SECTION 8K: AERONAUTICAL MOBILE SERVICE (TERRESTRIAL)

REPORT 926*

FACTORS THAT SHOULD BE CONSIDERED WHEN ESTABLISHING PROTECTION CRITERIA FOR AERONAUTICAL SAFETY SERVICES

(Question 62/8 and Study Programme 21A/8)

(1982)

1. Introduction

For the purposes of this Report, "electromagnetic noise" or "noise" is defined as all electromagnetic energy from both intentional and unintentional radiators, except from a desired signal for a specific system of interest.

Existing and proposed protection criteria, sometimes referred to as "maximum permissible interfering signals", "maximum permitted interfering field strengths", or "noise limits", are often stated in the following manner:

N µV/m at 30 m for the frequency band 108 to 112 MHz

This type of statement may be insufficient in itself as it fails to consider a number of pertinent factors, some of which will be identified in § 2.

* The Director, CCIR, is requested to bring this Report to the attention of the International Civil Aviation Organization (ICAO) and the International Electrotechnical Commission (IEC), and Study Group 1.

2. Specific factors

2.1 The conditions for the field strength measurement of the interfering signal should be stated. Failure to specify the conditions for field strength measurements, such as the receiver bandwidth (e.g., 10 kHz, 100 kHz or 1 MHz, 3 dB, 6 dB, or effective impulse bandwidth), receiver detector characteristics, calibration techniques, type of antenna used, polarization and antenna height above ground, leaves the method of measurement open to interpretation: this could then result in erroneous conclusions and inability to compare with data obtained by other experts. Dissimilar characteristics of the many different types and makes of field strength meters widely used also prevent a direct comparison of data obtained by different experts. A recent survey of field strength meters used for the measurement of noise produced by power lines has shown a less than satisfactory correlation in some frequency bands.

2.2 Systematic and random measurement errors result from errors in instruments and their calibrating sources and from errors in test set-up and measurement procedures. Error problems also exist because electromagnetic interference problems are often probabilistic, rather than deterministic, in nature. The method of error analysis in the development of parameter limits becomes important where regulatory aspects must be considered.

2.3 Interference prediction techniques, noise models and communication system models are currently under development or refinement by a number of administrations, educational institutes, and industrial research organizations. A non-exhaustive list of noise measurement parameters and techniques used includes:

- average voltage (V_{avg}),
- root-mean-square voltage (V_{rms}),
- quasi-peak voltage (V_{qp}) (both CISPR and ANSI),
- peak voltage (V_p),
- impulsiveness ratio $V_d = 20 \log (V_{rms} / V_{avg})$,
- effective antenna noise factor (F_a),
- mean noise power (P_n),
- amplitude probability distribution (APD),
- noise amplitude distribution (NAD),
- average crossing rate (ACR).

Some of these parameters are useful principally as means of detecting the presence or absence of unwanted emissions from some area or object. Ideally, the emission or radiation parameter or measurement technique selected should correlate directly to how the noise is degrading the performance of a radio communication or navigation system.

2.4 A single protection ratio covering all noise sources within a fixed frequency band may not be realistic. Such a protection ratio may fail to take into account the characteristics of the noise (that is, whether the noise is continuous wave, Gaussian, random or impulsive). Noise sources may have to be broken down into groups such as power lines, industrial-scientific-medical apparatus and ignition systems, with protection ratios defined for each of these groups.

2.5 The time characteristic of the noise is an important consideration. Depending on the grade of service required, a noise source that exceeds the protection criterion only 0.5% of the time may have to be treated differently from a noise source that exceeds this criterion 95% of the time.

2.6 Protection criteria may be required to take into account variations in radio communication and navigation equipment performance. One approach may include the determination of susceptibility of radio communication and navigation systems to man-made noise and the establishment of parameters and levels that describe the noise that these systems can withstand without intolerable degradation in performance.

2.7 Where the sources of noise are manufactured in quantity, control of their radio frequency emission limits may be effected by statistical sampling tests (e.g. CISPR test method). Such tests may only give guarantees that a certain proportion of the manufactured items conform to a stated limit. A detailed examination of the statistical sampling test may therefore be necessary to establish whether the statistical guarantees are compatible with the particular protection required. Annex I gives such an examination of the CISPR statistical method.

