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Inspection of radio stations

SM Series

Spectrum management

International Telecommunication Union

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REPORT ITU-R SM.2130-1

Inspection of radio stations

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1 Introduction

This Report presents an overview of Inspections Procedures in response to Question ITU-R 225/1 regarding inspection techniques and procedures. The Question relates to how administrations proceed in planning and conducting radio station inspections.

The purpose of this Report is to provide general guidelines for planning and performing inspection activities on various types of radio stations. Inspection activities are here considered as those conducted “on-site”, by visiting the transmitter location and often include review and verification of both technical and administrative conditions assigned to a radio station or other spectrum user.

Although the term “licensed” is used throughout the Report, this term can be considered here to include not only stations with licences issued by the regulatory authority, but also other authorized spectrum users (such as those operating with “licence exempt” devices like low-power radios and RF devices operating under equipment standards approval).

Included in Annexes are some specific examples in certain services, to provide examples of how the general guidelines can be applied. This Report should be considered a general guidance document for inspections planning.

2 Role and organization of inspection activities

The value of radio spectrum has become increasingly important to the economic and social development of many countries. Control of the radio spectrum by telecommunication regulatory authorities has become even more important, as national administrations seek to maximize the efficient use of spectrum, control interference, and promote new technologies without adversely affecting existing ones.

The technical and administrative radio regulations of an administration help ensure that radio services can operate on a non-interference basis. Spectrum users who operate outside their authorized parameters can generate interference to other users by various methods (such as co-channel and adjacent channel interference, harmonics and other spurious emissions). Regulatory authorities typically use various methods to help ensure that the spectrum is used properly and efficiently. These methods include spectrum monitoring/measurements made at a distance, radio station on-site inspections/measurements, and enactment of compliance specifications for certain equipment (both radio and non-radio equipment which generates RF spectral energy). Some combination of these methods, followed by the application of enforcement sanctions (formal notice of violations) to problems discovered, have been used successfully by administrations to help control the efficient use of spectrum.

Depending on the administration, all these functions may be:

– all in one unit of the regulatory authority/organization (such as a field enforcement force who conducts monitoring, conducts inspections, and issues enforcement sanctions), and
– in different parts of the same regulatory authority/organization (with a separate monitoring unit, an inspections unit and a sanctions unit), or
– sometimes in different organizations (for example, broadcast inspections may be carried out by a totally different authority/ organization than inspections and monitoring for other services).

How this is organized within an administration is often determined by national regulations, the number of licence holders or other authorized spectrum users, the number of private versus government-operated stations and for other reasons. While some efficiency can be achieved if all of these functions are in the same unit or sub-unit, the most important factor is that the different parts of the organization responsible for each area communicate and coordinate with each other on identifying, prioritizing, conducting and reporting the work. However, a strict distinction between on-site inspections and spectrum monitoring becomes more and more difficult. On the one hand the monitoring of low power devices requires virtually being on-site and on the other hand the on-site inspection of a broadcasting transmitter may comprise the determination of its radiated power which in turn may require a measurement distance of a few kilometres.

In addition, inspection activities should be supported by relevant legislative acts and officially approved regulations that provide detailed implementation of the legislative acts. The regulations should include coverage of the organization, technology, and procedures of inspections, the rights and obligations of inspectors and spectrum users, and provisions for resolving disputes between inspection authorities and spectrum users, etc. Obligations of spectrum users should include provisions to ensure free access to radio installations by inspectors and measures to prevent any obstacles to their work. These provisions are usually part of national regulations. The credentials an inspector carries to identify himself as authorized to conduct inspections on behalf of the regulatory authority are usually based on these regulations.

The inspection function, at least during the initial stage of its implementation can be effectively combined with the "over-the-air" (distance) monitoring function based on the uniformity of the monitoring and measurement equipment and other facilities used for both the monitoring and on-site inspection tasks.

