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.

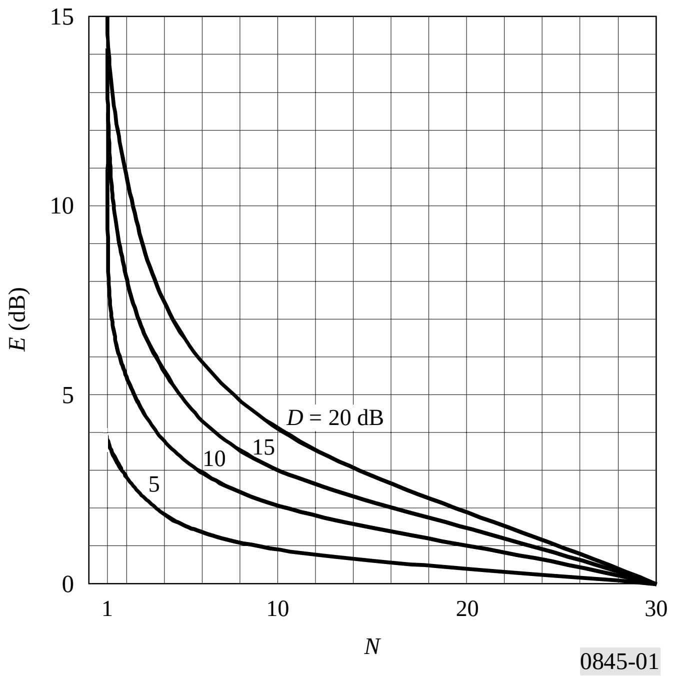
2 Choice of circuits and periods of operation

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:

$$E = \frac{D}{1.28}\sqrt{\frac{1}{N} - \frac{1}{30}} \qquad \text{dB} \tag{1}$$

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

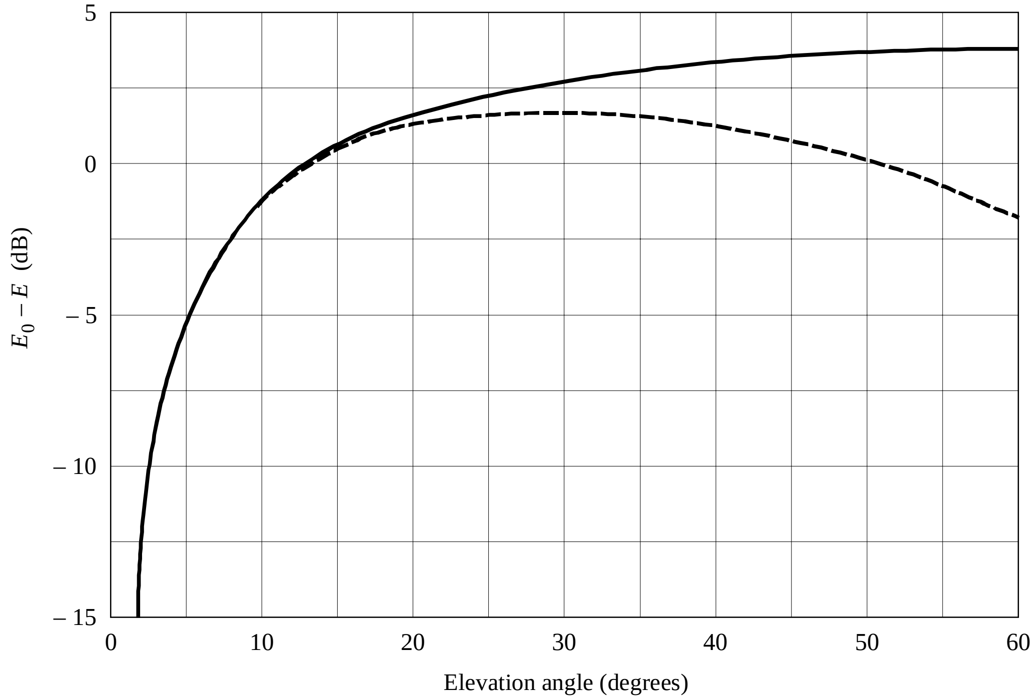
Since existing methods of prediction of signal intensities do not take account of field distortion effects due to local features at the receiving site such as undulating ground, obstacles like buildings and foliage and adjacent antennas which act as re-radiating structures, it is important to site the 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.

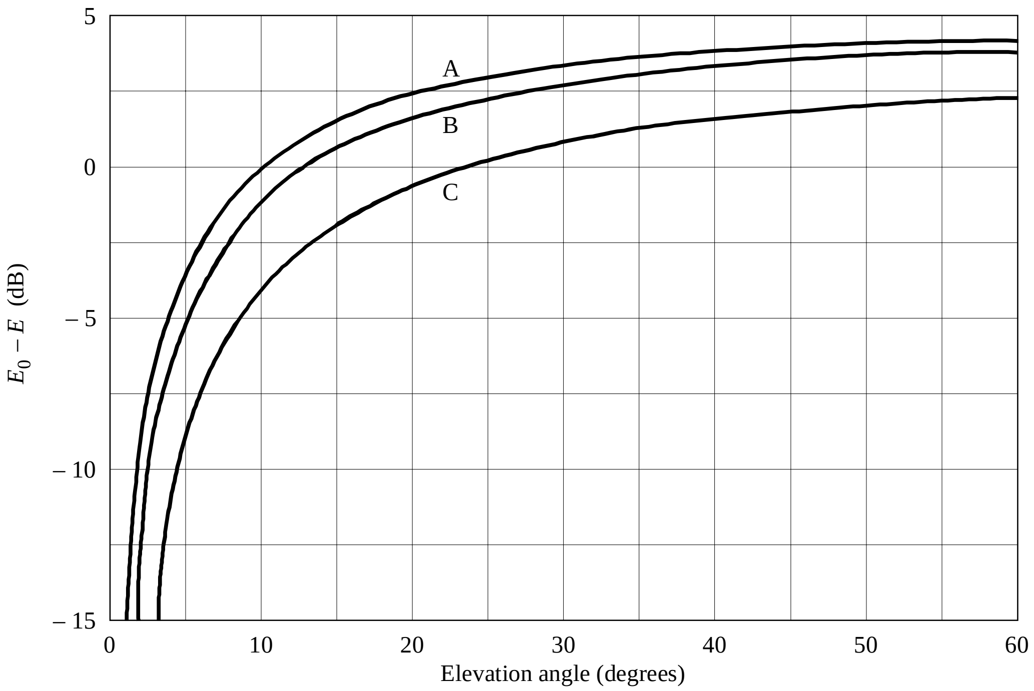
FIGURE 2

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 σ = 0.01 S/m, relative dielectric constant ε = 15

monopole
loop



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

Curves A: wet ground σ = 0.02 S/m, ε = 20
B: average ground σ = 0.01 S/m, ε = 15
C: very dry ground σ = 0.002 S/m, ε = 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 $m^2P/4$.

