RECOMMENDATION ITU-R SM.1753

Method for measurements of radio noise

(Question ITU-R 1/45)

(2006)

Scope

For radio noise measurements there is a need to have a uniform, frequency-independent method to produce comparable, accurate and reproducible results between different measurement systems. This Recommendation provides a set of processes or steps that need to be integrated in a measurement procedure resulting in these comparable results.

The ITU Radiocommunication Assembly,

considering

a) that, due to the introduction of new radiocommunication systems (e.g. ultra-wide band (UWB) and power line communication (PLC)), the radio noise levels stated in Recommendation ITU-R P.372 might increase;

b) that, for efficient spectrum management, administrations need to know the exact noise levels;

c) that there is a need to harmonize the measurement method for noise measurements to achieve reproducible results that can be mutually compared,

noting

a) that the Handbook on Spectrum Monitoring contains a large amount of information on monitoring and measurement equipment;

b) that, for noise measurements, there is a need for additional receiver specifications,

recommends

1 that measurements of radio noise should be carried out as described in Annex 1.

Annex 1

Method for measurements of radio noise

1 Introduction

This Annex describes a frequency-independent method for measuring radio noise in practical radio applications.

2 Properties of noise

Using the definition given in Recommendation ITU-R P.372, radio noise is the sum of emissions from multiple sources that do not originate from radiocommunication transmitters. If, at a given measurement location, there is no dominance of single noise sources, the characteristic of the radio noise has a normal amplitude distribution and can be regarded as white Gaussian noise. Signals from single sources, like pulses and continuous carriers, are outside the scope of the radio noise measurements described in this Recommendation and should be excluded.

3 Equipment specifications

3.1 Receiver

The measurement receiver can be a standard transportable measurement receiver or spectrum analyser with some additional requirements, like a low equipment noise floor and high frequency and gain stability, which are essential for the performance of noise measurements. Table 1 does not describe a new set of measurement receiver specifications but only points out the additional or specific requirements necessary for a receiver used for radio noise measurements. Also the frequency band designations are based on the practical implementation of a noise measurement system and do not point to a specific receiving system.

TABLE 1

Receiver

Function	**Frequency range**		
Frequency range	9 kHz – 30 MHz	30-500 MHz	0.5-3 GHz
Input (antenna input) VSWR	50 Ω, nominal < 1.5		
3rd order intercept (dBm)	≥ 20 (> 3 MHz)	≥ 10	≥ 0
2nd order intercept (dBm)	≥ 60 (> 3 MHz)	≥ 50	–
Preselection	Set of suboctave band filters or tracking filter	Tracking or fixed filter Low pass/high pass filter	
Noise figure	15 dB (> 2 MHz)		
Sensitivity (500 Hz bandwidth) (dBμV)	−10	−7	−7
LO-phase noise (dBc/Hz)	−120 in 10 kHz offset	−100 in 10 kHz offset	−100 in 10 kHz offset
IF rejection (dB)	> 80	> 90	> 100
Image rejection (dB)	> 80	> 90	> 100
AGC	Measurement outputs should have no AGC applied		
Electromagnetic compatibility of the measurement set-up, including computers and interface	All interference produced and received by the set-up should be > 10 dB below the average noise to be measured		

The IF selectivity between 6 and 60 dB should be accurately known to calculate the equivalent noise bandwidth when measurements with different IF filters have to be compared.

3.2 Low noise amplifier (LNA)

An LNA is necessary for frequencies > 20 MHz

To guarantee a reasonable measurement accuracy it is required to keep the measured noise at least 10 dB above the equipment noise floor if an RMS detector is used. An LNA can assist in this goal. The requirements for such an amplifier are given in Table 2 which does not describe a new set of measurement receivers or LNA specifications but only points out the additional or specific requirements necessary for an LNA used for noise measurements.

TABLE 2

LNA

Function	**Frequency range**		
	20-50 MHz	**50-500 MHz**	**0.5-3 GHz**
Input (antenna input) VSWR	50 Ω, nominal < 1.5		
Gain (dB)	≤ 18	≤ 25	≤ 25
Gain stability	≤ 0.1 dB at 10-30° C		
Noise figure (dB)	≤ 2	≤ 2	≤ 2
Gain flatness over the frequency range of interest (dB)	< 0.1	< 0.2	< 0.5

Care should be taken not to overload the receiver when using an LNA. An external bandfilter can be applied to prevent overloading.