Providing standardized measurement procedures might not only be useful to administrations, in order to ensure the quality of inspections performed by different enforcement agents, but also to the service providers and the spectrum users, in order to provide the bases in which all licensees can rely to perform their own measurements and ensure the quality of the data provided to support the spectrum management activities.

A few administrations for various reasons do not conduct radio inspections. In the long term, however, the absence of an inspection programme can lead to several negative consequences. Without inspections, the completeness and reliability of a national frequency assignment register cannot be guaranteed, since one purpose of the inspection is to verify that the radio station is actually installed and operating in accordance with its assigned parameters. Valuable reference data for subsequent spectrum monitoring (such as reference field-strength values) often cannot be easily obtained. These two factors considerably decrease the effectiveness of automated spectrum management systems in detecting infringements and unauthorized use. From an administrative point of view absence of inspections provides a corrupting influence on spectrum users because they may come to believe that they can ignore compliance with their licensed parameters since the risk of detection is lower without on-site inspections. In this respect even limited inspections can considerably increase spectrum users' responsibility.

3 Inspection techniques

The inspection techniques used by administrations can generally be defined as the decision factors, planning steps and implementation methods used by administrations to plan and conduct station inspections. Several decisions must be made about inspections, including – what radio services need to be inspected, how many to inspect, how frequently they need to be inspected, and what level of detail to collect at each inspection.

There are a range of techniques used by administrations in organizing their inspections plans, ranging from inspecting all stations to inspecting a few or none. Some examples of organization are enumerated on the following items:

– **All stations inspected**

  Some administrations set as a goal (or have as a requirement in regulations or policies) the inspection of all stations in selected services or sometimes all services during a certain timeframe. The adoption of such procedure is often limited due to the increasing spread of radio devices and limited resources to administrations but can be useful in specific cases, such as to perform a census of all users and allow the systematic and comprehensive correction of database errors on licensed users.

– **Inspection of a certain percentage**

The inspection of a certain percentage of the stations only reduces the work load of the inspectors and the inconvenience for the license holders rapidly.

– **Inspection based on statistical methods**

Some administrations use statistical methods to estimate overall compliance rates, with the results being used to plan future inspection levels. In its simplest form, by inspecting a small sample of all stations, the overall compliance can be inferred by the compliance rate in the sample. A high rate of compliance, for example, might result in fewer inspections (lower sampling) in that radio service in the next year. Such methods reduce the work load of the inspectors and the inconvenience for the license holder.

– **Triggered inspections**

Inspections may also be triggered by specific impetus such as interference complaints, non-compliant parameters discovered by spectrum monitoring or any other indications of possible infringements. Furthermore, inspections may be triggered by special events (for example major sport events) or by the need to determine the compliance level of one particular item (for example, tower coordinate accuracy).

– **Limited inspections**

Limited inspections may check only a specific item which is of interest to the regulatory authority, e.g. a certain station administrative record, or the transmitter output power.

– **Risk based inspections**

Some licences can be considered "high risk". These licences are related to radio stations having a greater potential to create interference than others. Such "high-risk" licences could include those at sites with a high concentration of RF transmitters, licences on frequencies adjacent to safety services or licences in spectrum with both high and low-power level transmitters. Administrations may put a greater emphasis on inspecting stations with a "high risk licence".

When an administration commences with inspection activities, especially in the situation of absence of experience, it is helpful to focus inspection resources into several areas which will have the greatest benefit to the administration in terms of efficient spectrum utilization. Some suggested priorities for inspections planning are:

– Inspections of all newly installed stations;
– Inspections of the most powerful transmitters (such as broadcast transmitters);
– Inspections of those services where statistics show greater number of violations. Based on the experiences of other administrations, these are typically PMR (private mobile radio) stations.