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 μV))
- r: antenna load resistance (Ω).

Then

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

In particular for $r = 50$ Ω:

$$P_a = V_0 - 137 \qquad \text{dB} \tag{2}$$

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 μV))
- 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):

$$P_a = V_r + L + T - 137 \qquad \text{dB} \tag{3}$$

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 μV)), 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:

$$P_a = V_m + L + T - 135.4 \qquad \text{dB} \tag{4}$$

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(μV/m)), when this is known (see § 6.2), by

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

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(μV/m))

V_m: median voltage developed across receiver input terminals (dB(1 μV)) and let l_{ei} be expressed in metres. Then again assuming Rayleigh fading:

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

For a vertical monopole of physical length l (m)

$$l_{ei} = \frac{\lambda}{2\pi} \tan \frac{\pi l}{\lambda} \tag{7}$$

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

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

$$l_{ei} = \frac{2\pi n A}{\lambda} \tag{8}$$

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

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

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:

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

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

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

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:

$$P_a = E + G_r + 10 \log r_a - 20 \log f - 124.2 \qquad \text{dBW} \tag{12}$$

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(μV)) (without correcting for receiving antenna effects);

– incident field strength (dB(μV/m)) (receiving antenna allowance ignores reflection of the downcoming sky-wave near the receiving antenna);

– sky-wave field strength (dB(μV/m)).

Although received power would be the most suitable parameter, presently it is desirable to use incident field strength because the receiving antenna allowance is probably better known at the receiving site.

7.1 Circuit and operating details

A sample sheet for the technical information needed is contained in Table 1. Tables 2 and 3 provide a brief amplification of what is asked for in Table 1. The purpose of these three tables is that they be used by organizations undertaking HF signal-amplitude measurements.

TABLE 1

Technical information sheet

ITU-R data bank of HF signal-amplitude measurements		
This technical information sheet must accompany the hourly data sheets		
Kind of information	Transmitter	Receiver
Location		
Geographical latitude	N/S	N/S
Geographical longitude	E/W	E/W
Name and address of station and/or telephone, telex and telefax numbers		
Ground conductivity	S/m	S/m
Ground permittivity		
Antenna: type		
polarization		
horizontal beam	degrees	degrees
vertical beam	degrees	degrees
gain	dBi	dBi
length	m	m
height	m	m
groundscreen		
number of elements		
Frequency	kHz	
Call sign		
Class of modulation		
Carrier power	kW	
Power at antenna feed point	kW	
Hours of operation	UTC	
Source of information		
Reliability of information		
Receiver type		
Recording time		min/h
Receiver bandwidth		kHz
Hourly parameter reported (please tick which)		median mean r.m.s.
Units reported (please tick)		
Received power		dBW
Receiver input voltage		dB(μV)
Incident field strength		dB(μV/m)
Sky-wave field strength		dB(μV/m)
Data reduced to 1 kW		(yes/no)
TX-antenna reduced to isotropic	(yes/no)	
Assumed elevation angle	degrees	degrees

7.2 Monthly tabulation sheets of signal-amplitude measurements

Table 4 contains a sample sheet for recording the hourly and monthly values of signal-amplitude measurements. Table 5 explains Table 4. Table 4 is required for each frequency and month, whereas Table 1 is only needed once for each frequency.

The evaluation of count, upper and lower deciles, upper and lower quartiles and median is done by a computer or, if not available, by means of the procedure described in Table 6.

TABLE 2

Explanation of the technical information sheet (Part 1)

ITU-R data bank of HF signal-amplitude measurements	
Explanations of the technical information sheet	
Location	Name of transmitter/receiver site
Geographical latitude	Latitude of transmitter/receiver (degrees and min)
Geographical longitude	Longitude of transmitter/receiver (degrees and min)
Name and address of station	Name of the organization that is responsible for the transmitter/receiver and mailing address and/or telephone/telex/telefax number
Ground conductivity	At the transmitter/receiver site
Ground permittivity	At the transmitter/receiver site
Antenna	Type (dipole, log-periodic, curtain ...) Horizontal or vertical polarization Horizontal main beam direction (degrees) Vertical main beam direction (degrees) Gain (dBi) in the main lobe Length (m) Height (m) Groundscreen, if any, provide details Number of elements
Frequency	(kHz)
Call sign	If any
Class of modulation	Broadcast, rtty, fax ...
Carrier power	Nominal power of the transmitter (kW)
Power at antenna feed point	Carrier power minus cable and matching loss between transmitter and antenna (kW)
Hours of operation	In UTC

Hourly median values should be expressed to the nearest 1 dB. Where, for some reason, values are believed only correct within 2 to 4 dB, they should be accompanied by an appropriate descriptive letter and qualified as uncertain. If an estimate to within 4 dB cannot be made, then only a descriptive letter and no numerical value should be quoted. The following letters are to be used:

– qualifying letters (preceding numerical values)

  D : to indicate that the numerical value is a lower-limit value;

  E : to indicate that the numerical value is an upper-limit value;

  U : to indicate that the numerical value is uncertain;

– descriptive letters (following numerical values or alone)

  C : no measurement was carried out or was possible because of technical trouble;

  S : measurements influenced or impossible because of interference or atmospherics.

