International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R BS.2213-4

(10/2017)

Impact of audio signal processing and compression techniques on terrestrial FM sound broadcasting emissions at VHF

BS Series

Broadcasting service (sound)

International Telecommunication Union

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2017

REPORT ITU-R BS.2213-4

Impact of audio signal processing and compression techniques on terrestrial FM sound broadcasting emissions at VHF

(2011-2013-2015-2016-2017)

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Introduction

Audio signal processing techniques have developed rapidly in the last few years based on advances in digital signal compression techniques. Applying the compressed audio signal to the FM modulator can increase the modulation power without exceeding the frequency deviation limit given in Recommendation ITU-R BS.412. The processed modulation signal can also result in an increased bandwidth so increasing interference to other VHF FM stations operating on the same or adjacent channels.

Recommendation ITU-R BS.412-9 – Planning standards for terrestrial FM sound broadcasting at VHF, provides the necessary RF protection ratios under the condition that the maximum deviation of the interferer signal is 75 kHz and its multiplex power (MPX) does not exceed 0 dBr. Field measurements show that nowadays a significant number of FM transmitters exceed the 0 dBr limit of the MPX power and have a higher potential to cause interference in the reception of other FM broadcast stations and in other radio services (e.g. air radionavigation). Recommendation ITU-R BS.412-9 specifies that in these cases the transmitted RF power should be decreased, but does not provide quantitative figures for the necessary reductions. As the FM band is overcrowded and introduction of new digital stations is also considered, it is very important that the FM stations operate in line with the international regulations.

As proposed in Question ITU-R 129/6 measurements were carried out to study:

– What is the impact of audio signal processing and compression techniques on the average power of the complete multiplex signal and the maximum deviation of the emission?

– What techniques are available to ensure that the emission complies with the planning parameters given in Recommendation ITU-R BS.412 when audio signal processing and compression techniques are used?

This Report presents in Annex 1 the measurement specification used in Germany for the measurement of the frequency deviation and multiplex power of FM. Annexes 2 to 5 contain summaries of measurements performed to assess the impact of the MPX power. Annex 2 presents a study carried out in Hungary and Annex 3 a study performed in France, both on the protection levels against interferers with exceeded MPX power in the FM sound broadcasting. Annex 4 provides the results of measurements done in Germany on the impact of multiplex power levels higher than 0 dBr on the RF protection ratio of sound broadcasting emissions in VHF band II and presents some comparisons with Annexes 2 and 3. Finally, Annex 5 presents a study performed in France on the relationship between loudness and multiplex power. The results of these measurements and analysis may help to understand better the potential impact of the multiplex power in FM sound broadcasting when the 0 dBr MPX power limit is exceeded due to application of audio signal processing and compression techniques.

Annex 1

Measurement specification used in Germany for the measurement of the frequency deviation and multiplex power of FM sound broadcasting transmitters

1 Purpose and scope

This measurement specification describes the methods used by the Bundesnetzagentur to measure the frequency deviation and multiplex power of FM sound broadcasting transmitters in VHF band II at the air interface and to document the measurement results. The aim is to lay down a uniform procedure for measurement and evaluation.

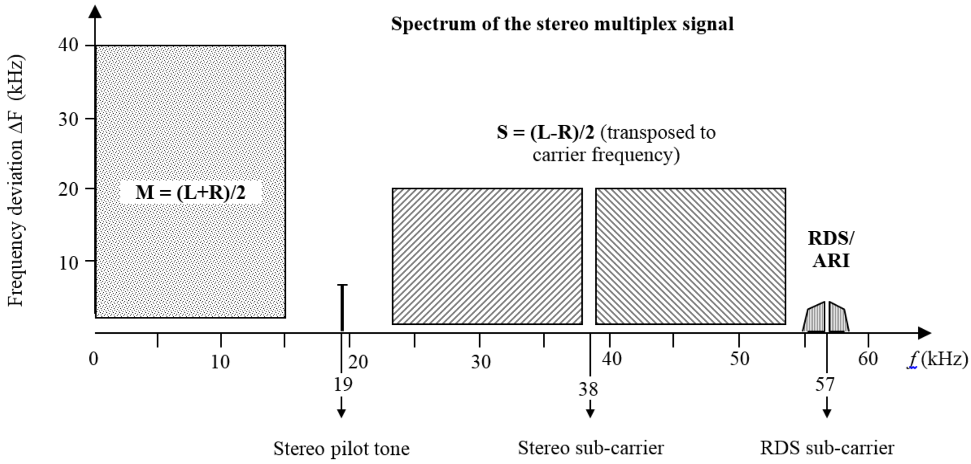
The measurement can also be carried out as described at the measurement output of the transmitter. In this case the requirements specified in §§ 5.3.2 to 5.3.4 do not apply.

2 Terms and definitions

The following terms are used for stereophonic transmission using the pilot-tone system:

Signal L:	Signal L corresponds to the information in the left stereophonic channel.
Signal R:	Signal R corresponds to the information in the right stereophonic channel.
Sum signal M:	M = (L+R)/2 (monophonic or compatible signal)
Difference signal S:	S = (L-R)/2 (side information)
Stereo sub-carrier:	The sub-carrier (38 kHz) is used to transpose the S signal to the carrier frequency (between 23 kHz and 53 kHz). It is suppressed before transmission to reduce the signal energy of the difference signal on the transmission path.
Pilot tone:	The pilot tone (19 kHz) is used to retrieve the stereo sub-carrier, which is suppressed before transmission, in the stereophonic receiver.
ARI signal:	The ARI signal indicates and switches traffic information on a 57 kHz sub-carrier locked in phase with the stereo sub-carrier.
RDS signal:	Radio data signal as defined in DIN EN 50067 and Recommendation ITU-R BS.643-2
Supplementary signal:	According to Recommendation ITU-R BS.450 all additional signals in the 15-23 kHz and 53-76 kHz bands (e.g. DARC, SWIFT)

Multiplex signal: The multiplex (MPX) signal includes all stereo information (including the pilot tone, ARI and RDS). It is the signal added to the modulator (the "modulating signal").



Multiplex power: According to Recommendation ITU-R BS.412, the power of the multiplex signal must be averaged over a floating measurement interval of 60 s. The multiplex power (modulation power) P_{mod} is derived from the instantaneous deviation Δf(t) using the following formula:

$$P_{mod} = 10 \log \left[\frac{2}{60s} \int_{T}^{T+60s} \left(\frac{\Delta f(t)}{19\ \text{kHz}} \right)^2 \mathrm{d}t \right] \qquad \text{dBr}$$

The value 0 dBr thus corresponds to the modulation power of a sinusoidal signal (without the pilot tone and without supplementary signals) which causes a peak deviation of ±19 kHz.

Frequency deviation: In the case of frequency modulation, the deviation of the instantaneous frequency from the unmodulated carrier frequency f_0. Where no further information is given, the peak deviation Δ*F* is meant.

Instantaneous deviation: In the case of frequency modulation, the instantaneous deviation of the frequency at any given time *t* from the frequency of the unmodulated carrier f_0:
$f(t) = f_0 + \Delta f(t)$

Peak deviation: In the case of frequency modulation with any signals, the maximum deviation of the frequency *f* from the frequency of the unmodulated carrier f_0. In frequency modulation with sinusoidal signals:
$f = f_0 + \Delta F * \sin(\omega t)$. The peak deviation Δ*F* is given in kHz.

3 Limits

According to Recommendation ITU-R BS.450-2, the peak deviation may not exceed ±75 kHz at any time. This limit is likewise to be complied with where supplementary signals such as ARI and/or RDS are also transmitted.