A brief example of an inspection programme structure is shown below:

– Inspect at least 15% of the radio base stations of the mobile personal services.
– Inspect at least 15% of the transceivers used by the public switched telephone networks (PSTN).
– Inspect at least 15% of the fixed and mobile stations of the radio taxi services.
– Inspect 100% of the scientific research services.
– Inspect at least 15% of the satellite earth stations.
– Inspect 100% of the authorized stations used for fixed and mobile services whose licences are expired or will expire in the current year.
– Inspect at least 20% of the technical parameters of fixed and mobile stations.

– Accomplish, in a maximum of 30 days before licensing, the inspection of new or modified stations.
– Inspect, or check for continuing operation, at least 15% of all stations whose licences have expired/been removed from the national database system.

In this example, one can see some elements of the above categories are taken into account, and how some of the factors can be based on an administration's regulations, government policies and results of past inspections. Typically, the guidelines would be evaluated and adjusted yearly, based on the results of the previous year's inspections programmes.

Also in the above example, we can see that the sample sizes are different for different categories of stations. This may be due to several factors, including the number of stations authorized in the service, past compliance history, or administration goals or policies in the specific radio service class.

4 Technical parameters

Generally, any item specified on a station's licence or operating conditions may be an item to be measured or verified during an inspection. The operating parameters of a station are important in controlling interference, allowing multiple stations to coexist on the same frequencies and/or in the same geographic areas, and are useful in ensuring the efficient use of the spectrum. Specified parameters are important in determining a station's coverage area and the amount of spectrum occupied. The following list comprises technical parameters that may be checked during inspections.
– Frequency (offset and stability);
– Transmitter output power;
– Radiated power;
– Geographical coordinates;
– Harmonics, intermodulation products and spurious emissions;
– Electric, magnetic and electromagnetic field strength;
– Bandwidth;
– Antenna height;
– Direction of the main lobe;
– Antenna pattern;
– Antenna tilt;
– Modulation parameters;
– Power flux-density.

The specific items to be checked will vary by type of station/radio service, radio regulations of the country and regulatory administration policies. Other factors affecting what is checked could be: problems discovered previously, items judged to have interference potential, or items related to actual interference reported. Indirect factors could be the regulatory administration's staffing/workload issues or availability of equipment. Administrations planning inspection work will typically focus the items to be checked based on these factors.

5 Equipment complement

The following items comprise a recommended list of equipment that is commonly used during a radio station inspection:

Primary equipment:

– Frequency meter

Power meter/directional couplers

– Spectrum analyser/measurement receiver

– Antennas.

Key parameters of operating frequency, transmitter power and RF spectral properties can be evaluated with these instruments.

Additional equipment:

Field-strength meter

– Power flux-density meter with isotropic E and H field sensor

– Modulation and Protocol analysers

– Rangefinder/telemeter

– Distance measuring tapes

– Compass / Inclinometer

– GPS

– Antenna supports/tripods

– Power resistive load

– Cables, connectors, accessories.

Some of these items are used in confirming tower heights/locations, antenna orientation, and measuring special parameters unique to a particular communications service (for example, a TV or digital modulation analyser).

Administrations have noted that additional special measuring equipment may be necessary for some inspections, depending on the emission types, assigned frequencies, introduction of new communications technologies and inspection tasks. For example, a recent model of radiocommunication analyser with advanced digital modulation features may be necessary in some inspections in order to properly detect and measure digital carriers using new modulation/spectrum access techniques, if that type of measurement is a requirement of the administration.

An important factor to be considered in using any instrumentation is the calibration accuracy and measurement uncertainty of the equipment. Equipment manufacturer guidelines should be consulted in determining calibration requirements.

General measurement practices include applying tolerances to inspections measurements based on the measurement uncertainty/repeatability of the measuring instrument. A recommended practice in inspection planning is to assemble the equipment to be used (along with its operating manuals and measurement procedure guides), and verify proper operation in advance of the inspection work.

