable. It is difficult to interpret the results obtained on an extended antenna system in the presence of a complex field built up of several waves incident at different angles, but measurements made with such antennas may be acceptable for the purpose in hand, if they can be related consistently to those that would be obtained at the same time on a standard antenna. In making a choice between antennas responding either to vertical or horizontal polarization, it is prudent to check that, if propagation paths involve waves with markedly non-circular polarization, reception (or transmission) is predominantly that of the stronger ordinary wave.

The receiving antenna should be connected to the receiver via a buried coaxial cable and appropriate matching circuitry. This latter may take the form of a transformer or a wideband pre-amplifier. The receiver bandwidth should be as narrow as possible consistent with the bandwidth of the transmitted signals, in order to optimize the received signal/noise ratio. For continuous-wave signals and for the monitoring of the steady tone sideband signals of standard-time transmissions, bandwidths of the order of 100 Hz or less are suggested.

Received signal intensity depends on radiated power within the receiver bandwidth. This is a function of the carrier, modulation and recording arrangement. For a receiver bandwidth which encompasses the carrier and all sidebands, the operative radiated power is equal to the sum of that of the carrier and all other components. Figures for different types of modulation are given in Recommendation ITU-R SM.326. In the case of narrowband reception of a single sideband of a standard time transmission of carrier power P where the amplitude modulation depth is m , the sideband power is $m^2 P/4$.

Signals should be detected, applied to appropriate integration-smoothing circuitry, and then recorded in suitable form.

Some organizations monitor signals over oblique paths in order to note the occurrence of events like sudden ionospheric disturbances (SIDs) and magnetic storms, or to study fading statistics. In these cases, special recording procedures may be necessary. Where, however, the prime requirements are to collect representative hourly signal-intensity data, measurements are best made using a pen-chart recorder with a logarithmic amplitude scale (i.e. linear in decibels) and a chart speed of about 2 cm per hour. The integration time constant should be about 20 s. This arrangement provides a convenient length of record for manual smoothing whilst at the same time permitting the rejection of sections shown to be contaminated by interfering signals or strong atmospherics. It is often simpler to record the automatic gain-control voltage from a commercial receiver after modifications to equate and lengthen the rise and decay time constants to the 20 s noted above. However, this approach may lead to unacceptable errors under some conditions, even after continuous-wave calibration of the response. Output voltage is usually approximately proportional to the logarithm of the input voltage, but since this non-linearity is associated with the detection process and occurs prior to integration, recordings give the mean logarithm of the signal intensity and not the mean in logarithmic units as required. These quantities differ when there is signal fading present. An alternative acceptable form of recording involves digital quantization of instantaneous amplitudes at a convenient sampling rate so as to cover the known periodicity of typical fading components (with fading durations up to about 20 min). Representative values may then be determined by computer processing. Apart from identification problems, the use of a computer to control the measuring receiver can greatly accelerate and simplify both measurements and statistical analysis. It cannot be emphasized too strongly though that with these techniques some form of regular check must be introduced to ensure that what is measured is the wanted transmission.

Hourly figures each day are best expressed in the form of median values. With chart recording it is preferable to derive the median directly as that amplitude which is exceeded for a total of half the recording duration (i.e. 30 min for hourly medians). This procedure is independent of the chart amplitude scale. When a precise logarithmic amplitude scale is used for recording, the median may alternatively be given approximately by two-thirds the chart deflection between the quasi-minimum value (exceeded for $Q\%$ of the time, say, where $Q \geq 90\%$) and the quasi-maximum value (exceeded for $(100 - Q)\%$ of the time), assuming that fading follows a Rayleigh distribution. With computer recording and processing it is suggested in Annex 2 that a minimum of 12 independent samples are needed to produce representative hourly median values. The samples should ideally be distributed uniformly throughout the hour, but if switched recording of signals from several transmitters is required, groups of 4 samples within 4 min, repeated three times during the hour, are acceptable.

5 Calibration measurements

Pen-chart recorder deflections or computer-recorded data should be related to the associated voltages injected directly into the receiver from a signal generator. Periodic calibration measurements are needed to express r.m.s. signal-generator voltage readings in terms of the corresponding amplitudes of the recorded sky waves. Two approaches are possible. In the one, cable, mis-match and coupling losses, together with antenna impedance measurements, are needed so that signal data may be expressed as available receiver powers and associated field strengths. In the other, appropriate only to reception of vertically-polarized wave components, a direct comparison is made with meter values indicated by a portable "field-strength" measuring system incorporating a vertical loop antenna. In this case, it is important to be certain what assumptions have been made in calibrating the meter and what field strengths are quoted (see § 6.2).