The multiplex power must, in accordance with Recommendation ITU-R BS.412-9, not exceed 0 dBr over any measurement interval of 60 s.

These limits are also a constituent part of the basic characteristics in the frequency assignments granted by the Bundesnetzagentur for VHF sound broadcasting transmitters.

4 Technical non-compliance values

Taking into account the measurement uncertainties specified in Recommendation ITU-R SM.1268, including the possible influence of reflections, co-channel and adjacent channel emissions and individual, unnoticed interferers on the measurement, the limits can be assumed to be exceeded in terms of the measurement if:

- the cumulative frequency of the instantaneous deviations relative to a frequency deviation of 77 kHz exceeds $1*10^{-4}$% within a measurement period of one hour, or
- the multiplex power exceeds 0.2 dBr.

The values of 77 kHz frequency deviation and 0.2 dBr multiplex power, derived taking into account the measurement uncertainties, are based on the limits given in § 3 and assuming a confidence level of 95%.

5 Measurement method

5.1 Measuring equipment requirements

The measurement system must meet the requirements in Recommendation ITU-R SM.1268. Accordingly, the maximum permissible measurement error of the system used to measure frequency deviation may not exceed the following values:

Instantaneous deviation	**Measurement error[1]**
≤ 80 kHz	≤ ±2 kHz
> 80 kHz	≤ ±5 %

The maximum permissible measurement error of the system used to measure multiplex power may not exceed the following values:

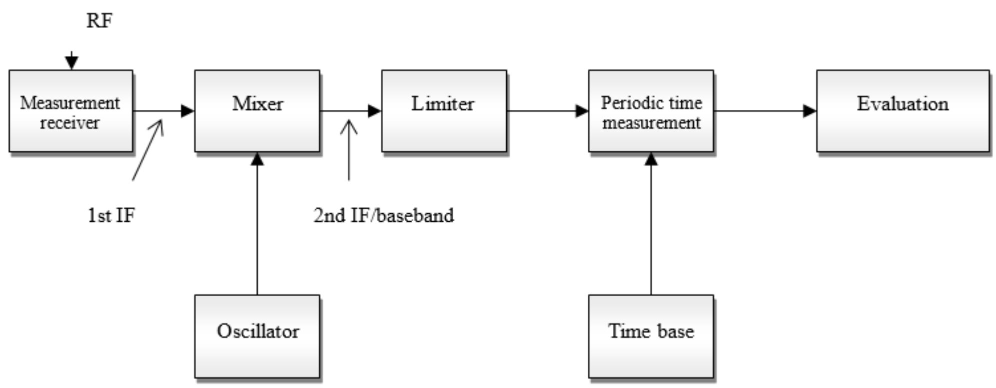
Multiplex power	**Measurement error[1]**
< −2 dBr	≤ ±0.4 dB
−2 dBr to +2 dBr	≤ ±0.2 dB
> 2 dBr	≤ ±0.4 dB

[1] In determining the non-compliance values, the measurement error of the measurement system is taken to be the measurement uncertainty given an equal distribution of the measured value with a confidence level of 100%.

5.2 Measurement principle

The frequency deviation and multiplex power measurements are carried out at the Bundesnetzagentur using digital methodology by measuring the intervals between the zero crossings of the signal mixed down to IF or baseband level.

Block diagram of a typical frequency deviation/multiplex power measurement system with IF input



To achieve sufficient measurement accuracy, the measuring equipment must have the following characteristics:

– The receiver may have either Gaussian IF filters or rectangular "channel" filters. Rectangular filtering applies in particular where the signal to be measured is limited in bandwidth digitally, e.g. in the case of broadband receivers using FFT. The type of filter used and its frequency characteristic must be known in particular to determine the required protection ratio in relation to adjacent channel transmitters.

– The IF bandwidth (3 dB) of Gaussian filters must be at least 150 kHz and that of rectangular/channel filters at least 200 kHz.

– The sampling rate for the periodic time measurement must be at least 200 times higher than the (intermediate) frequency at which sampling is carried out.

– The counter resolution must be at least 8 bits.

5.3 Required measurement conditions

To ensure the required measurement accuracy, the following measurement conditions must be met.

5.3.1 Wanted signal input level

To ensure a sufficient signal-to-noise ratio, the wanted signal input level must be at least 80 dBμV.

5.3.2 Degree of distortion and reflection

Multipath reception caused by reflections leads to frequency-selective increases or decreases in the resulting signal amplitude and hence to an apparent amplitude modulation of the wanted signal, which can distort the deviation measurement value. This effect can also be caused by co-channel and adjacent channel transmitters. A measure for such interference to the wanted signal is the degree of distortion. The degree of distortion *S* is defined as the maximum gradient of the complex sum envelope normalised to the wanted signal envelope through changes to the instantaneous frequency (caused by modulation with the modulating signal) expressed in %/kHz.

$$S = Max\left(\left|\frac{\partial|U_K|}{\partial(v(t)\cdot 2\pi\Delta F)}\right|\cdot\frac{1}{|U_N|}\cdot 10^2\cdot\frac{1}{10^{-3}}\right) \qquad [\%/\text{kHz}]$$

where:

U_k: complex envelope of the FM signal in front of the demodulator

U_N: complex envelope of the wanted signal

$v(t)$: normalised modulating signal ($|v(t)| <1$)

ΔF: peak deviation (Hz).

Where the interference is caused exclusively by reflections, the degree of distortion is equal to the degree of reflection R:

$$R = 2\cdot\pi\cdot\tau\cdot|r|\cdot\frac{10^2}{10^{-3}} \qquad [\%/\text{kHz}]$$

where:

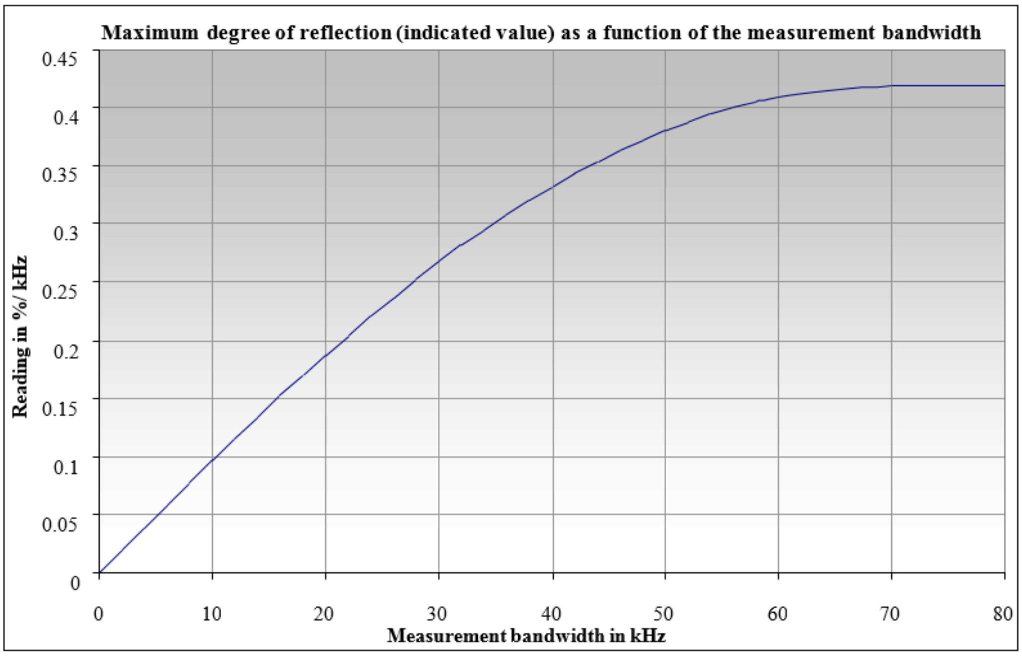
τ: time delay of the reflected wave in relation to the direct wave in seconds

r: complex reflection factor.