2.8 For the protection of aeronautical safety services it may not be realistic to formulate protection ratios based on field strength measurements made at or near ground level when, in the real world, aircraft fly over noise sources. An examination of available literature has shown that in some cases, noise levels at a given distance measured laterally from a noise source are lower than those measured at the same distance above the noise source. In addition, aircraft in flight could be subjected to noise from many possible sources; although the noise produced by one source may be of little consequence, the effect of many such sources could be significant. It should be noted that aircraft in flight regularly experience unwanted signals that are not detected by ground monitoring.

Considering the mobility of aircraft and the large viewing area to which aircraft are exposed, together with the variability and uncertainty of assessing and controlling harmful interference to safety of life services, the impracticability becomes obvious of accurately accounting for all of the signal characteristics of the unwanted signal sources that aircraft may encounter. Nevertheless, these factors must be accommodated if the high reliability of civil air transport is to be maintained. One method of accommodating these factors is by including a compensation in the form of a margin added to the protection ratios.

2.9 The protection of radio communication and navigation systems might be better achieved by a combination of protection criteria in a prescribed critical area around a site. This would assist in land-use planning around airports and around off-airport radio communication and navigation facilities. In regard to protection of aeronautical radiocommunication and/or navigation facilities at airports, attention is drawn to the coordination procedure presented in Report 929.

3. Conclusion

In order to safeguard aeronautical safety of life services, it is essential to establish adequate protection criteria from unwanted signals. However, the formal derivation of such protection criteria is considerably complicated by factors which introduce significant uncertainties. Some of these factors have been presented in this Report.

ANNEX I

AN EXAMINATION OF THE CISPR (INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE) STATISTICAL TEST PROCEDURES FROM THE VIEWPOINT OF INTERFERENCE PROTECTION TO THE AERONAUTICAL SERVICES

1. Introduction

1.1 The CISPR has published much valuable work on the methods of measurement of radio frequency energy and corresponding recommended limits of radiation from various types of equipment which may cause interference [CISPR, 1975a and b; 1976 and 1977]. Some of these equipments are manufactured in quantity, and in these cases the CISPR recommends a statistical sampling method for checking compliance with corresponding RF radiation limits. This Annex is a first assessment, in statistical terms, of the potential interference to aeronautical services from equipments whose RF radiation limits are measured by the CISPR statistical method.

2. The CISPR statistical testing method

2.1 Full details of the method recommended and a comprehensive exposition of its mathematical derivation are available in CISPR publication 13 {CISPR, 1975b]. In essence two choices are offered: either taking measurements from a relatively small sample of the production run or from one item only.

In the latter case the value measured must be at least 2 dB more stringent than the CISPR recommended limit for the particular equipment type. Only if the item does not meet this more stringent limit is the sampling method obligatory.

In the sampling method, compliance with the CISPR limits is judged by measuring the variable interference attribute (e.g. field strength radiated in a particular band) in accordance with the test procedure and measuring instrument characteristics laid down (e.g. typically using a quasi-peak detector on a test site).

Depending on the sample size, and with the set of results to hand, (typically 5 to 12 values of field strength expressed in dB relative to 1 μV/m), the mean and the standard deviation of these values is calculated. These values are, in turn, substituted in the formula:

$$\overline{X} + KS \leq L$$

where

$\overline{X}$: arithmetic mean of measured levels from the items;

S : standard deviation of the same measured levels;

L: appropriate CISPR permissible limit; and

K: factor depending on the sample size (n);

K: given in Table I:

TABLE I

Sample size (n)	3	4	5	6	7	8	9	10	11	12
K	2.04	1.69	1.52	1.42	1.35	1.30	1.27	1.24	1.21	1.20

2.2 If the sample results satisfy the relationship given above then the whole production of the item is classified as "meeting the CISPR limit".

2.3 Clearly, the factor K is very important and the CISPR references show that K is based on the assumption that the production output exhibits a normal distribution and that the "consumer's risk" is that there shall be an 80% confidence that 80% of all the production items shall be below the CISPR limit.

