RECOMMENDATION 182-4

AUTOMATIC MONITORING OF OCCUPANCY OF THE RADIO-FREQUENCY SPECTRUM

(Question 29/1)

(1956-1966-1982-1986-1992)

The CCIR,

considering

a) that the increasing demand of radio services requires the most efficient use of the radio-frequency spectrum;

b) that the most efficient use of the spectrum can be arranged only when the distribution in time, magnitude and direction of the signals occupying it is known;

c) that automatic monitoring equipment is now in use by administrations and that further development in automatic observation is foreseen, including methods for the analysis of records;

d) that, by the use of automatic monitoring equipment, a number of parameters can be evaluated which are of considerable value in enabling more efficient utilization of the spectrum;

e) that digital computing techniques and equipment offer a number of advantages and opportunities over analogue techniques in the implementation of automatic monitoring systems and in the processing of information gathered by these systems;

f) that in designing an automated system to gather occupancy data for use in spectrum management, one must determine what parameters are to be measured and how often measurements have to be taken to ensure the data are statistically significant,

recommends

1. that although automatic monitoring equipment will not completely replace manual observations, it is a valuable aid. Administrations should be encouraged to undertake the use and further development of such equipment;

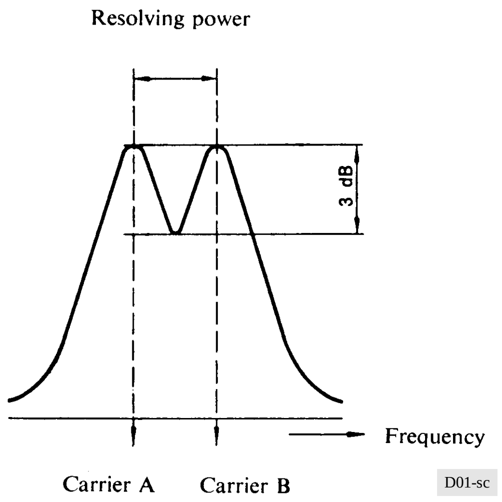
2. that, although further study is needed to enable administrations and frequency-planning authorities to derive the greatest benefit from the records produced, it is desirable that equipment should possess the following principal characteristics:

– total frequency range	minimum 2 MHz to 2.7 GHz: desirable 9 kHz to 10 GHz or more
– swept frequency range	a) variable; typical range 20 to 5 000 kHz for analogue equipment b) variable, typical range 20 kHz to 100 MHz for digital equipment
– number of sweeps per minute	variable; 6 to 6 000; manual stop on the required frequency
– maximum rate of sweeping	variable; dependent on the desired frequency resolution for the band being swept and the class or classes of emission being recorded
– sensitivity	1 μV/m or better; applicable to the frequency range up to 2.7 GHz
– resolution bandwidth	variable; approximately 10 Hz to 10 kHz; applicable to the frequency range up to 2.7 GHz *Note 1* – The frequency stability of the equipment has to be consistent with the resolution bandwidth.

– signal characteristics recorded	– carrier frequency
	– bandwidth
	– field strength
	– duration of occupancy
– type of record	computer-operated magnetic tape, cartridge form, digital format; calibration at appropriate intervals

Note 1 – Frequency resolving-power is the smallest frequency difference between two stable carriers of the same level which can be distinguished. For equipment using oscilloscopes, this power is the limit to which two stable carriers of the same level can be observed separately with a difference of 3 dB between the peak levels of the emissions and the minimum level between those peaks (see Fig. 1);

FIGURE 1



3. that it is desirable that the records should also contain, if possible, the following information:

– name and location of monitoring station

– date and period of recording

– frequency band

– identification of the emission recorded, as appropriate

– class of emission, as appropriate

– direction of signal

– noise level;