The maximum permissible degree of reflection is 0.4%/kHz.

Environmental and weather conditions (e.g. vehicle traffic) can also influence the reflection factor.

An exact measurement of the degree of reflection is only possible if the reflection meter has a measurement bandwidth of at least 75 kHz. Since most reflection meters currently available have a narrower bandwidth, measurements may be erroneous in that the degree of reflection indicated is too low. The following diagram shows the maximum indicated degree of reflection as a function of the measurement bandwidth of the reflection meter.



5.3.3 Co-channel and adjacent channel protection ratios

The required protection ratios in relation to co-channel and adjacent channel transmitters depend on the type, width and frequency characteristic of the IF filter used.

Emissions from other radiocommunication services in adjacent bands (public safety agencies and the aeronautical service) must be treated as co-band, adjacent channel interferers with a corresponding frequency separation.

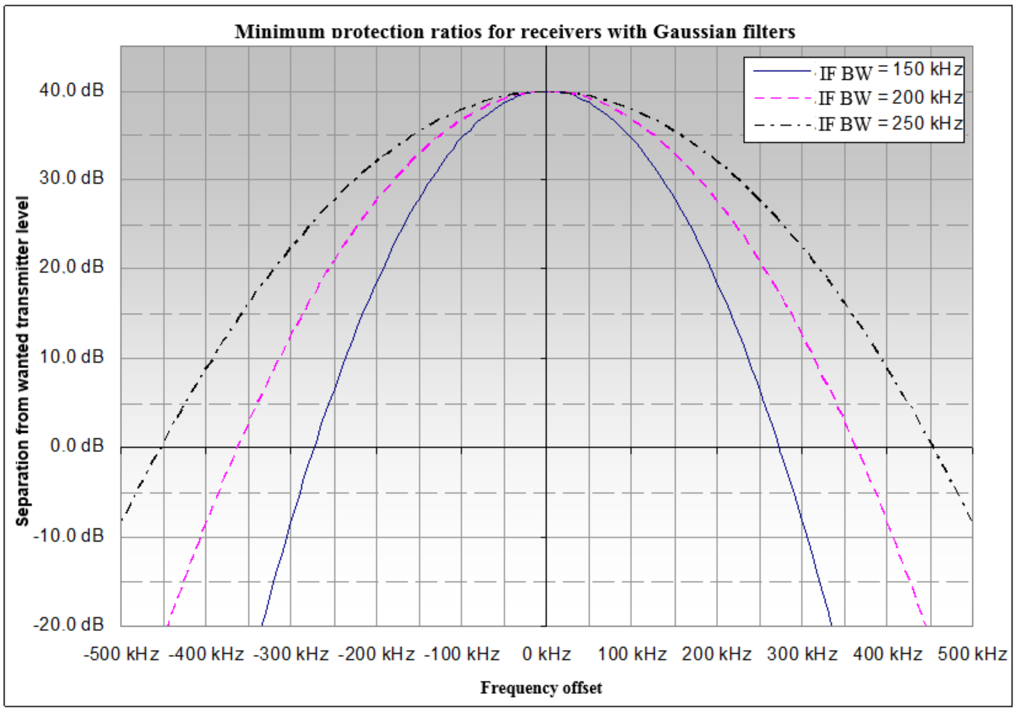
5.3.3.1 Receivers with Gaussian filters

The following protection ratios in relation to co-channel and adjacent channel transmitters are required where measurement receivers with Gaussian filters are used:

Frequency difference ±Δ*f* (kHz)	**Required minimum protection ratio (dB)**
0	40
X	$40\text{-}3.01{*}(2X/B)^2$

B is the nominal (3 dB) bandwidth of the IF filter. The required minimum protection ratio in relation to interfering adjacent channel transmitters thus starts at the co-channel value of 40 dB and decreases as the frequency separation increases by the attenuation of the IF filter.

The following diagram shows the required protection ratios for example filter bandwidths (IF BW) of 150, 200 and 250 kHz.



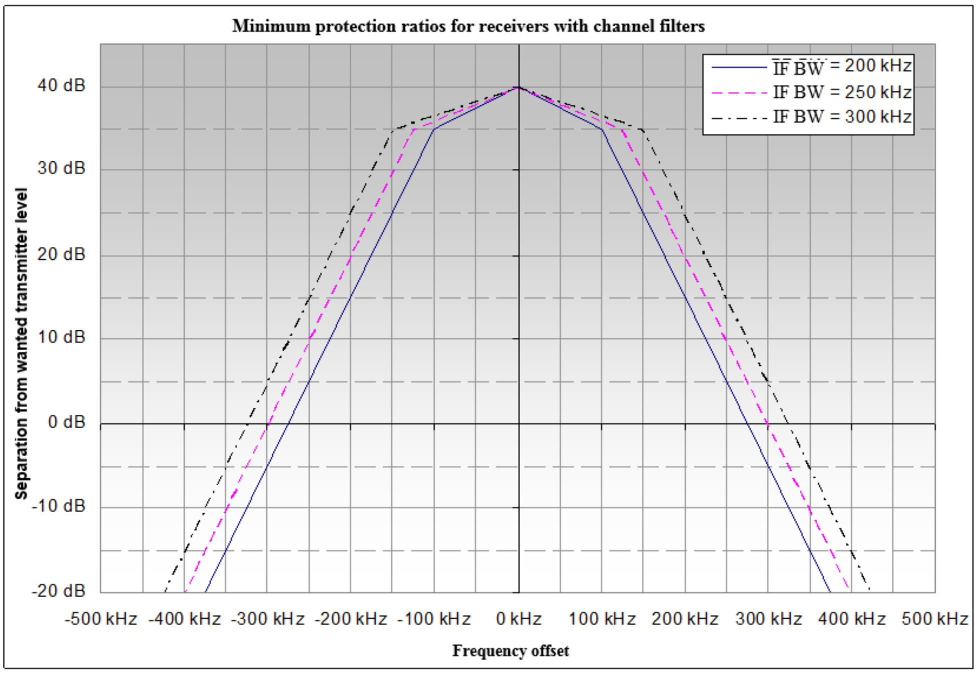
5.3.3.2 Receivers with channel filters

The following protection ratios in relation to co-channel and adjacent channel transmitters are required where measurement receivers with rectangular/channel filters are used:

Frequency difference ±Δ*f* (kHz)	Required minimum protection ratio (dB)
0	40
B/2	35
X (for *X* > *B*/2)	35-0.2*(*X* − *B*/2)

B is the nominal (3 dB) bandwidth of the IF filter. Linear interpolation is used between the values given in the table.