3.3 Antennas

There is no universal antenna for all types of noise measurements as well as for all frequency ranges, but there are some general requirements. The radiation pattern of the antenna needs to be optimized for the propagation mode of the noise to be measured, e.g. sky wave or direct wave. The gain needs to be as constant as possible over the relevant receiving aperture. Although affected by environmental conditions noise in itself is unpolarized, so a polarization-independent antenna or a combination of antennas would be ideal. For antennas placed in an environment where noise sources are distributed evenly around the antenna, the antenna pattern is less relevant than in cases where the noise is received from a defined angle. In the first case only the antenna efficiency or average gain over the total antenna aperture needs to be used as a correction factor. This is particularly the case with measurements in the higher frequency ranges. The lower the frequency the more relevant the 3D properties of the antenna diagram are.

3.4 Uncertainty analysis

The end result of the measurement should reflect a real value that can be reproduced even when another measurement set-up is used. Not only the average accuracy but also the limits in which the values can change are required. An uncertainty budget containing all contributors to the total uncertainty should be made for each measurement. Information about this can for example be found in ISO (insert nr) “Guide to the Expression of Uncertainty in Measurements”.

4 Measurement method/algorithm

Noise can basically be measured in two different ways: one method uses a RMS detector to determine the noise power, and the second method uses raw sampling using a sample detector. The end results of both methods are the same but both methods offer different ways of presenting and processing the data. While the RMS detector method is more suitable for measurements in the HF bands, the raw sampling method is more suitable for VHF/UHF measurements.

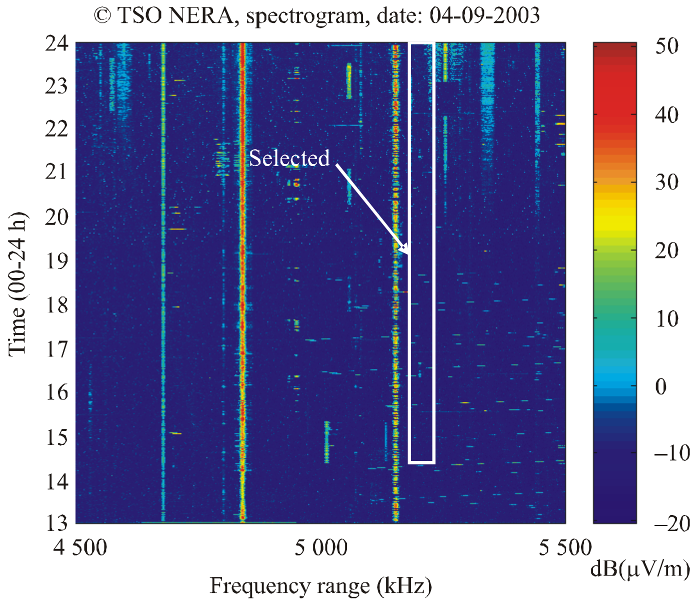
4.1 Selecting a frequency band or frequency

It is possible to perform measurements on one single frequency (channel) or in a certain frequency band (e.g. 100 kHz). These observations can be made automatically and the results processed according to a pre-defined protocol.

In case of a frequency band scan the best quality of results is obtained by measuring a frequency band with as few as possible strong signals. Data from historical measurements or a test measurement can be used to make the choice of a band with low occupancy in which the final measurements are made. For a single frequency measurement the frequency should be only occupied with interfering signals for a low percentage of time during the registration. Here we can also use historical data. Although the raw data method can be used in combination with a frequency scan, a single frequency measurement is more practical.