Equipment control software can be used to capture standardized, repeatable measurements at inspections. The software can be a useful tool for ensuring that all considerations about measurement tolerances will be taken in account. The software, running in a notebook or handheld computer, helps the inspection agent during the measurement process. Using an interface the laptop can communicate with the measurement equipment and gather all data needed, and then automatically compare the results with the licensed data and prepare a report.

Depending on the organization of the administration's inspection service, other technical and administrative items (such as electrical safety, radio-frequency radiation hazard conditions, tower safety and other items) may also be checked.

Table 1 summarizes the equipment complement and parameters measured as discussed above.

TABLE 1

Summary of equipment and parameters measured

Equipment	Measured parameter
Spectrum analyser/measurement receiver, antenna	Frequency, bandwidth, field strength, harmonics, intermodulation products and spurious emissions
Signal analyser, antenna	Frequency, bandwidth, power, harmonics, intermodulation products and spurious emissions, modulation parameters
Frequency meter, antenna	Frequency and frequency offset
Power meter, directional coupler, resistive load	Transmitter output power (direct and reflected)
Field-strength meter with calibrated antenna/cable	Field strength
Power flux-density meter	Electric, magnetic and electromagnetic field strength
Modulation analyser	Modulation parameters of specific types of signals and presence of additional signals
Distance or range meter	Distances, including antenna height
Measuring tapes	
Compass	Antenna azimuth
Inclinometer	Antenna tilt
GPS	Site location

6 Records reviewed

The station licence and conditions of operation are some of the main administrative records reviewed when stations are inspected. These texts need to be studied before the inspections are carried out because the required measurement equipment depends on the technical parameters to be evaluated. Some technical parameters cannot be derived from the licence documentation, e.g. the type of connectors used on a high-power transmitter, and therefore need to be determined by additional investigations.

An important goal of the inspection is to confirm that the station is operating in accordance with the parameters assigned by the administration for the use of the frequency spectrum. Measured or observed parameters are compared to the licensed parameters to determine if the station is in compliance. Other records reviewed include: certifications/approval status of installed equipment, records related to daily operations (such as transmitter operating logs and programming logs), and other special records that may be required for certain types of stations.

Inspection results are typically captured on an appropriate form or checklist (in paper, on a handheld device or notebook computer) designed to collect the information of importance as determined by the administration. Typically this will include verification of the licence parameters discussed previously, notations regarding any non-compliance or deviations from licensed parameters, transmitter site description (with photos if necessary), personnel present during inspection, equipment used, and inspector's comments with a description of further action that is needed. Out-of-compliance conditions are brought to the station's attention for correction, as well as being recorded on the inspection report and elsewhere in the administration's inspections or compliance database.

Information from these records (compliance levels or other inspection results) may be used to adjust the inspection plans for the future.

The inspection results are also useful to some administrations for verifying or improving the accuracy of existing licence databases. This can be helpful when the administration's database is missing information, or contains information that is different from what is observed at the inspection, and the database is determined to contain the error.

7 Spectrum monitoring versus on-site inspections

Some key station parameters such as frequency, frequency deviation, bandwidth and strong power excess and hence the compliance of a station's parameters with the station licence as well as the operator's operational discipline can be checked efficiently by using fixed or mobile monitoring stations. Advantages of this method are that several stations may be checked from one location if the signal level is sufficient and that the station operators do not need to be contacted or engaged.

Especially VHF and UHF broadcasting transmitters can be measured effectively from the distance. The measured field strength or receiver input voltage can be compared with the results of a planning tool or even better with previous results which are already stored in a database. Any anomalies are disclosed immediately. It should be noted that varying propagation conditions should not be neglected, especially at lower frequencies.

It should be noted that spectrum monitoring results cannot always be regarded as legally valid. Instead they may have to be verified by supplementary on-site inspections.