TABLE 3

Explanation of the technical information sheet (Part 2)

ITU-R data bank of HF signal-amplitude measurements	
Explanations of the technical information sheet	
Source of information	Where is the information about the transmitter from?
Reliability of information	Subjective judge of the reliability of the above information. Most reliable is direct information from the transmitting station. Rather unreliable e.g. is information from the International Frequency List
Receiver type	Manufacturer, type of receiver
Recording time	How many minutes per hour are recorded to derive the hourly value?
Receiver bandwidth	(kHz)
Hourly parameter recorded	Are the measured data, median, mean or r.m.s. values?
Units reported	Are the values measured received power (dBW) (without correction for receiving antenna effects) or receiver input voltage (dB(μV)) (without correction for receiving antenna effects) or incident field strength (dB(μV/m)) (receiving antenna allowance ignores reflection of the downcoming sky-wave near the receiving antenna) or sky-wave field strength (dB(μV/m))?
Data reduced to 1 kW	Are the measured data reduced to 1 kW radiated power?
TX-antenna reduced to isotropic	Are the measured values reduced to an isotropic transmitting antenna?
Assumed elevation angle	How was the elevation angle of the incoming wave calculated or assumed, when the transmitting antenna gain was deduced or when the measured data were converted to sky-wave field strength?

Medians, quartiles and deciles should not be quoted if these figures are less than 2 dB above the received background noise intensity.

If more than half of all possible daily numerical values within a month are missing or qualified for any reason, then the median, the quartile and the decile values should be qualified by U and be accompanied by the relevant descriptive letter which is that appropriate to the majority of the missing and qualified data. When the median, quartile or decile is only between 2 and 4 dB greater than the noise background, it should also be qualified by U and described by S.

7.3 Tabulation of data for computer processing

If signal-intensity measurements are made with the aid of a computerized system, the data exchange should be in accordance with the procedure described in Table 7.

TABLE 4

Sample sheet for hourly and monthly signal-amplitude measurements

ITU-R data bank of HF signal-amplitude measurements	Circuit:	Frequency: kHz	Month:	Year:

Time UTC / Day	0030-0130	0130-0230	0230-0330	0330-0430	0430-0530	0530-0630	0630-0730	0730-0830	0830-0930	0930-1030	1030-1130	1130-1230	1230-1330	1330-1430	1430-1530	1530-1630	1630-1730	1730-1830	1830-1930	1930-2030	2030-2130	2130-2230	2230-2330	2330-0030
1																								
2																								
3																								
4																								
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27																								
28																								
29																								
30																								
31																								
Count																								
Upper decile																								
Upper quartile																								
Median																								
Lower quartile																								
Lower decile																								

Qualifying letters:	E: receiver input below recording threshold	D: receiver input above recording maximum	U: uncertain value
Descriptive letters:	C: no measurement carried out or technical trouble	S: interference	

TABLE 5

Explanations for the hourly and monthly signal-amplitude measurements

ITU-R data bank of HF signal-amplitude measurements	
Explanation of the tabular sheet for the hourly measurements	
Circuit	Name of transmitting/receiving station
Hourly values	For continuous transmissions, the average signal from 30 min before the hour to 30 min after the hour is to be taken. If a transmission lasts 60 min, from one hour to the next full hour, it will be split into two 30-min periods and two hourly values shall be entered into the table For hours where there was no measurement the letter C shall be entered into the table For hours where there was a measurement but this is judged to be influenced by interference or atmospherics the letter S shall be entered into the table For hours where there was a measurement but the wanted signal was below the recording threshold, that threshold and the letter E shall be entered into the table For hours where there was a measurement but the wanted signal was above the recording maximum, that maximum and the letter D shall be entered into the table For hours where there was a measurement but the wanted signal was uncertain due to any reason, the measured value and the letter U shall be entered into the table All daily and monthly summary amplitudes shall be quoted only to the nearest integer decibel
Count	The number of hours with numerical values, including those qualified by D, E and U, is the "count"
Deciles, quartiles and medians	All measured values should be sorted in order of reducing amplitude. D-values have to appear at the upper end and E-values at the lower end. Deciles, quartiles and medians are yielded according to Table 6

TABLE 6

Table for deriving deciles, quartiles and medians

ITU-R data bank of HF signal-amplitude measurements			
Table for deriving deciles, quartiles and medians			
In the table below, the procedure how to calculate deciles, quartiles and medians is given. If the sorted table contains 31 values, the 4th from the top is the upper decile, half of the sum of the 8th and 9th value is the upper quartile and the 16th value is the median. If the sorted table contains 30 values, the upper decile is taken as 9 times the 4th value plus the 3rd value divided by ten etc. Upper deciles and quartiles are counted by starting at the upper end of the table. Lower deciles and quartiles are counted by starting at the lower end of the table.			
Count	Values to be used in the calculations		
	Decile	Quartile	Median
31	4th	(8th + 9th)/2	16th
30	(9*4th + 3rd)/10	(3*8th + 9th)/4	(16th + 15th)/2
29	(4*4th + 3rd)/5	8th	15th
28	(7*4th + 3*3rd)/10	(3*8th + 7th)/4	(15th + 14th)/2
27	(3*4th + 2*3rd)/5	(7th + 8th)/2	14th
26	(3rd + 4th)/2	(3*7th + 8th)/4	(14th + 13th)/2
25	(2*4th + 3*3rd)/5	7th	13th
24	(3*4th + 7*3rd)/10	(3*7th + 6th)/4	(13th + 12th)/2
23	(4th + 4*3rd)/5	(6th + 7th)/2	12th
22	(4th + 9*3rd)/10	(3*6th + 7th)/4	(12th + 11th)/2
21	3rd	6th	11th
20	(9*3rd + 2nd)/10	(3*6th + 5th)/4	(11th + 10th)/2
19	(4*3rd + 2nd)/5	(5th + 6th)/2	10th
18	(7*3rd + 3*2nd)/10	(3*5th + 6th)/4	(10th + 9th)/2
17		5th	9th
16		(3*5th + 4th)/4	(9th + 8th)/2
15		(4th + 5th)/2	8th
14		(3*4th + 5th)/4	(8th + 7th)/2
13			7th
12			(7th + 6th)/2
11			6th
10			(6th + 5th)/2

TABLE 7

Explanation of the computerized data-exchange sheet

ITU-R data bank of HF signal-amplitude measurements		
Explanations of computerized data exchange		
Technical information must also accompany the measurements if the data exchange is by computer. The daily and monthly measured values, however, will have the following format:		
Columns 1-3	Circuit and frequency code	
Column 5	1: 2: 3: 4: 5: 6:	daily values upper deciles upper quartiles medians lower quartiles lower deciles
Column 7	1: 2: 3:	median mean r.m.s.
Column 8	1: 2: 3: 4:	available receiver power (dBW) receiver input voltage (dB(μV)) incident field strength (dB(μV/m)) sky-wave field strength (dB(μV/m))
Columns 10-11	Year (two digits)	
Columns 13-14	Month (two digits)	
Column 16	1 = 01-12 UTC 2 = 13-24 UTC	
Columns 18-19	Day of month	
Remaining columns from 21 to 80: 5 columns each for 12 h		
	Column 1: Column 2: Column 3: Column 4: Column 5:	qualifying letter (or space if none) data value – hundreds data value – tens data value – units descriptive letter (or space if none)
Data should be written on diskettes (3½ in MS-DOS format).		