FIGURE 1

Determine a frequency slot in the 5 MHz band

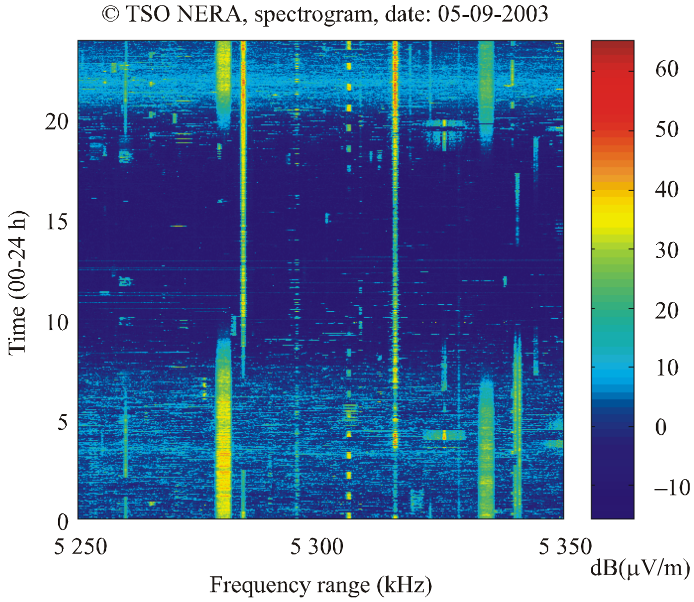


1753-01

In the example in Fig. 1 the band segment 4 500-5 500 kHz is measured over 24 h and a part of it, in this case 5 250-5 350 kHz, is selected for further measurements. Figure 2 shows the result of a 24h measurement in this band which is used to determine the noise level.

FIGURE 2

The band 5 250-5 350 kHz is selected



1753-02

4.2 Analyser/receiver settings

Some settings providing usable results are given in Table 3:

TABLE 3

Analyser/receiver settings

Measurement time	It is practical to produce a result every 10 or 20 s, so a sweep time, scan time or raw data processing time of 10 to 20 s is useful
Frequency range	The observation frequency range depends fully on the use of the chosen frequency band. This frequency band can even be split in sub-bands or frequencies, depending on the frequency band
RBW	If the frequency scan method is used the bandwidth of the applied filter depends on the frequency span divided by the required resolution. The raw sampling method dictates an RBW of at least twice the sampling frequency. The shape factor of the filter should be determined to make it possible to compare measurement results from different receivers
Detector	For noise power measurements a true RMS detector is necessary; any other detector is unsuitable. When the measured values are less than 10 dB below the equipment noise floor this detector requires a custom calibration. The raw data method has to use a sample detector because the processing including RMS calculations are done afterwards
Attenuator	3 dB An attenuator is required to set a defined receiver input impedance to guarantee a low measurement uncertainty
Pre-selector	On

4.3 Measuring period

The measuring period should be chosen with the time in which significant changes in the measured noise can be expected in mind. For example, to include day and night differences normally each HF frequency band should be measured over a ≥ 24 h period. To take into account variation due to seasons, the measurements should be repeated a number of times each year. There are also reasons to measure ≥ 24 h periods for non propagation related reasons. For example, locally produced noise can change over a 24 h period due to equipment switched on during working hours.

4.4 Post-processing

A spectrum analyser scans a frequency band in a number of steps (frequency bins). A normal number of bins with modern spectrum analysers is 500-10 000. If the scan time, for instance, is 10 s, the result of the measurements is a database (matrix) of 500 × 8 600 to 10 000 × 8 600 field-strength values. To have the possibility to exclude certain parts of the measurement and to apply different statistical methods, this database should be processed afterwards with dedicated software.

4.4.1 Order of processing and plotting

Table 4 presents the different processing steps for the different measurement methods.

TABLE 4

Processing steps

Processing step	Frequency scan	Single frequency	Raw sampling
Correct results for *K*-factor of antenna (see § 4.5.1)	x	x	x
Correct results for equipment noise (see § 4.5.2)	x	x	x
Correcting for filter shape/bandwidth (see § 4.5.3)	x	x	x
Plot PDF of the raw samples			x
Calculate RMS value for each block of raw samples			x
Selecting noise containing samples by: – Sort every scan of the matrix in ascending order – Separate the noise from the non-noise samples by taking out the 20% (or *x*%) lowest values – Validation of chosen percentage of 20% (or *x*%) (see § 4.6) – Correcting for 20% (or *x*%) values. (see § 4.5.4)	x	x	Optional
Calculate the average from the *x*% selection from every scan	x	x	Optional
Calculate from every 10 or *n* scans the minimum, average and maximum value	x	x	Optional
Plot the minimum, average and maximum results	x	x	Optional

4.5 Corrections to be applied

In the different stages of the post-processing's process, a number of corrections, as already mentioned in § 4.4.1, should be applied.