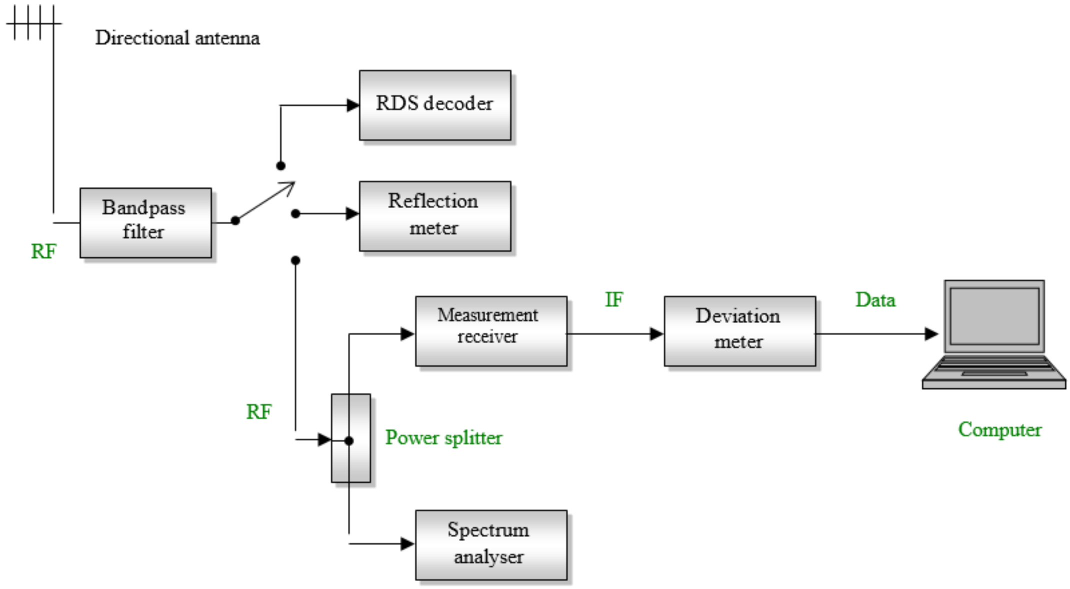
The following diagram shows the required protection ratios for example filter bandwidths (IF BW) of 200, 250 and 300 kHz.



5.3.4 Overrange

Before the measurement starts it must be ensured that there are no significant conditions for overrange reception.

5.4 Measurement set-up



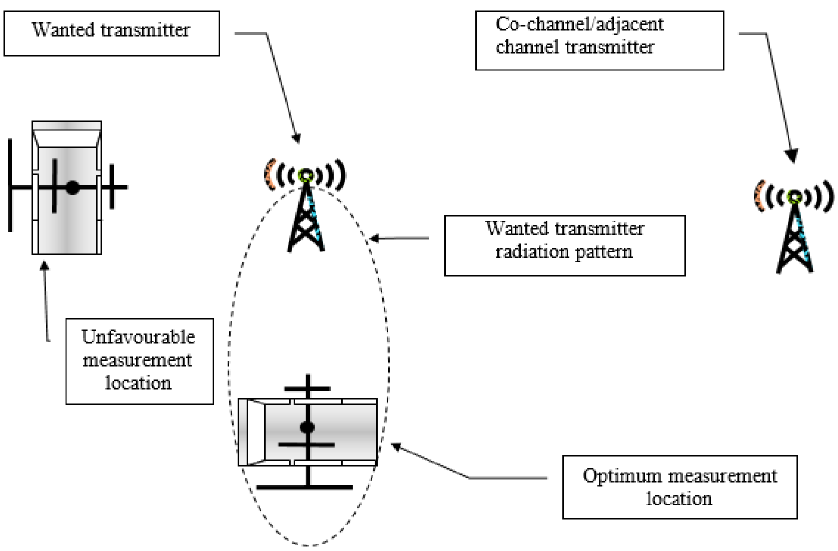
The separate functional blocks can be incorporated in one or more items of equipment.

5.5 Measurement procedure

5.5.1 Determination of the measurement location

The measurement location is chosen on the basis of an analysis of the antenna patterns of the transmitter to be measured and the determination of the locations of the adjacent channel transmitters such that a sufficient adjacent channel protection ratio can be expected.

Once the location has been reached, a check is first made to determine any possible interfering conditions (e.g. traffic near the measurement location, high voltage lines).



5.5.2 Measurement of the wanted transmitter and adjacent channels

The wanted signal level is measured using the measurement receiver.

Settings:

- Frequency: (centre frequency of the wanted transmitter)
- Measurement bandwidth: ≥120 kHz
- Detector: Average (AV) or RMS

The required wanted signal input level is described in § 5.3.1. If the required level is not achieved, a different measurement location must be chosen.

The adjacent channels are measured using the spectrum analyser for the entire duration of the measurement.
Settings:

- Centre frequency: (centre frequency of the wanted transmitter)
- RBW: 10 kHz
- VBW: 30 kHz
- Span: 1 MHz
- Sweeptime: auto
- Trace 1: max hold
- Trace 2:clear/write
- Attenuation: dependent on input level
- Scale: 10 dB/div

To measure the 100 kHz adjacent channels the clear/write curve (trace 2) must be frozen in a modulation interval or, in the case of a wanted transmitter with low modulation, using the view function of the analyser.

The level of the adjacent channel transmitters with a separation ≥200 kHz are measured in the max hold curve (trace 1).

The protection ratios must be optimised by rotating the antenna. The required protection ratios are described in § 5.3.3. If they are not achieved, a different measurement location must be chosen.

Further improvement can be achieved by using a bandpass filter. Such filters must have a bandwidth of at least 150 kHz. If the filter edge coincides with the wanted emission, however, the measurement results may be erroneous. To rule this out, it is necessary to check the indicated degrees of reflection for compliance with the values in § 5.3.2.

The spectrum analyser plot is saved for later documentation.

5.5.3 Measurement of the reflection factor and determination of the RDS programme name and PI code

The degree of reflection in the antenna signal is determined using a reflection meter.

The maximum permissible degree of reflection is described in §5.3.2. If this is exceeded, a different measurement location must be chosen.

Since frequency deviation and multiplex power also depend on the level and characteristics of the audio signal fed from the studio to the transmitter, the values measured may differ if there is a change of programme provider. To enable clear identification of the programme provider transmitting the measured signal, the programme identification code (PI code) is to be determined using the RDS decoder and documented in the measurement report.

5.5.4 Determination of the measurement location coordinates

The coordinates of the final measurement location are to be determined using a GPS receiver and documented in the measurement report together with the address or as accurate a description as possible of the location.

5.5.5 Measurement of the frequency deviation and multiplex power

Receiver settings:

- Centre frequency: (centre frequency of the wanted transmitter)
- Bandwidth: ≥150 kHz (receivers with Gaussian IF filters)

  ≥200 kHz (receivers with rectangular/channel filters)
- Attenuation: dependent on the input level such that the level at the IF output complies with the specification of the subsequent measurement system

Start of recording:

Depending on the measurement system the deviation and multiplex power measurement programme or recording is started. The measuring/recording time must be at least 60 minutes.

During the measurement:

Unusual events such as a change of programme provider or studio or a transmission outage that can have an influence on frequency deviation and multiplex power must be documented.

If during the measurement interfering signals (for example from electrical equipment, vehicles or machines) that have an effect on the measurement results or transmitter outages occur, the measurement must be restarted. Impulse interferences are characterised for instance by short deviation peaks that are considerably higher than the peaks caused by modulation that occur at intervals throughout the whole measurement period.

5.6 Evaluation of frequency deviation and multiplex power

The evaluation software is used to present at least the following in diagram form:

- peak deviation as a function of time (measurement interval: 10 s)
- multiplex power as a function of time
- cumulative frequency of all deviations measured

The following measurement results are presented in numerical form:

- frequency of individual deviations above 77 kHz in %
- maximum multiplex power during the measurement in dBr

The diagrams and figures form part of the measurement report.

6 Documentation of the results

A measurement report is to be drawn up to document the measurement results. An example is contained in the Attachment 1 to this Annex 1.