ANNEX 2

HF field-strength measurement technique – Specifications for a field-strength measurement campaign intended for future improvements in prediction methods

1 Introduction

Major difficulties arise in HF field-strength measurements in the positive identification of transmissions and in the characteristics of equipment and antennas available for those measurements. Thus it is recommended that a network of new computer-controlled transmitters and receivers be installed with the characteristics described in this Annex. These arrangements will minimize the uncertainties, ensuring data of high quality, and should permit a large number of moderately priced receiving installations to be provided around the world.

2 The HF field-strength measurement campaign

The required data cannot be obtained unless new transmitters and receivers are installed. It is recommended that these transmitters should be frequency agile, each radiating on up to five frequencies sequentially according to a predetermined schedule. In each case there should be a period of steady signal emission for manual measurements and coded sequences permitting aural identification of the source, computer identification of the source and computer evaluation of the intensities of both the signal and the background noise or interference.

To minimize the possibility of interference, the transmissions should be on assigned frequencies probably in the fixed service bands.

A number of receiver implementations are possible, meeting the specification given below, but a single standard for the receiving antenna is recommended. Each receiver should operate on a rapid measuring sequence, dwelling on each frequency for up to 12 s, and should be able to measure signal levels on many of the transmitted frequencies during each hour. At least one model of receiver, including the interface, computer and software, is available and it is hoped that some administrations will provide some equipments on loan to those developing countries where there is a great need for new measurement data.

3 Transmitter

3.1 Transmitter locations

In order to collect data representative of HF propagation conditions on a worldwide scale, there should preferably be at least nine transmitters. These should be located in the Northern and Southern Hemispheres at middle latitudes and in the tropics in Regions 1, 2 and 3 (see Table 8). It should be noted however that useful results can be obtained from a more limited number of transmitters should the distribution proposed in Table 8 not become available.

TABLE 8

	Region 1	Region 2	Region 3
Northern Hemisphere	North/Central Europe	North America	Asia
Tropics	Tropical Africa	Caribbean Area	South-East Asia
Southern Hemisphere	Southern Africa	South America	Australasia

3.2 Transmitter power

Transmitter power should be in the range of 5-10 kW.

3.3 Transmitting antennas

Transmitting antennas should be omnidirectional in azimuth and should have a broad elevation pattern. In order to avoid the necessity for frequent switching of high RF powers, a single broadband monopole or conical structure is preferable. However, such antennas usually have a changing vertical radiation pattern (vrp) for frequencies greater than about three times the lowest design frequency, which is when the antenna height is approximately $\lambda/4$, and the characteristics of particular proposed antennas should be studied carefully before implementation. The criterion for the vrp is that at the higher operating frequencies the pattern should not depart by more than 3 dB from the vrp of a $\lambda/2$ monopole (the mid-band case) over the range of elevation angles up to 65°. A possibility is to select a broadband antenna which is operating at about three times its lowest design frequency at the highest operating frequency and that operation on the lowest operating frequency is permitted by the use of a frequency selective matching network.

The antenna should be installed on flat ground of no more than 2° slope and should be located on an unobstructed site with obstacles of not higher than 4° elevation.

3.4 Frequencies and transmitter schedules

Transmissions from one location should take place in five frequency bands on frequencies, preferably in the fixed service bands, near 5.5, 8, 11, 15 and 20 MHz. The emissions on each frequency should be radiated sequentially commencing at 0, 4, 8, 12 . . . etc. minutes after each hour. The frequency schedule should be communicated to the Director, BR, for dissemination to all participants in the measurement campaign.

Should more than five transmitters operate simultaneously, more than one frequency will be needed in all bands if mutual interference is to be avoided. Six to 10 transmitters require two frequencies in each band, 11 to 14 require three per band, etc.; the number required for n transmitters is $| (n – 1)/5 | + 1$. Table 9 shows a schedule for nine transmitters that use two frequencies, 1 and 2, in each band A to E.

TABLE 9

Frequency schedule for nine transmitters

Transmitter \ Min	0–4	4–8	8–12	12–16	16–20
1	A1	B1	C1	D1	E1
2	B1	C1	D1	E1	A2
3	C1	D1	E1	A2	B2
4	D1	E1	A2	B2	C2
5	E1	A2	B2	C2	D2
6	A2	B2	C2	D2	E2
7	B2	C2	D2	E2	A1
8	C2	D2	E2	A1	B1
9	D2	E2	A1	B1	C1

3.5 The transmitted signal

3.5.1 The emission should be of class F1B with a frequency shift of 850 Hz. In accordance with Recommendation ITU-R F.246 the “mark” should be on the lower frequency i.e. 425 Hz below the assigned frequency.

NOTE 1 – If the emission is generated using suppressed carrier single-sideband techniques then it may be convenient to use, for example, as a reference frequency, a suppressed carrier frequency 1 225 Hz below the assigned frequency, in conjunction with upper sideband modulation frequencies of 800 Hz for the “mark” frequency and 1 650 Hz for the “space” frequency.

3.5.2 The transmitted sequence on each frequency should be as described below having a duration of 12 s. The sequence should be repeated for 4 min, curtailing the final repetitions as necessary so as to allow time for the transmitter frequency change:

– FSK preamble at 100 bit/s for 1 s, comprising signal reversals commencing on the mark frequency;

– a pause of 50 ms;

- an identification signal in Morse code on the higher frequency (see Recommendation ITU-R F.246) contained within a period not exceeding 3.3 s:
  - the ratios of lengths within the Morse code sequence shall be in the following ratios:
    - dot element length 1 unit
    - dash element length 3 units
    - space between elements within a character 1 unit
    - space between characters of the call sign 3 units
  - the length of the unit for the dot element length, etc., shall be a greatest multiple of 100 ms, so that, to the greatest extent possible, the call sign fills the 3.3 s time available; the call sign shall commence at the beginning of the available period, with any unused time at the end of the period;
  - if permissible this identification signal could with advantage be based on the international locator code used by radio amateurs, provided that the signal can be contained within the period specified;
- a pause of 50 ms;
- a 256-bit complementary sequence transmitted at 1 200 bit/s as follows:

  Sequence 1:

  1110010000101000000010100110110000000110110010100011101011110110000000110
  1111010111000101001101100011100100110101111110101111011000000110111101
  0111111010110010011100011011001010001110101111011000111001000010100011
  1010110010011111100100110101111110101111011000
- a pause of 50 ms;
- a second 256-bit complementary sequence transmitted at 1 200 bit/s, as follows:

  Sequence 2:

  0001101111010111111010110010011111100100110101110001010000100111000110
  1111010111000101001101100011100100110101111110101111011000111001000010
  1000000101001101100011100100110101110001010000100111111001000010100011
  1010110010011111100100110101111110101111011000
- a pause of 50 ms;
- a series of FSK reversals, comprising 273 bits at 100 bit/s, commencing on the lower frequency;
- a 127 bit Gold code identifier sequence, at 100 bit/s, commencing on the lower frequency. The sequences to be used by each transmitting station taking part in the campaign may be obtained from the BR. The Bureau will also advise receiving stations of the sequences in use;
- a constant signal on the higher frequency for a duration of at least 3 s, which should continue until the total time for the sequence is 12 s.

NOTE 2 – The automatic identifier takes the form of a Gold code, length 127 bits, obtained using the following 7 stage shift-register generator algorithm:

$$s_1 = x^7 + x^3 + x$$

$$s_2 = x^7 + x^3 + x^2 + x + 1$$

the sequences successively assigned to transmitter stations should be in the order:

$$s_1 \; ; s_2 \; ; (s_1 \; + \; s_2); (s_1 \; + \; \tau \cdot s_2); \; ......(s_1 \; + \; \tau^{126} \cdot s_2)$$

where τ^n represents a cyclic shift of n places.

3.6 Log-keeping

Detailed logs containing information on the status of the transmitter and particularly on the transmitter power should be completed at all sites and should be forwarded periodically to the Director, BR.

4 Receiver

4.1 Receiver locations

There should be as many receiving stations for the recording of the nine proposed transmitters as possible. Due to the null in the elevation pattern of vertical transmitting antennas, measurements should not be made at ranges shorter than about 500 km.

4.2 Antennas and siting

Short vertical active antennas are recommended for use with field-strength measurements according to the specifications given in Appendix 1. The antennas should be installed on flat ground of no more than 2° slope and should be located on an unobstructed site of at least 25 m radius, with more distant obstacles not higher than 4° elevation, measured at ground level. The antenna should be situated away from electric power lines and other metallic structures. The antenna may be protected against damage by a wooden fence or stockade not higher than 2 m at a distance of at least 3 m. It is preferable that the site should be in an area of good and homogeneous ground conductivity; in any case the conductivity needs to be known for use in the analysis of results.

4.3 Receiver specifications and calibration

The field-strength measuring receiver should meet the following minimum performance requirements:

– synthesizer control (10 Hz step);

– external bus available for computer control;

– frequency accuracy ±1 part in 10^6;

– synthesizer noise sidebands: reciprocal mixing performance better than 70 dB in a bandwidth of 3 kHz at 20 kHz offset;

– sensitivity SSB 1.0 μV terminated for at least 10 dB $(S + N) / N$ for a bandwidth of 3 kHz;

– unwanted spurious responses (e.g. image, IF) better than 70 dB;

– selectivity: approximately 3 kHz bandwidth, shape factor (– 60 dB to – 6 dB) 2:1;

– linearity: 3rd-order intercept, 20 kHz spacing, +10 dBm;

– true average measuring capability within 4 s;

– timing accuracy within the receiver system should be maintained within 1 s.

4.4 Receiver measurement sequence

Within the 12 s code sequence transmitted, only 4 s are required for computer measurement, allowing sufficient tolerance for timing differences.

Section 5 indicates that 12 samples are required to establish a median signal level within a 1 h interval. Thus it is sufficient to measure 4 samples within 4 min, repeating three times in the hour using the 20 min cycle of transmission. In this way measurements can be accommodated on 5 frequencies within 4 min and on 25 frequencies within 1 h. The sequence is illustrated in Fig. 3.

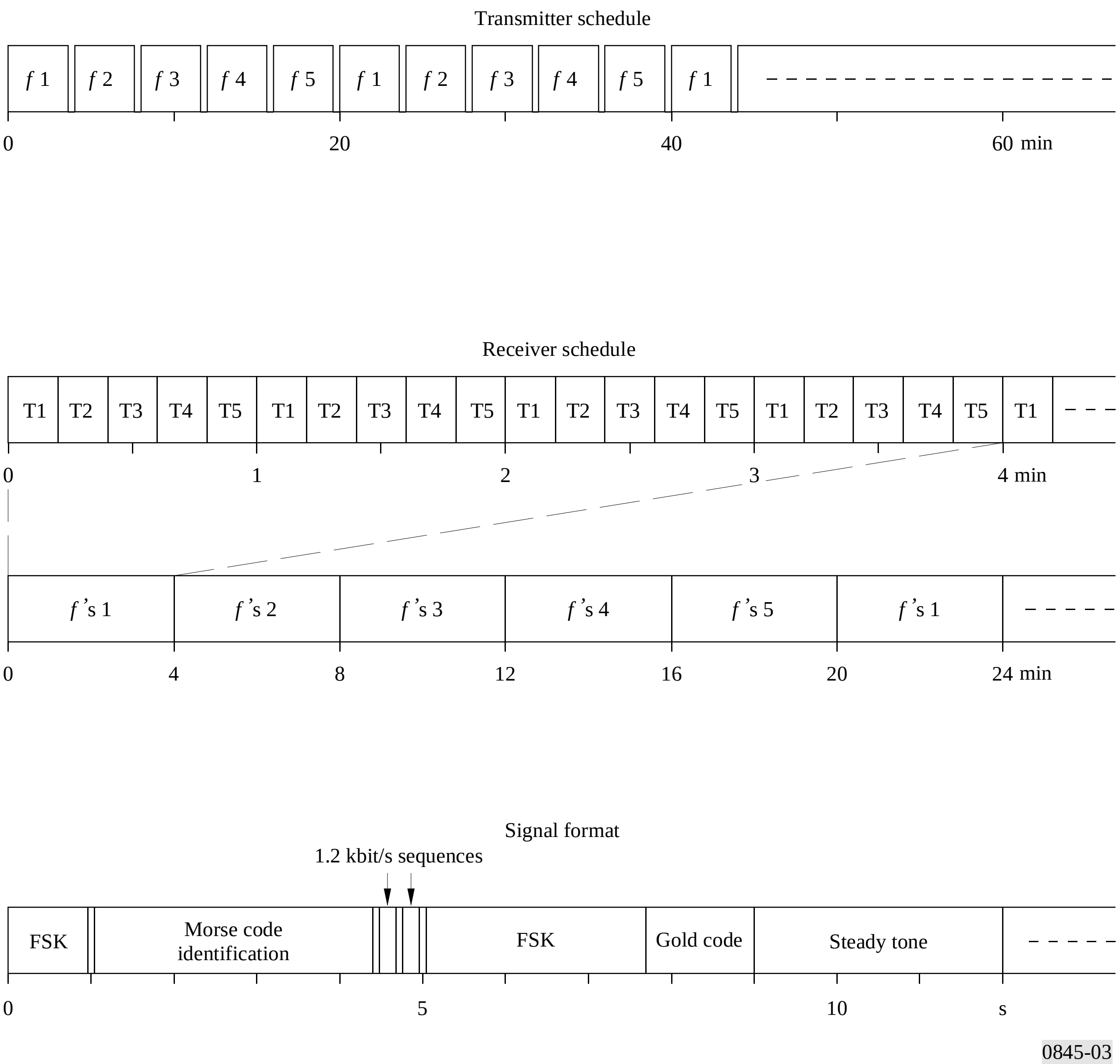
Organizations operating only one receiver may select up to 25 transmissions for measurement from the potentially available 45 transmissions in order to meet the above requirement. Alternatively, two receivers can be operated in parallel, to monitor more than 25 transmissions. Advice on the selection of suitable transmissions should be available from the “international group” as recommended in § 6.