6 Conversion of measured data to mean available receiver power and r.m.s. sky-wave field strength

The existing method of Recommendation ITU-R P.533 for estimating sky-wave signal intensities gives values of mean available receiver power in the absence of receiving-system losses and r.m.s. sky-wave field strength. Hence, conversion relationships are needed between the measured voltages developed across the receiver input terminals and these quantities.

6.1 Mean available receiver power

The relationship between measured receiver input voltage when fed from a practical antenna and the available power from an idealized lossless receiving antenna coupled to a matched load depends on the receiving-system losses and the impedances of the antenna and receiver. In general, the receiving-system losses and the antenna impedance are frequency-dependent factors. In particular, the relationship is not a function of the wave-arrival directions or polarizations.

Consider first the idealized case of a lossless receiving antenna feeding a matched load.

Let

- P_a : available power from receiving antenna (dBW)
- V_0 : r.m.s. voltage developed across matched load (dB(1 μ V))
- r : antenna load resistance (Ω).

Then

$$P_a = V_0 - 10 \log r - 120$$

In particular for $r = 50 \Omega$:

$$P_a = V_0 - 137 \quad \text{dB} \quad (2)$$

Now consider the practical case of an antenna coupled to a receiver via a feeder cable and a transformer or other matching circuitry, but where some matching losses arise, r is then the load resistance presented by the receiver.

Let

- V_r : r.m.s. voltage developed across receiver input terminals (dB(1 μ V))
- L : cable loss (dB)
- T : mis-match and coupling losses (dB).

In general, the evaluation of T involves a knowledge of the antenna impedance. T includes losses in transformers and other antenna-matching circuitry, and losses associated with the matching of the feeder cable to the receiver. Then

$$V_0 = V_r + L + T$$

so that, from equation (2):

$$P_a = V_r + L + T - 137 \quad \text{dB} \quad (3)$$

Now for reception of fading sky-wave signals where P_a represents the mean available power (dBW) and V_m is the hourly median receiver input voltage (dB(1 μ V)), a fading allowance must be included in equation (3). Assuming Rayleigh fading, the r.m.s. voltage is 1.6 dB greater than the median, so that:

$$P_a = V_m + L + T - 135.4 \quad \text{dB} \quad (4)$$

Equation (4) may be used to relate measured values of V_m to P_a provided the various system losses are known. If it is not possible to determine L and T as, for example, where calibration is by standardization with a portable field-strength meter, then alternatively P_a may be given in terms of E , the r.m.s. sky-wave field strength (dB(μ V/m)), when this is known (see § 6.2), by

$$\begin{aligned} P_a &= E + G_r - 120 + 10 \log \left(\frac{\lambda^2}{480 \pi^2} \right) \\ &= E + G_r - 20 \log f - 107.2 \quad \text{dB} \end{aligned} \quad (5)$$

λ is the wavelength (m) and f the frequency (MHz). G_r is the receiving antenna gain (expressed in decibels relative to an isotropic radiator in free space) which, in particular, depends on wave-arrival direction. This direction is not usually measured but must be predicted. Hence, this means of deriving P_a is less appropriate, since it does not lead to independent data to test the accuracy of the predictions.

6.2 R.m.s. sky-wave field strength

Measured receiver input voltages may be expressed in terms of the corresponding voltages induced in the receiving antenna, and thence as associated field strengths. In the case of simple configurations such as a vertical monopole antenna and a broadside or end-on dipole or loop antenna responding to waves with a single (horizontal or vertical) polarization, it is convenient to introduce the concept of an equivalent-incident field strength. This refers to a resultant field with the same polarization as that to which the antenna responds. It may be regarded as the sum of a downcoming sky wave and a ground-reflected wave. Portable commercial field-strength meters are usually calibrated to indicate equivalent-incident field strength. On the other hand, for extended antennas composed of separate limbs with different orientations, such as the horizontal rhombic antenna, the term "equivalent-incident field strength" has no physical significance. The signal pick-up and the resultant field vary for the different limbs. In the case of the off-axis pick-up on a simple antenna like a dipole or a loop antenna, the equivalent-incident field concept also is not particularly useful. The antenna then responds to waves of elliptical polarization, and induced voltages depend not only on the wave strengths, but also on the match between the wave polarizations and the polarizations to which the antenna responds for the particular directions of incidence. Waves of different polarization and intensity incident from the same direction may then produce the same induced voltage.