4.5.1 Correct results for *K*-factor of antenna

Each measured frequency point should be corrected with the right *K*-factor, especially for narrow-band antennas used in semi-wideband measurements. Keep in mind that narrow-band antennas should not be operated outside their frequency range because of the changes in the antenna diagram. As stated in § 3.3 the application of correction factors depends on the measurement situation.

4.5.2 Correcting for equipment noise

The signals we measure are in fact signals superimposed on the equipment noise. The way for correction is as follows. Measure for a short period without connected source (passive antenna), but with connected and properly terminated low noise amplifiers and the same settings as the original measurement. Now select the samples with the lowest value using the same method and same percentage as during the original measurement and subtract this value linearly from the measured average level value.

4.5.3 Correcting for 20% or *x*% values

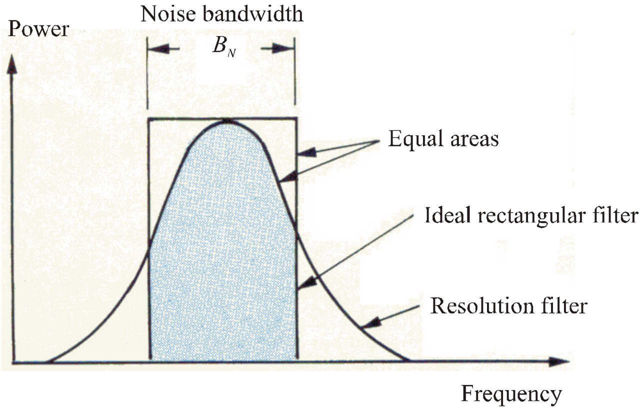
The unwanted noise components, e.g. carriers, are filtered out by the 20% method. However the wanted noise is also filtered by this method. A correction factor needs to be applied to compensate for the introduced error. This error can be determined with a Gaussian noise source and the actual settings to be used in the measurements, both IF filter, video filter and wanted *x*% percentage. For a specific noise type alternative noise sources should be used.

4.5.4 Correcting for filter shape/bandwidth

Although, in spectrum monitoring, we like to speak about noise levels, noise is almost always expressed as power/bandwidth. For such an expression the filter bandwidth needs to be integrated and basically presented in a rectangular form.

FIGURE 3

Rectangular presentation of filter bandwidth



1753-03

If we want to compare measurements made with two different RBWs, we have to apply a correction factor to one of the results that is equal to the ratio of the two RBWs. So, to convert measurements made with RBW_1 into measurements made with RBW_2, a correction of:

$$10 \log(RBW_2/RBW_1)$$

has to be applied to the measured values (dB).

In order to get bandwidth-independent results, the measured values are normalized to the thermal noise level which can be calculated as follows:

$$P_0 = k\,T_0\,B$$

where:

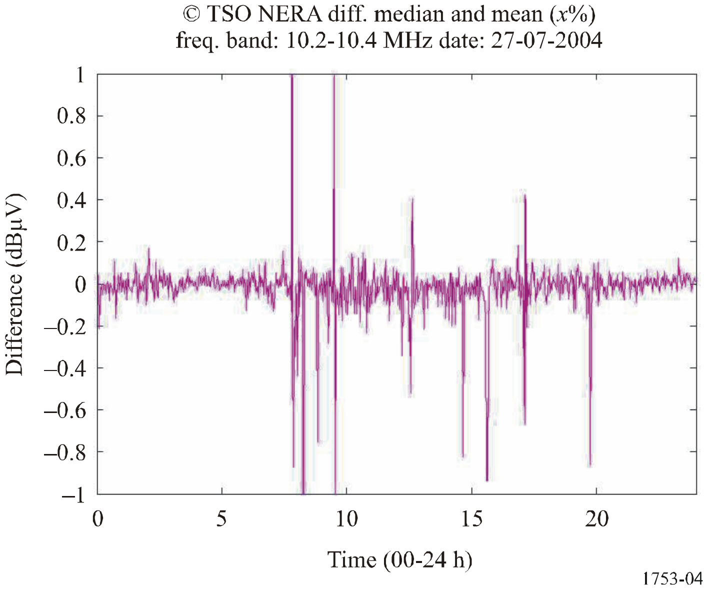
k: Boltzmann's constant = 1.38×10^{-23} W/Hz
T_0: ambient temperature (K)
B: noise equivalent bandwidth of the measurement filter.