4.5 Recording units and calibration

Use of a standardized receiving antenna and receiving system permits a common conversion to field strengths to be applied for all sites during data analysis. Measured amplitudes should be expressed in terms of corresponding receiver input voltages by injecting a reference calibration signal ideally once each day. This should be of fixed amplitude giving approximately full-scale receiver output. The strength of the calibration signal should be noted in the station log together with a record for any input attenuation used and the receiver output level should be recorded on floppy disk.

FIGURE 3

Schedules and formats



5 Signal and background noise measurement and data processing

This section describes the basic procedures to be applied to yield signal amplitudes for inclusion in a future ITU-R data bank. The transmitter signal format (§ 3.5.2) is designed to also permit additional measurements to be carried out for other types of propagation studies if desired.

5.1 Sampling

For each selected circuit (transmitter/receiver/frequency combination) the receiver records sufficient amplitude samples within each hour to permit statistically meaningful estimates of the hourly medians of both the signal and noise intensities to be determined in relation to the likely within-an-hour fading. Using either analogue or digital signal processing, average voltage amplitudes over a period of 4 s within each 12 s transmission cycle should first be determined. A minimum of 12 such samples within a given hour on a given day should be taken, these to be distributed approximately uniformly over the period that the transmitter is radiating. This results in a standard error due to sampling of less than 2 dB.

5.2 Input attenuation

To allow for the varying signal amplitude on different circuits and at different times of day, it is suggested that a switched attenuator under computer control may be inserted between antenna and receiver, values of attenuation to be recorded on floppy disk along with the signal and noise data.

5.3 Data recording

Data should be dumped to floppy disk in an agreed format (Appendix 2). Hourly medians are to be calculated centrally. Rules for dealing with samples in which the signal is not discernable from noise and interference are given in Appendix 3.

5.4 Determination of monthly medians and deciles

Monthly medians and upper and lower decile values of signal amplitude should be calculated by combining together the hourly median signal-amplitude data at a given hour for the different days. Rules for dealing with daily samples in which the signal is below the noise are given in Annex 1.

5.5 Data normalization

Data provided from the separate receiving sites should be accompanied by corresponding receiver and antenna system calibration factors for each circuit. Using this information together with that from the transmitter logs, centralized data normalization will be applied to the different daily/hourly values for incorporation in the data bank.

6 Data handling, quality assurance and training

The scheme envisages a large number of receiving locations (some operating in areas where there is a severe shortage of skilled engineers), with a large quantity of data, probably in floppy-disk format, being sent to a central agency for compilation and processing. Such a scheme will work only if adequate attention is given to organization and training.

It is recommended that an international group should be set up to oversee the measurement programme and to provide guidance and assistance to participants. It is further recommended that ITU support should be provided to receive and process the data in consultation with the group.

The necessary tasks are to:

– collect and validate measured data provided from the different receiving sites;

– create and maintain summary files of daily hourly median field strengths;

– normalize these results in accordance with the known transmitting and receiving system performance, generate a definitive data bank, and

– arrange training workshops in various parts of the world so as to ensure the satisfactory operation of receiving systems.

It is recommended that all data recorded by such equipment be forwarded to the Director, BR, to facilitate the development of a new ITU-R data base of field-strength measurements.

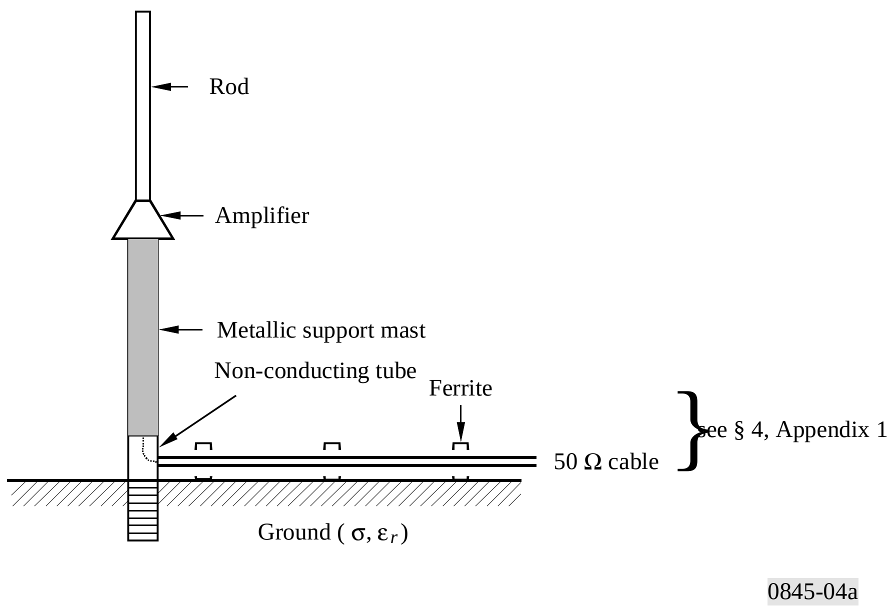
APPENDIX 1

Specifications for a vertical antenna as a field probe for field-strength measurements