Some types of stations have complex filter and combining networks which make direct connections of instruments difficult, and measurement results sometimes uncertain. Further, direct connections to the transmitter output do not comprise the antenna pattern and thus usually do not reveal any anomalies with antenna systems. Measuring the maximum frequency deviation or the multiplex power at FM broadcasting stations requires low reflections and sufficient attenuation of other broadcasting signals. For obvious reasons these measurements are carried out by spectrum monitoring without participation of the operator.

As already discussed in § 2 there is a smooth transition between the radio monitoring function and the on-site inspection function and the designation of a measurement task often depends on legacy structures.

8 Conclusion

This Report provides information to be considered by administrations in planning radio station inspections. It should be recognized that it is not possible to develop a detailed, specifically-defined inspections plan that is suitable for all administrations, over all radio services and in all circumstances. Rather, it is the goal of this Report to present general guidelines for planning, examples for specific cases, and a procedure for inspections planning that administrations can use to tailor to their specific requirements.

Annex 1 contains more detailed descriptions of inspection procedures that may also be useful to administrations in order to understand and organize their activities.

Annex 1

Criteria for determination of sample size for inspections planning

1 Introduction

Obviously it is not possible to examine all radio equipment of all users within a single year. Giving due consideration to economic aspects (investment in terms of costs and time) and the target of obtaining definitive results, the application of sampling for verifying frequency usage is deemed expedient. The method described below is used by the German Federal Network Agency. It allows consequences to be drawn on the overall set from the results of a partial examination (sample). The question that needs to be answered here concerns the size of the sample and how the objects to be examined should be chosen.

2 Method for the determination of the sample size

The determination of the sample size and the selection of the objects to be tested are to be based on a recognized statistical method yielding regular and precise information about the adherence to assignment conditions within a radio application. In principle, such a method can be applied to all radio applications. The sampling method is an economic test method for determining the status quo. Prerequisite for the application of the method is the specification of the following boundary conditions:

Equipartition of the samples:

To ensure a representative selection, each element (assignment) of the overall set (number of assignments) must be chosen with the same probability.

Temporal aspects:

The period in which the sample is to be tested and the survey frequency must be specified. This has a decisive impact on the personnel expenses.

Spatial criteria:

There is a difference between an outcome relating to the entire country and one relating to individual regions. The sampling quantity increases considerably if the result is intended to illustrate regional differences.

Statistical criteria:

The result of the analysis yields the percentage P of radio networks/assignments with shortcomings. The requisite minimum sample size is largely dependent on the specified certainty probability S and the value of the tolerable error e. The complementary probability Q = 1-P indicates the percentage of assignments without shortcomings.

Tolerable error:

An error of, say, 5% means that each sample value (e.g. 30%) can deviate up or down by 5% from the actual value of the basic certainty, i.e. the actual value may lie between 25% and 35%.

The certainty of a sample indicates the number of cases in which the sampling method yields “correct” and precise results. A certainty of, for example, 90% implies that a 100-fold application of the method will only lead to “incorrect” results in 10 applications but these results are nevertheless fairly close to the “correct” value, e.g. ±5%.

3 Number of necessary samples

The minimum number of samples needed to achieve the desired level of certainty is calculated using the following formula:

$$n \geq \frac{N}{1 + \frac{(N-1) \cdot e^2}{z^2 \cdot P \cdot Q}}$$

where:

- n: minimum sample size needed
- N: overall number of assignments
- e: selected tolerable error
- z: value of the specified certainty probability S calculated from the central probability of the standard normal distribution:

$$\Phi(z) = \frac{1}{\sqrt{2\pi}} \cdot \int_{-\infty}^{z} e^{-t^2/2} \mathrm{d}t$$

$$S(z) = 2 \cdot \Phi(z) - 1$$

- P: percentage of assignments in which the assignment conditions are not fulfilled (fail)
- Q: $Q = 1 - P$, percentage of assignments in which the assignment conditions are fulfilled (success).