7 Standards and Recommendations

This measurement specification was drawn up on the basis of in particular the following national and international standards and Recommendations:

- FTZ 175 R4 "Directive for the assessment of VHF sound broadcasting (mono and stereo) transmissions by ARD and DBP"
  Contents: minimum wanted field strengths, degree of reflection, protection ratios, receiving antenna characteristics
- ITU-R BS.412-9 – Planning standards for terrestrial FM sound broadcasting at VHF
  Contents: minimum usable field strengths, protection ratios (monophonic/stereophonic)
- ITU-R BS.450-2 – Transmission standards for FM sound broadcasting at VHF
  Contents: description of the signal in the case of monophonic and stereophonic transmissions, e.g. pre-emphasis, peak deviation, supplementary signal; description of pilot-tone system and polar-modulation system, table of transmission systems (including parameters) used in different countries worldwide
- ITU-R SM.1268-1 – Method of measuring the maximum frequency deviation of FM broadcast emissions at monitoring stations
  Contents: description of a method for standards-based indicative measurements of the frequency deviation and multiplex power of frequency modulated sound broadcasting transmitters, measuring equipment requirements

Attachment 1
to Annex 1

Konstanz Regional Office

Job no V271/00698/07 – Radio FR 1, 94.7 MHz

Measurement report (example)

Summary

Contents	Measurement of the frequency deviation and multiplex power of the transmitter Freiburg-Lehen 94.7 MHz on the basis of the “Instructions for measuring the frequency deviation and multiplex power of VHF sound broadcasting transmitters at the air interface”
Results	The peak deviation non-compliance value of 77 kHz (75 kHz + 2 kHz tolerance) was not exceeded. The maximum multiplex power was 0.19 dBr and thus was not higher than the non-compliance value of 0.2 dBr (0 dBr + 0.2 dB tolerance).

Measurement date

Date	20 November 2009
Time (CET)	10:48 to 11:48

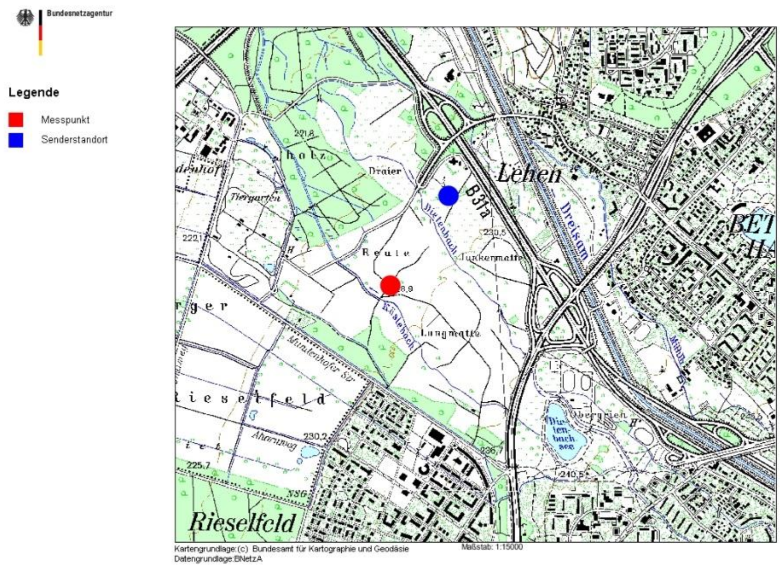
Transmitter data

Name	Freiburg-Lehen
Coordinates (WGS84)	07E47’36“ 48N00’47“
Frequency (MHz)	94.7
Polarisation	Horizontal

Measurement location

Location description	Freiburg (Lehen) on a farm track south of the transmitter
Coordinates (WGS84)	07E47’24“ / 48N00’31“
Weather	Sunny, dry

Map extract



Photograph of measurement location

Equipment used

Name	Type/number	Inventory no	Calibration date
Monitoring vehicle	MKW 822 MZ-10712		
Measurement antenna	FT01; UKW-Z	BAPT 6047581	22.09.08
Measurement receiver	ESVB	BAPT 6020861	15.01.09
Spectrum analyser	ESPI	RegTP 11007500	21.11.08
Broadcasting measurement receiver	RME 320	BAPT 2003629	09/08
Coupler	BN923050		
FM analyser	RBT	BAPT 6020926	28.04.09
Software	USB-FM-Analysator Version 1.1		
Laptop	IBM Thinkpad	RegTP 6005406	

Measurement error

The measurement system was checked for proper functioning.

The maximum measurement error of the measurement system is ±2 kHz for frequency deviations <80 kHz and 5% of the measured value for larger frequency deviations and ±0.2 dB for a multiplex power in the range from –2 dBr to +2dBr and ± 0.4 dB for a multiplex power outside the range.

Equipment settings

Measurement receiver (frequency deviation recording)	IF BW: 300 kHz; detector: AV; operating mode: low distortion; preamplifier: off; RF attenuation: 40 dB
Measurement receiver (multiplex power measurement)	IF BW: 120 kHz; detector: AV; operating mode: low distortion; preamplifier: off
Spectrum analyser	Span: 1 MHz; RBW: 10 kHz; VBW 30 kHz; clear/write / max hold
FM analyser	Multiplex power integration: 60 sec; deviation peak hold: 10 sec; recording time: 60 min

Measurement results

Peak deviation/multiplex power			
	Measured value	**Non-compliance value**	**Non-compliance**
Frequency deviations above 77 kHz (peak hold 10 s)	$3.64*10^{-5}$%	$1*10^{-4}$%	No
Maximum multiplex power (integration time 60 s)	0.19 dBr	0.2 dBr	No

Frequency, field strength, identification	
Transmitting frequency (MHz)	94.7
Receiver input voltage (dBµV)	80.0
Field strength (dBµV/m)	89.6
Polarisation	Horizontal
Antenna height (m)	4.7
Antenna orientation (°)	24
Reflection factor (%/kHz)	0.1
RDS programme name/PI code	Antenne 106.0/1702

Appendices

1 Wanted-to-unwanted signal ratio with spectrum plot

2 Record of special events during frequency deviation recording

3 Recording results

Measurement staff

(First name, surname, official title/grade)

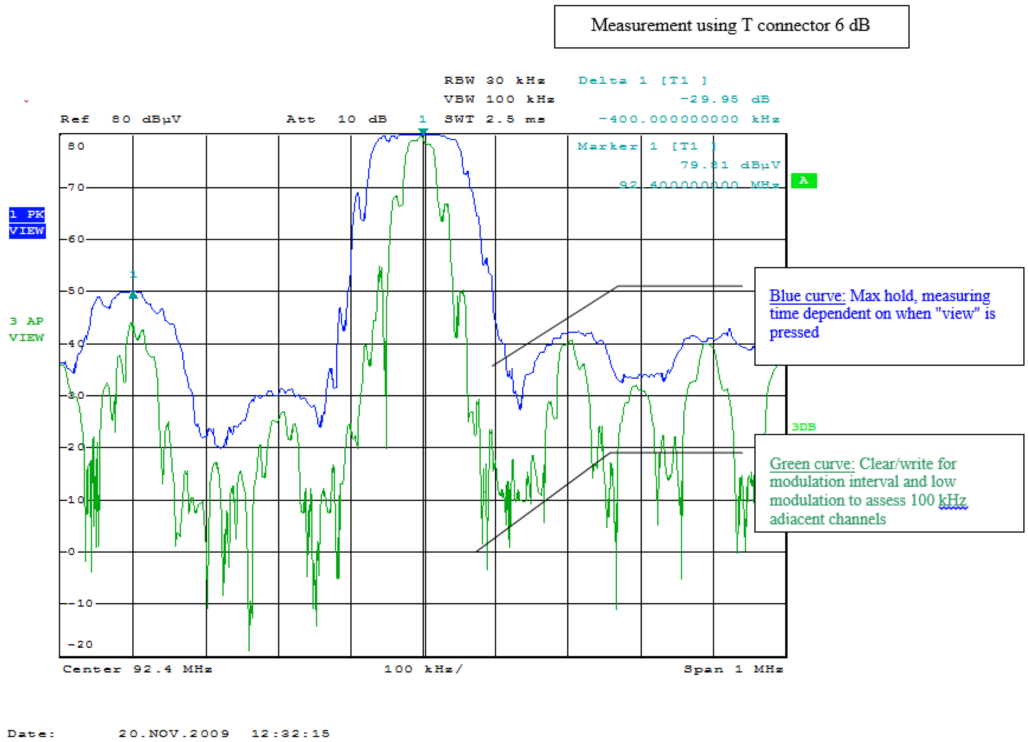
Drawn up by (surname, first name, official title/grade, date) **Checked by** (surname, first name, official title/grade, date)