From the viewpoint of the degree of protection offered to an interfered with service it is important to note that the consumer risk, in turn, means that 20% of the items must be assumed to radiate RF energy greater than the CISPR limit – how many and how much greater will depend on the parameters of the particular distribution in practice, which depends on the manufacturer's design decisions. For example purposes two hypothetical cases are given below in Table II:

TABLE II

CISPR limit = L dB	Case a)	Case b)
Production line mean value (manufacturer's choice) (dB)	$(L-5)$	$(L-1)$
Corresponding standard deviation required to meet CISPR "80%/80%" consumers's risk exactly (dB)	5.95	1.2
Resulting approximate radiation level exceeded by 5% of items (dB)	$(L+5)$	$(L+1)$
Resulting approximate radiation level exceeded by 0.5% of items (dB)	$(L+10)$	$(L+2)$

Thus, in both of these hypothetical cases the production line would "meet the CISPR limit" and yet a wide variation of higher radiation levels would exist.

2.4 Further examination also shows that the factor K is very sensitive to changes in the percentage values chosen for the consumer's risk. Table III gives examples of the variation of K for more stringent risk values. It is evident that such changes might have important economic repercussions for the manufacturers of the items being tested.

TABLE III — *CISPR statistical sampling method*

(Source: Biometrika Tables for Statisticians)

K (80%/80%)	2.04	1.69	1.52	1.42	1.35	1.30	1.27	1.24	1.21	1.20
K (95%/95%)	—	5.13	4.19	3.70	3.39	3.18	3.02	2.83	—	—
K (99.5%/99.5%)	—	17.25	11.77	9.37	8.01	7.15	6.56	6.12	—	—

3. Statistical requirements of the aeronautical services

It is clearly difficult to assess the probability of actual harmful interference occurring in practice from a knowledge of the statistical probabilities of certain manufactured items exceeding certain radiation limits.

However it is pertinent to note that some aeronautical services are designed to meet statistical targets which are extremely stringent and several orders higher than the values implied by a consumer's risk of "80%/80%" (see Report 927). There is therefore some justifiable doubt whether the current CISPR consumer's risk is acceptable in these cases and further study is required on this matter.

4. Specific areas of concern

To assist in further study some particular points of concern have been identified, as follows:

4.1 The use of a statistical test method based on a small number of samples and a simple statement of "consumer's risk" does not provide strong practical control over the range of actual radiation limits likely to be met in practice, possibly in significant quantities. As § 2 shows, a significant proportion of equipments manufactured to meet a CISPR limit could exceed the actual limit value by quite a high margin.

In practice, commercial pressures may lead a manufacturer to adopt a tighter specification than the CISPR consumers' risk indicates, in order to give the manufacturer better assurance that his products will be accepted when tested by sampling. However this possible factor cannot easily be taken into account by the aeronautical community.

4.2 The ability, as an alternative within the CISPR test method, to assess compliance with the CISPR limit by testing only one item from a production series – albeit to a 2 dB more stringent level – offers statistically no guarantee of protection to any consumer at any level of consumer's risk. There would therefore seem to be a strong need for the justification of this alternative to be re-examined.

4.3 There would appear to be a basic need for justified aviation protection requirements to be stated as precisely and fully as possible, including statistical criteria where applicable.

4.4 The most difficult area of investigation would seem to be the *practical* conversion of limits established by § 4.3 above into corresponding limits for the testing of production items by the CISPR sampling test method.

4.5 Following on from § 4.1 above it would seem to be important to examine if it would be possible to limit the actual use of equipment which emits radiation above certain levels (higher than the relevant CISPR limit). It should be noted here that in view of the stringent statistical requirements referred to in § 3 the prime aim may need to be to prevent interference from occurring rather than to seek to identify and remove the interference after it has occurred.

5. Conclusions

This Annex indicates some specific areas of concern in relation to the use of the CISPR statistical test method in cases where very high protection from interference is required, e.g. aeronautical radionavigation.

REFERENCES

CISPR [1975a and 1976] Publications 11 and 11A. Limits and methods of measurement of radio interference characteristics of industrial, scientific and medical radio-frequency equipment (excluding surgical diathermy apparatus).

CISPR [1975b] Publication 13. Limits and methods of measurement of radio interference characteristics of sound and television receivers.

CISPR [1977] Publication 16. CISPR specification for radio interference measuring apparatus and measurement methods.