4.6 Validation of chosen percentage of *x*%

For HF, 20% of the lowest values is a practical value to determine the noise level. For other frequency ranges it should be checked whether this 20% value is correct or should be changed to another value. It is assumed that *x*% values are containing noise samples only. In that case the median and mean value should be the same. A practical test is the difference between the mean and median value, which is obviously influenced by non-noise signals.

FIGURE 4

Difference between mean and median values (20% selection)



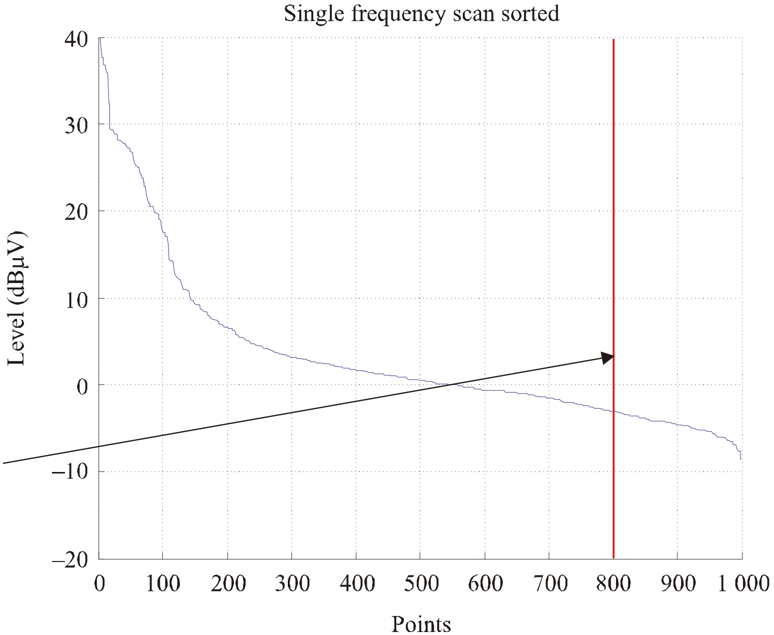
1753-04

As an example the graph above shows the difference between mean and median values with a fixed percentage of 20% for all scans. The observation period is 24 h (00:00 to 23:59). During the time period 07:00 h till 20:00 h, thunderstorms cause the distribution of the 20% selection to have large slopes and thus large differences between the median and mean power values.

Another test would be to check whether the curve at the right side of the "20%" point is smooth and has a small slope. Both test methods require some *a priori* calibration. Also, a meaningful number of samples needs to be used in the calculation, for example a single sample cannot be used in this type of test.

FIGURE 5

Randomly chosen scan with sorted values



Value below this level are used for noise power estimation

1753-05

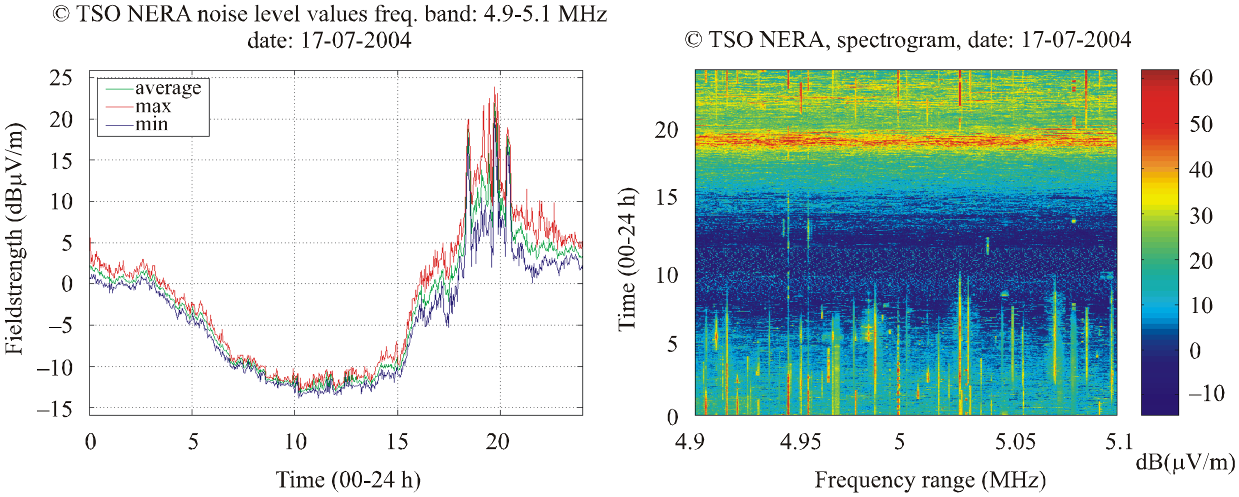
5 Presentations

In frequency ranges below 30 MHz, the radio noise significantly changes over the time of day. Therefore the calculated results should be presented over 24 h.