(Surname, first name, grade), 20.11.09 (Surname, first name, grade), 20.11.09

Record 1 to measurement report

Input wanted-to-unwanted signal ratio

Spectrum plot



Input wanted-to-unwanted signal ratio

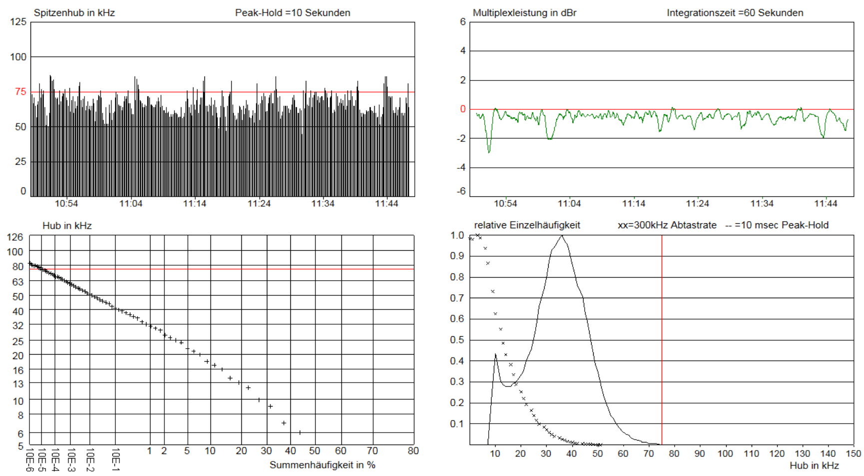
Frequency difference (kHz)		Wanted/unwanted ratio (dB)		Required minimum protection ratio (dB)
0				40
−100	+100	55	62	40
−200	+200	49	38	30
−300	+300	57	45	27
−400	+400	29	38	15
−500	+500	43	38	0

Record 2 to measurement report

Time CET	Unusual events
10:48	----- Start of recording -----
11:48	----- End of recording -----

Record 3 to measurement report

BNetzA ASt. Konstanz, V271/00698/07 Freiburg (Lehen) im Feldweg südlich vom Sender Sender/Programm: Antenne 106.0 Frequenz : 94,7 MHz	DATUM :20.11.2009 MESSZEIT :10:48-11:48 max. Mod.leistung:0,19 dBr Hübe >77kHz: 3,64E-5% = 1,3 ms



Annex 2

Measurement results performed in Hungary on the protection levels against interferers with exceeded MPX power in the FM sound broadcasting

Introduction

Recommendation ITU-R BS.412-9 – Planning standards for terrestrial FM sound broadcasting at VHF, provides the necessary RF protection ratios under the condition that the maximum deviation of the interferer signal is 75 kHz and its multiplex power (MPX) does not exceed 0 dBr. Using modern audio processing/compressing techniques which result in an increase of the average power of the complete multiplex signal may lead to an increase in interference to sound broadcasting stations which do not use such techniques. Measurements were carried out in Hungary to investigate how can be ensured that the emission complies with the planning parameters given in Recommendation

ITU-R BS.412 when the 0 dBr MPX power limit is exceeded due to application of audio signal processing and compression techniques.

Using modern audio processing/compressing techniques the 0 dBr MPX power limit can be exceeded while the 75 kHz limit for the maximum deviation is kept. The increased interference potential of the processed/compressed higher MPX power signal can be compensated either by decreasing the transmitted RF power or by reducing the maximum FM deviation of the transmitter. The aim of the measurements was to find quantitative figures for the reduction of the RF power and the peak deviation of the FM broadcast signal exceeding the 0 dBr MPX power limit, which can restore the audio signal-to-noise ratio (*S*/*N*) of the interfered FM broadcast service to the required 50 dB value.

1 Measurement setup and measurement methods

The measurements were carried out using the setup shown in Fig. 1 based on Recommendation ITU-R BS.641 – Determination of radio-frequency protection ratios for frequency-modulated sound broadcasting. The list of the instruments used and the main settings can be found in the Annex.

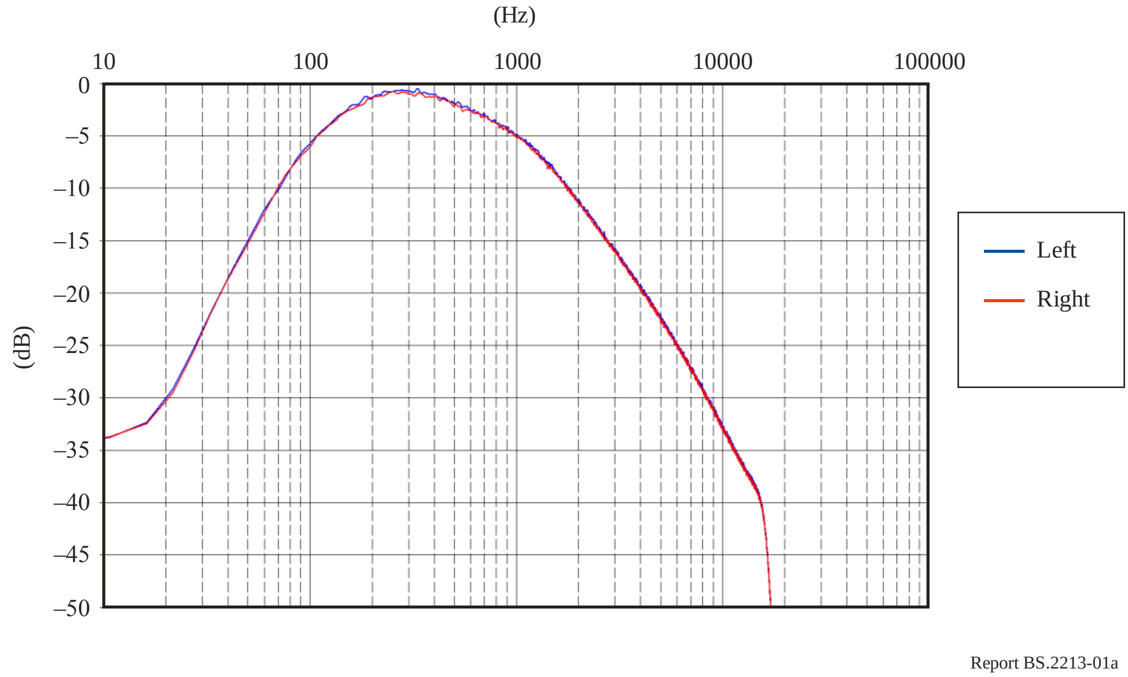
The signals of the wanted (Generator 6) and the interfering (Generator 7) transmitters were combined and applied to the FM receiver. The output audio signal of the receiver was then measured by an audio analyser.