For a large number of assignments (*at least 30*), the equation for n simplifies to:

$$n \geq \frac{z^2 \cdot P \cdot Q}{e^2}$$

It can be seen from the formula that the minimum sample size required is highly dependent on the product $P \cdot Q$. For $P=50\%$ and $Q=50\%$ the term $P \cdot Q$ is maximised. At the German Federal Network Agency, the following values are assumed:

Certainty probability:	90%
Tolerable error:	5%

Example:

Within a certain area there are 8 000 radio networks of a specific radio application. From earlier investigations it is known that about 30% of the radio networks do not comply with requirements. How many radio networks need to be inspected to be able to identify the proportion of faulty networks among these 8 000 networks with a probability of 90%? The error rate of the outcome should not exceed ±5%.

$S(z) = 90\%$ yields $\Phi(z) = 0.95$. For this, the value $z = 1.645$ can be taken from the relevant mathematical table or calculated with a spreadsheet program. If $N = 8\,000$, $e = 5\%$, $P = 30\%$ and $Q = 70\%$, then $n = 221$ samples or networks respectively.

4 Number of samples within a radio network

If the above reflections were consistently applied to the number of radio installations within the individual networks, unreasonable test volumes would be obtained. In the case of a network with 20 radio installations, 19 networks would have to be tested and even in the case of a network with 100 radio installations 73 units would still have to be tested.

It therefore makes more sense, for example in the case of private mobile radio (PMR), to test all fixed radio installations and only a limited number of the mobile radio equipment. Should it turn out that the number of shortcomings exceeds the average value noticeably, the number of checked radio equipment within the network could be increased.

5 Selection of objects to be tested

Although each sample should be randomly selected without reposition from finite or infinite population, indeed a totally random selection of objects to be tested is not possible in practice. For this reason a systematic selection method is used. If N is the overall quantity of assignments and n the number of networks to be investigated, each k-th element is selected from the database with $k = N/n$. This method requires the elements in the database being arranged in line with a certain criterion, e.g. according to the assignment holder's name.

Example: The assignments in the database are sorted according to regional office, postal code and name. The assignments to be tested are selected by means of a random generator. Assignments which have already been examined in the past two years are excluded.

Experience has shown that it is not possible to test all selected networks within the test period. Some of the frequency assignments had meanwhile been returned to the agency or the radio network had been taken out of service without the frequency assignment having been returned. To achieve the required statistical accuracy in spite of this, in such cases it is necessary to select further objects to be tested. It has happened in practice that double the number of networks had to be selected before being able to achieve the necessary number n which could be checked.

As a rule, the holder of the frequency assignment is informed at an early stage of the measurements so that the radio equipment is indeed accessible.

6 Impact of the parameters on the test volume

Figure 1 illustrates that the number n of necessary samples barely changes within the range beyond N = 2 000. By contrast, the requisite certainty probability has a considerable impact on the test volume.

Figure 1 shows the number of samples versus the number frequency assignments needed for the various values of the certainty probability S @ percentage P=50% of assignments in which the assignment conditions are not fulfilled (fail).