The relationship between equivalent-incident field strength and voltage induced in the receiving antenna is a function of frequency, but unlike the corresponding relationship for sky-wave field strength, it is independent of wave-arrival direction and ground constants. In both cases the conversion factor has the dimensions of length, so that where the concept of an equivalent-incident field strength is meaningful, it is convenient to refer to two different antenna effective lengths. Let l_{ei} be the effective length relating equivalent-incident field strength to antenna induced e.m.f., and l_{es} be the effective length relating sky-wave field strength to antenna induced e.m.f. To compare equivalent-incident field strength and sky-wave field strength, which is the same as to relate l_{ei} to an appropriate l_{es} , is usually complicated and involves assumptions about the prevailing wave-field component amplitudes, polarizations and arrival angles; also a knowledge of the antenna polar diagram is required.

Let

E_0 : r.m.s. equivalent-incident field strength (dB(μ V/m))

V_m : median voltage developed across receiver input terminals (dB(1 μ V))

and let l_{ei} be expressed in metres. Then again assuming Rayleigh fading:

$$E_0 = V_m + L + T - 20 \log(l_{ei}) + 7.6 \quad \text{dB} \quad (6)$$

For a vertical monopole of physical length l (m)

$$l_{ei} = \frac{\lambda}{2\pi} \tan \frac{\pi l}{\lambda} \quad (7)$$

and in particular for $l \ll \lambda$, $l_{ei} \approx \frac{l}{2}$.

For a small n -turn loop antenna of area A aligned in the plane of incidence:

$$l_{ei} = \frac{2\pi n A}{\lambda} \quad (8)$$

Now if E is the r.m.s. sky-wave field strength (dB(μ V/m)), and l_{es} is expressed in metres, then comparison with equation (6) leads to:

$$E = V_m + L + T - 20 \log(l_{es}) + 7.6 \quad \text{dB} \quad (9)$$

But l_{es} is given in terms of the antenna gain relative to an isotropic antenna in free space g_r and radiation resistance r_a (Ω) by:

$$l_{es}^2 = \frac{g_r \lambda^2 r_a}{120 \pi^2} \quad (10)$$

so that with $G_r = 10 \log g_r$ and f (MHz), E may be expressed alternatively as:

$$E = V_m + L + T - G_r - 10 \log r_a + 20 \log f - 11.2 \quad \text{dB} \quad (11)$$

The difference between equivalent-incident field strength and sky-wave field strength is given from equations (6) to (11) by equating values of V_m . This is shown in Fig. 2 for the cases of a short vertical grounded monopole and a loop antenna.

6.3 Preferred signal-intensity parameter for comparison of measured data with predictions

It has been seen in § 6.1 and 6.2 that whereas measured data are related to available receiver power in terms of the receiving-system parameters only, to express the measurements as corresponding sky-wave field strengths involves a knowledge of wave-arrival directions and polarizations. Since these directions are not normally measured but must be predicted, it follows that, where possible, the preferred signal-intensity parameter for the purpose of comparison exercises with predictions is the available receiver power. Therefore, it is recommended that when a new HF field strength measurement is made, the available receiver power P_a is derived directly from measured values of V_m by the use of equation (4) in § 6.1. On the other hand, in order to derive P_a from the monthly median value of the r.m.s. field strength E in the Data Bank D1, the following equation derived from both equations (4) and (11) should be applied:

$$P_a = E + G_r + 10 \log r_a - 20 \log f - 124.2 \quad \text{dBW} \quad (12)$$

7 Data-tabulation procedures

Four types of data-tabulation sheet may be prepared, depending on whether it is the wish of the organization undertaking measurements to quote values in:

- received power (dBW) (without correcting for receiving antenna effects);
- receiver input voltage (dB(μ V)) (without correcting for receiving antenna effects);
- incident field strength (dB(μ V/m)) (receiving antenna allowance ignores reflection of the downcoming sky-wave near the receiving antenna);
- sky-wave field strength (dB(μ V/m)).