Below is an example of measurement results at 5 MHz (4.9-5.1 MHz). The maximum, average and minimum values over 24 h (calculated as in § 4.4.1) can be seen in the left-hand plot, and the spectrogram, containing all the scans over 24 h, on the right side.

FIGURE 6

Mean, maximum and minimum values and spectrogram over 24h period



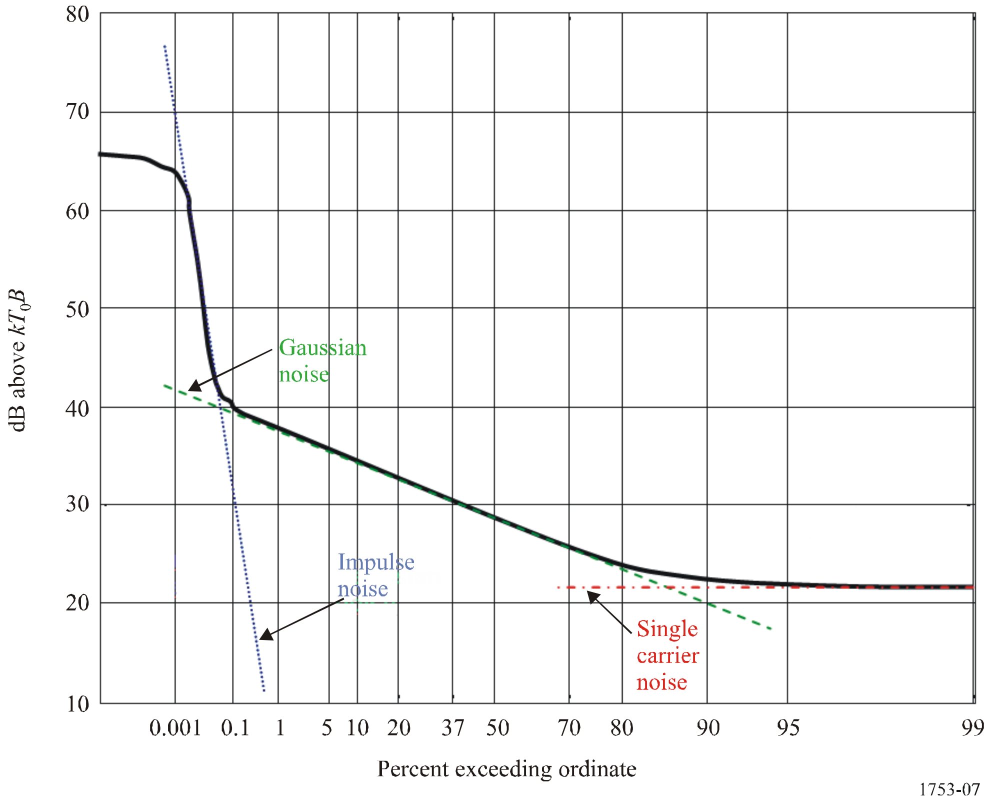
1753-06

In the VHF/UHF range, the radio noise level is rather constant during the day but mainly depends on the measurement location category (e.g. city/business, residential, rural). To condense all samples to one characteristic value, the so-called amplitude probability distribution (APD) graph should be preferred. This graph shows the percentage of measurement samples that exceeds a certain amplitude.

Figure 7 shows the results of a measurement at 410 MHz in a residential surrounding.

FIGURE 7

APD



1753-07

The x-axis of the APD graph has a Rayleigh scaling. With this scaling, it is easy to separate the different types of noise: white noise shows up as a straight sloping line (in the middle of the graph). The rising edge to the left indicates impulse noise from single sources. The levelling-out towards the right side is due to single carriers from nearby sources.

The overall RMS level is the 37% value.