The wanted signal was a stereo FM broadcast signal modulated by the output of the stereo coder while the stereo coder was driven by internal 500 Hz sinusoidal sources in both (left and right) channels. The level of the modulating signal was adjusted so that the peak FM deviation of the wanted signal was 75 kHz and it remained unchanged during the whole measurement.

The interfering transmitter was modulated by processed/compressed noise plus RDS signal. The input sound signal was a weighted (coloured) noise defined by Recommendation ITU-R BS.559-2 (see Fig. 1), which was recorded on a CD. The level of the modulating signal was adjusted so that the peak FM deviation of the unwanted signal was 75 kHz and it was checked by the modulation meter (8). The RF level of the interferer signal could be adjusted by two cascaded step attenuators ((10) and (11)) in 1 dB steps.

FIGURE 1

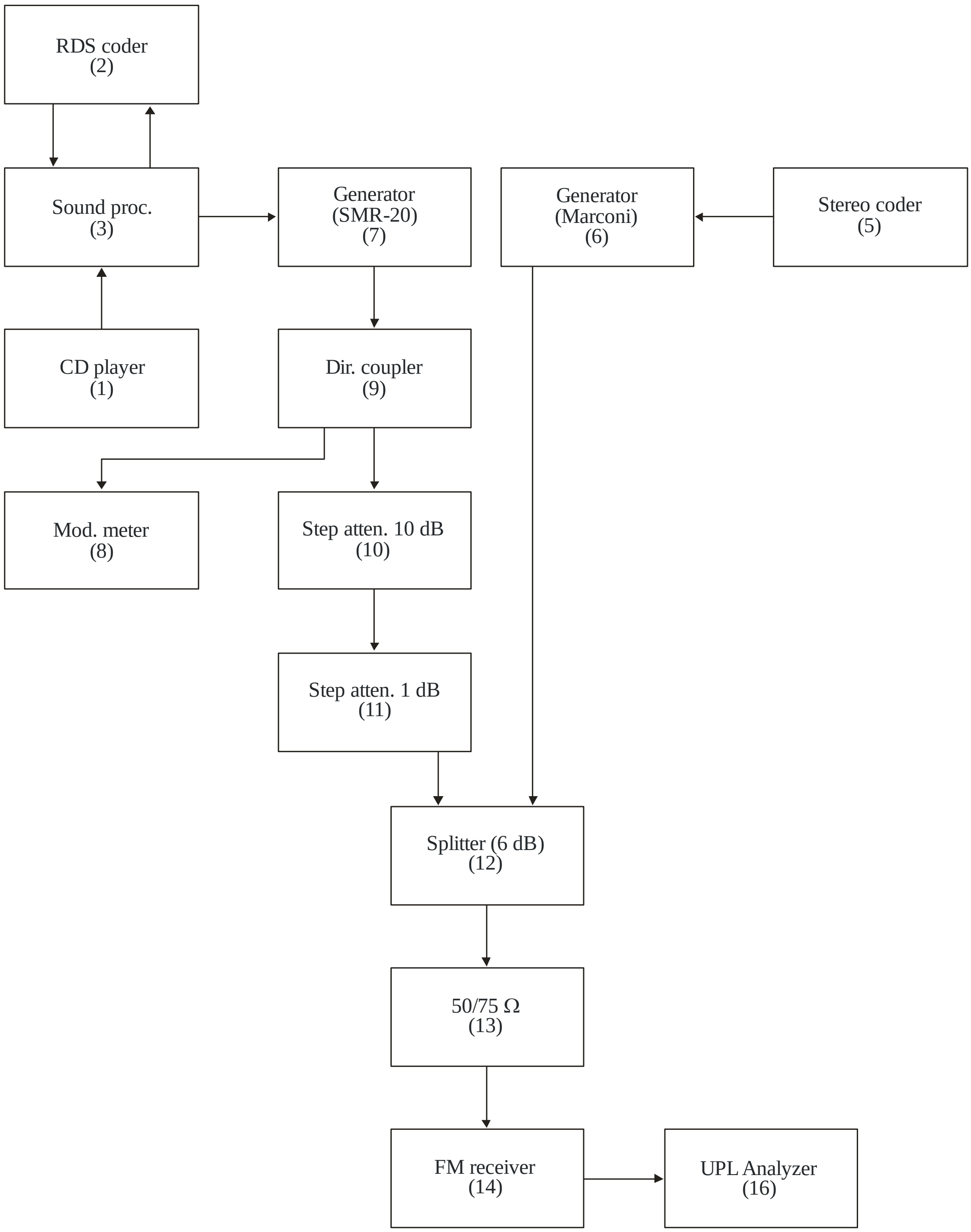
Weighted (coloured) noise defined by Recommendation ITU-R BS.559-2



The S/N ratio was observed at the audio output of the FM receiver (based on the specifications of Recommendation ITU-R BS.468-4 – Measurement of audio-frequency noise voltage level in sound broadcasting). The reference level of the signal was the level of the demodulated 500 Hz wave measured at 75 kHz peak deviation while the unwanted signal (interferer transmitter) was switched off. The level of the noise was measured using quasi-peak detector at the audio output of the FM receiver while the 500 Hz modulation of the wanted transmitter was switched off. Then the S/N ratio was calculated.

FIGURE 2

Measurement setup (the numbers in bracket refer to the list of equipment in Table 5)



Report BS.2213-01

The RF level of the wanted transmitter at the input of the FM receiver was set to 49 dB(μV). It was the lowest RF level where the *S*/*N* ratio at the output of the receiver reached the required 56 dB while the interferer transmitter was switched off.

1.1 Measurement of RF protection curves

The measurement procedure of the RF protection curves was as follows. The multiplex power of the interferer signal was set at the sound processor and was checked by the modulation and MPX power meter (8). The interferer transmitter was tuned to the required frequency distance from the wanted transmitter. The audio *S*/*N* ratio was observed at the output of the receiver and the step attenuators were adjusted until the *S*/*N* ratio was set to 50 dB. The actual value of the RF protection ratio was the difference in dB-s between the RF signal levels of the two transmitters. The measurement was repeated with different frequency distances and with different multiplex powers.

1.2 Measurement of the reduction of the peak deviation that can compensate the effect of the higher MPX power

The measurement setup was almost the same as in Fig. 1, except that a different type of audio analyser (UPA) was used (for availability reasons). This measurement was completed only for 100 kHz frequency difference between the two transmitters. The RF level of the interferer signal was 33 dB below the wanted signal.

First the peak deviation of the interferer signal was set to 75 kHz in the test mode of the audio processor. The processor keeps this peak value in normal operation mode regardless of the parameters of the input sound signal and the programmed multiplex power. After setting a certain value of the MPX power the signal-to-noise ratio was observed at the audio output of the FM receiver. Then the level of the modulating signal at the output of the audio processor was adjusted until the observed *S*/*N* ratio became 50 dB. This adjustment caused of course a change in the peak deviation of the FM signal as well. The processor was then switched to test mode and the peak deviation was checked by the modulation meter (8).

2 Measurement results

2.1 Measurement of RF protection curves

The results of the RF protection curve measurements are summarized in Table 1 and Fig. 3.