1 General outline

FIGURE 4a

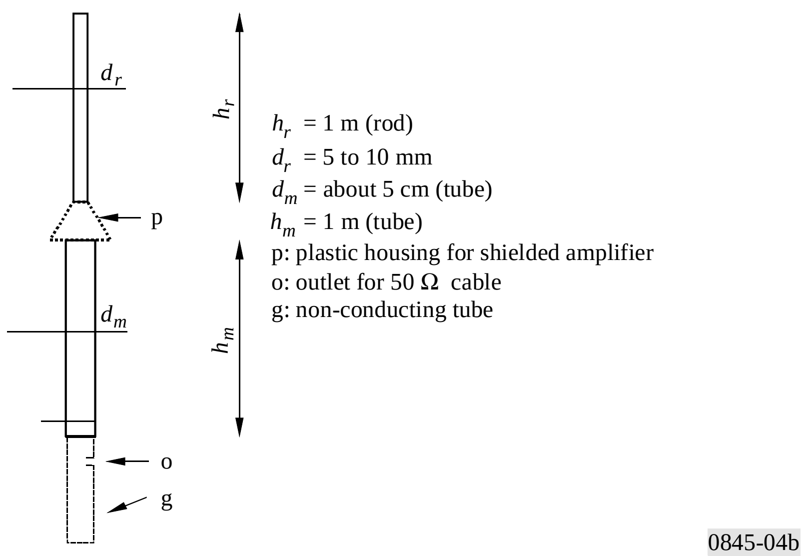
General outline of active antenna



2 Geometrical structure

FIGURE 4b

Geometrical structure of active antenna



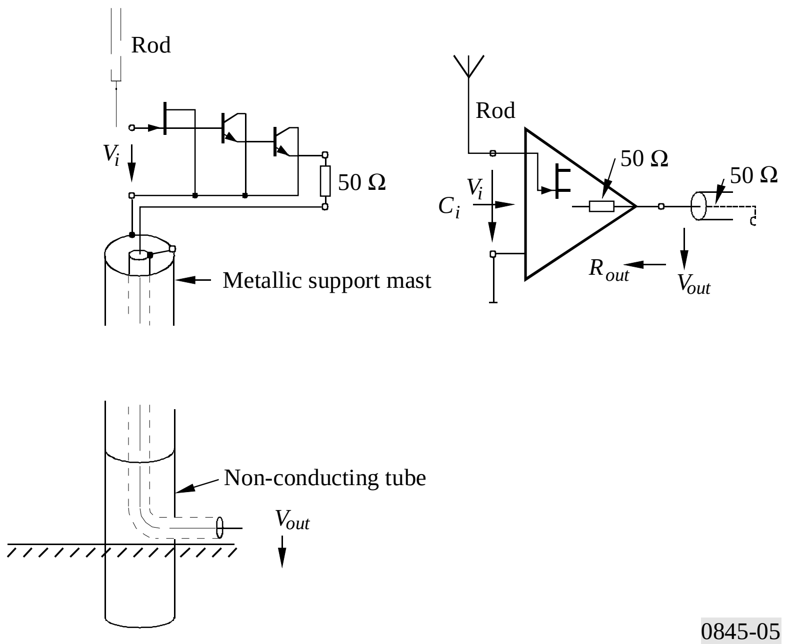
3 Amplifier of active antenna

3.1 Basic schematic

For example an FET source follower and bipolar emitter follower could be used. The d.c. power could be fed through the inner conductor of the coaxial cable.

FIGURE 5

Basic schematic of active antenna



0845-05

3.2 Electric characteristics of active antenna

– Amplification: $V_{out} / V_i \approx 1/2 \triangleq -6$ dB

– Input impedance: $C_i = 15$ pF

– Output resistance: $R_{out} = 50\ \Omega$, VSWR ≤ 2

– Noise figure measured at output:

$$F_{out} \leq 15 \triangleq 11.8 \text{ dB}$$

(Available noise power measured at the output of the shielded antenna or at the output of the amplifier when loaded with $C_A = 10$ pF at the input)

– Linearity range (signal level for 1 dB compression):

$$V_{comp,\, out} \geq 1{,}2 \text{ V (at a load of 50 } \Omega\text{) measured with dummy antenna}$$

– Intermodulation characteristics:

Intercept point 2nd order, measured at the output:

$$\text{IPOP2} \geq 50 \text{ V (ou 47 dBm) (with dummy antenna)}$$

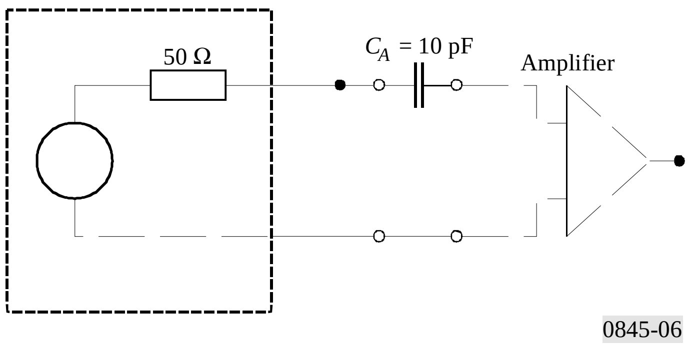
Intercept point 3rd order, measured at the output:

$$\text{IPOP3} \geq 5 \text{ V (or 27 dBm) (with dummy antenna)}$$

The intercept points to be measured by the method of two signal generators.