FIGURE 1

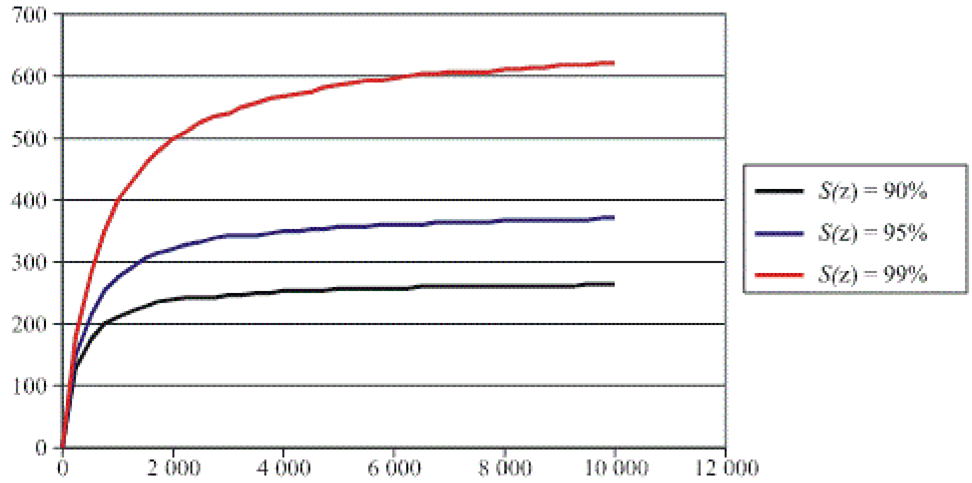
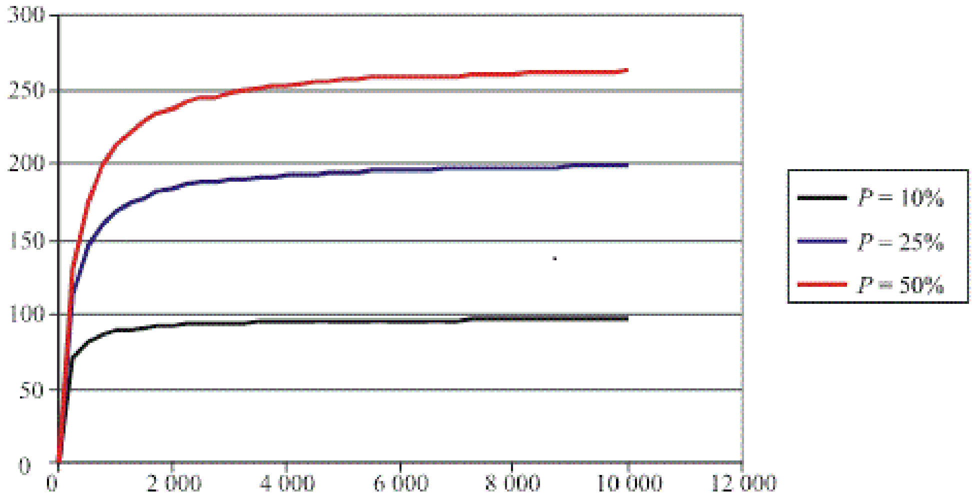


Figure 2 shows the number of samples versus the number of frequency assignments needed for the various values of *P @ a certainty probability of S=90%*.

FIGURE 2



7 Strategy

The method described above primarily serves to determine the status quo. It is therefore important not only to incorporate the results in the calculation of the test volume for the following test period but also to draw further conclusions.

First of all, the question must be asked as to whether the result is satisfactory or not. Are the assignment conditions for the most part being adhered to or is the rate of deficient networks so high that corrective action needs to be taken? A deficiency rate of 30% in PMR is certainly realistic. But if approximately every third radio network evinces shortcomings, then the result is not satisfactory.

The following corrective actions are merely examples for possible measures:

– inspection of additional networks;
– inspection of all new radio networks within a year;
– repetition of the inspection of those networks where shortcoming had been identified as early as in the following year;
– dissemination of information leaflets for frequency users and radio equipment dealers.

When evaluating the shortcomings for different regions, it may, for example, turn out that the monitoring or enforcement staff in the various regional offices uses different working methods or evaluate deviations differently. But it is also feasible that frequency users behave differently from region to region. In mountainous regions, for example, they may use higher powers or excessively high antennas to extend their range. In the wake of such a result the frequency assignment method should be examined. Are the applicant's requirements adequately met or should changes be made?

As a rule, the holder of the frequency assignment is informed at an early stage of the measurements so that the radio equipment is indeed accessible.

8 Conclusion

The method described above allows the determination of the minimum sample size required to evaluate the compliance of radio networks with its assigned parameters based on a recognized statistical method. This method, however, is only meaningful if conclusions are drawn from the results.