4. that in designing a spectrum occupancy measurement programme, administrations consider the statistical implications of demanding high accuracy and confidence levels, since the measurement times needed to obtain these values quickly become prohibitively long as shown in Table 1. The table compares independent sampling, i.e. assumed instantaneous measurements having no relation to each other and dependent sampling, i.e. sampling of finite messages with fixed sampling time intervals. Although of interest, independent sampling is not applicable to actual monitoring since messages have finite lengths and the rate of sampling can be variable. The values in the table for dependent sampling were developed using a first order Markov chain;

TABLE 1

Number of dependent and independent samples required to achieve ± 10% relative accuracy and a 95% confidence level at various occupancy percentages (assumes a 45 s sampling period)

Occupancy (%)	No. of required independent samples	No. of required dependent samples	Required hours of sampling
6.67	5 850	18 166	20.18
10	3 900	12 120	13.47
15	2 600	8 080	8.98
20	1 950	6 060	6.73
30	1 300	4 040	4.49
40	975	3 030	3.37
50	780	2 424	2.69
60	650	2 020	2.24
70	557	1 731	1.92
80	488	1 515	1.68
90	433	1 346	1.49
100	390	1 212	1.35

5. that, in considering the accuracy of automatic monitoring equipment in determining bandwidths of emissions, due consideration should be given to relating measurements of narrow-band emissions of the order of 2 kHz or less to the characteristics of the particular instrument in use. It has been determined, for example, that in some instruments which sweep a frequency range and resolve the bandwidth presentation by selective circuits, the shape factor of the selective circuits is such as to complicate bandwidth determinations at other than accurately known comparison levels. The variation of received signal levels due to propagation conditions, together with other factors, impose restrictions on the accuracy of indicated signal bandwidth of narrow-band signals. Consideration should therefore be given to the need for an analysis of the relative distribution of the signals level and the resolving capability of the instrument at several input levels. For signals with bandwidths of several kHz, the errors contributed by the above-mentioned equipment limitations become less important. Nevertheless, it may be desirable, in the interest of correlating data obtained with different instruments, to take into account their resolving power and the repetition rate and duration of discrete components of the observed signals;

6. that, in determining the accuracy of field-strength measurements made by automatic devices, the polarization and directivity of the antennas must be considered. In the 3 to 30 MHz range, where signals received over sky-wave paths contain both horizontally and vertically polarized components to a significant extent, a decision must be made as to the component to be measured. Since the vertical angle of arrival is most commonly less than 45°, less error will usually be introduced by measuring the vertically-polarized component rather than the horizontally-polarized component. Where greater accuracy is required, an appropriate correction may be applied, based upon a computed value for the vertical angle of arrival of the wave front.

Measurement of the vertically-polarized component may readily be accomplished by using a vertical receiving antenna, the electrical length of which is appreciably less than one-quarter wave, for the frequency band under study. To reduce errors due to non-homogeneous earth in the vicinity of the antenna, a ground screen, together with radial ground wires extending out at least 30 m (100 ft) in all directions has been found beneficial. The level of signal input to the recorder may be measured by comparison with a calibrated standard radio-frequency signal generator. The antenna effective height is determined by comparison with measurements made with an accurate field-strength meter using an antenna of like polarization.

In evaluating the field-strength data thus obtained, due allowance must be made for errors introduced by the various instruments. Allowance must also be made for fluctuations in signal-level, since, during the sweeping process, the receiver is tuned to a particular signal for only a small proportion of the time;

7. that wideband frequency domain spectrum analyzers, having large dynamic ranges of displayed signal amplitude be used as a means for rapidly recognizing and classifying various types of complex emissions and increasing the efficiency of monitoring operations by defining areas of current spectrum activity worthy of further examination. Provision of the required services to users of the radio spectrum is speeded by use of visual display techniques to synchronize the occurrence of interference with the activity of the emissions causing the interference. The application of microprocessor technology and digital signal processing techniques to spectrum analyzer instrumentation has improved both the performance characteristics and ease of use of these instruments. It should however be noted that analogue analyzers have advantages in some cases, compared with digital equipment.