– Dummy antenna for measurements on the amplifier

FIGURE 6

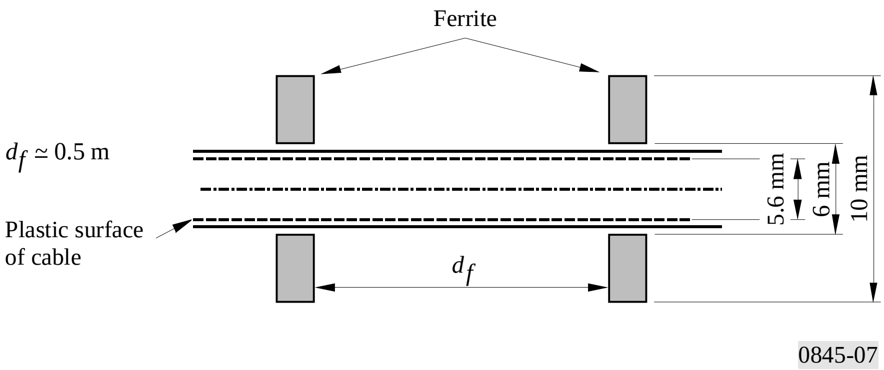


4 Antenna cable

– Characteristic impedance: $Z_c = 50$

– Suppression of currents on the outer conductor by ferrite rings

FIGURE 7



– Type of ferrite: $A_1 = 3\,000$ to $5\,000$ nH/turn^2

NOTE 1 – The arrangement shown above (ferrite beads spaced along the full length of the coaxial feeder) is convenient for temporary installations (e.g. site selection). For permanent installation fit 50 type-73 beads (do not use type-77 beads) on the antenna end of feeder coax, and use low loss buried cable to route the signal to the signal strength measuring instrument. The equivalent circuit of 50 beads on type-RG 58 coaxial cable (27 cm of cable fitted with 50 ferrite beads) is an unbalanced-to-unbalanced isolation transformer.

5 Lightning protection

The amplifier should be protected against discharge by means of diodes and a spark gap at the input.

The antenna should withstand a transient electric field of:

$$\left| \frac{\mathrm{d}E}{\mathrm{d}t} \right| \geq 500 \qquad \mathrm{kV/(m \cdot s)}$$

APPENDIX 2

Recording of signal and noise amplitudes and related information

1 Introduction

Individual 4 s average signal and noise amplitudes are to be recorded on diskettes. Whilst this will lead to the need for greater subsequent data processing by the international team than if hourly median amplitudes were recorded it will avoid the requirement for off-line data analysis at remote sites and will permit changes in analysis procedures to be introduced if subsequently found necessary.

2 General data organization

The signal and noise amplitudes will be stored in individual files, each covering a period of one hour.

Calibration information will constitute a separate file.

There will also be a general description file that contains information like disk titles, etc.

Data having predetermined values will be coded and organized into tables in order to save space and facilitate some verification throughout the process.

3 Tables

3.1 Receiver table

Each record contains:

– Receiver numeric code Maximum value 65 536 (binary)	2 bytes
– Receiver name 20 characters	20 bytes
Expected number of records:	- - - - - - -

3.2 Transmitter table

Each record contains:

– Transmitter numeric code Maximum value 65 536 (binary)	2 bytes
– Transmitter call sign 5 characters	5 bytes
– Transmitter name 20 characters	20 bytes
Expected number of records:	- - - - - - -

3.3 Frequency table

Each record contains:

– Frequency (binary) centre frequency quoted to the nearest 100 Hz	2 bytes
Expected number of records:	25

4 File formats

4.1 General description file

Only one record that contains:

– Title containing the string “SG 3 HF measurements”	32 characters
– Remarks (for incorporation of general pertinent information)	50 characters

4.2 Calibration file

Each record contains:

– Date and time of calibration (binary)	4 bytes
– One calibration signal for all 25 frequencies	
1 byte for each frequency	25 bytes
Total	29 bytes

The number of records depends on the number of calibrations that take place during the weekly period (there is one record per calibration).

4.3 Measurements file (for each hour and circuit)

– Date and time (binary)	4 bytes
– Transmitter code (binary)	2 bytes
– Frequency identification (index of the frequency tables)	1 byte
– Input attenuation (dB)	1 byte
– Signal and noise values 12 times (binary)	
– Signal amplitude	1 byte
– Signal qualifying or descriptive letter	1 byte
– Noise amplitude	1 byte
Total	44 bytes

5 Diskettes organization

Each diskette will contain data for a period of one week (7 days) consisting of the following:

– 1 general description file

– 1 calibration file

– 168 hourly signal and noise files.

6 Storage considerations

3 ½ in diskettes should be used to collect the data. The data corresponding to one week of recording can be accommodated on one diskette.

7 Remarks

– All receiving stations should register their activity with the international coordination group and be given an identification code.

– Date and time – a binary number (4 bytes) that contains the elapsed seconds since 00:00:00 UT, 1 January 1970, according to the system clock and permits calculation of the actual date and time.

– Qualifying letters are given in Annex 1.

– Rules for qualifying numerical values as uncertain are given in Annex 1.

– Signal and noise amplitudes will be recorded as integer values.

APPENDIX 3

Rules for determining hourly median signal amplitudes

For a particular circuit there will normally be 12 signal amplitude samples within a given hour on a given day. If all these samples have unqualified numerical values the median is readily determined by ranking them in ascending order and taking the average of the two middle numbers.

However, complications arise when some sample values are qualified or are accompanied or replaced by descriptive letters. The following qualifying and descriptive letters are proposed (see also Annex 1):

D : to indicate that the numerical value is lower than or equal to the true value (as for example when exceeding receiver full scale)

E : to indicate that the numerical value is greater than or equal to the true value (below the composite background of receiver noise, atmospheric noise and man-made noise and interference)

U : uncertain. A numerical value is classified as uncertain when it is not believed accurate to within ± (2 to 4 dB)

C : no measurement was possible because of technical trouble

S : measurement influenced by or impossible because of interference or atmospherics.

Every measured signal amplitude is accompanied by an associated amplitude of the composite background with which it is compared in selecting letters E and U.

Cases of C or S do not contribute to the signal sample count but numerical values accompanied by qualifying letters do.

When there are some data values accompanied by qualifying letters a first trial median is determined ignoring all qualifying letters. If then it is found that all values accompanied by D are greater than this median and all accompanied by E are less than this median, then the first trial median is the final median. Otherwise a second trial median is produced by moving all E values to the bottom of the list and all D values to the top. The final median is then the average of the first and second trial medians. If these differ by more than 2 dB then the final median is qualified by U.

If more than half of the signal samples are qualified by E (or D) the median is determined in the normal way and is also qualified by E (or D).