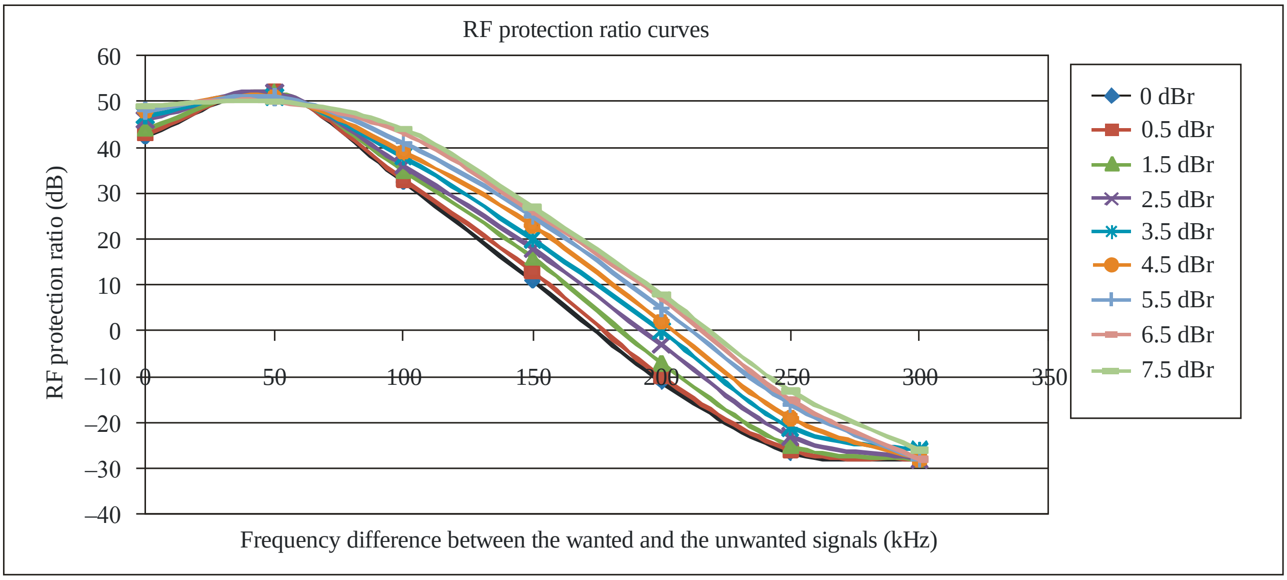
TABLE 1

RF protection ratios for different multiplex power and frequency difference values

Δ*f* (kHz)	**Multiplex power (dBr)**								
	0	**0.5**	**1.5**	**2.5**	**3.5**	**4.5**	**5.5**	**6.5**	**7.5**
0	42.5	43	44	46	47	48	48	49	49
50	52	52	52	52	51	51	51	50	50
100	32.5	33	35	36	38	39	41	43	44
150	11	13	16	18	20	23	25	26	27
200	−11	−10	−7	−3	0	2	5	7	8
250	−26.5	−26	−25	−23	−21	−19	−16	−15	−13
300	−28	−28	−28	−28	−26	−28	−28	−28	−26

FIGURE 3

RF protection ratios for different multiplex power and frequency difference values



Report BS.2213-02

It can be seen that – in spite of certain expectations – the measured 0 dBr protection curve is not identical with the S1 curve shown in Recommendation ITU-R BS.412-9. The most likely reasons of the difference is that the S1 curve of Recommendation ITU-R BS.412-9:

a) represents an average of the measurements made on a great number of different consumer radio sets while for the present measurements only two different, medium quality radio sets were used; and

b) it was measured with an interferer signal with less than 0 dBr MPX power.

However, the curves clearly indicate the tendency that the higher the MPX power the more protection is needed against it.

From the above results we can also derive curves that show how much reduction of the RF power level of an interferer signal can compensate its increased interfering effect if its MPX power exceeds 0 dBr, keeping the baseband audio *S*/*N* ratio at the required 50 dB. The three curves on Fig. 4 refer to the 0 kHz, 100 kHz and 200 kHz difference between the carrier frequencies of the wanted and the unwanted signal.

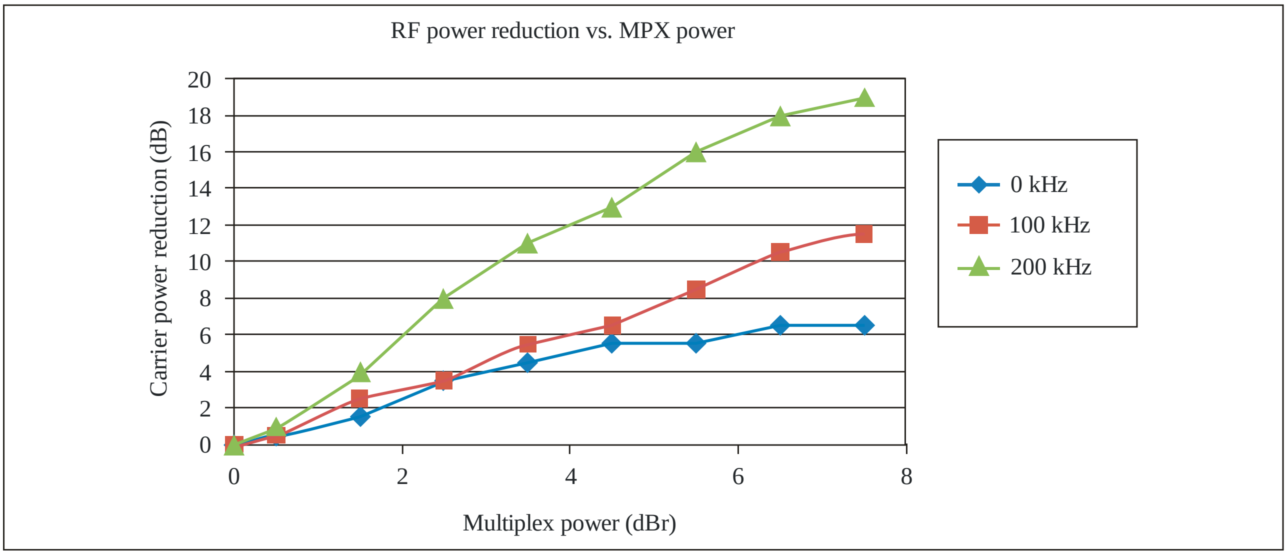
TABLE 2

RF power reduction that can compensate the effect of the higher MPX power of the unwanted transmitter

Δ*f* (kHz)	**MPX power (dBr)**							
	0.5	**1.5**	**2.5**	**3.5**	**4.5**	**5.5**	**6.5**	**7.5**
0	0.5	1.5	3.5	4.5	5.5	5.5	6.5	6.5
100	0.5	2.5	3.5	5.5	6.5	8.5	10.5	11.5
200	1	4	8	11	13	16	18	19

FIGURE 4

RF power reduction that can compensate the effect of the higher MPX power of the unwanted transmitter



Report BS.2213-03

2.2 Measurement of the reduction of the peak deviation that can compensate the effect of the higher MPX power of the unwanted transmitter

The higher interference potential of a signal exceeding 0 dBr multiplex power can also be compensated by the proportional reduction of the FM deviation. Table 3 and Fig. 5 show the applicable maximum deviations as a function of the original MPX power (before decreasing the peak deviation). The two curves refer to the "on" and "off" state of the RDS signal.

The results of the measurements of the maximum applicable peak deviation are summarized in Table 3 and Fig. 5.

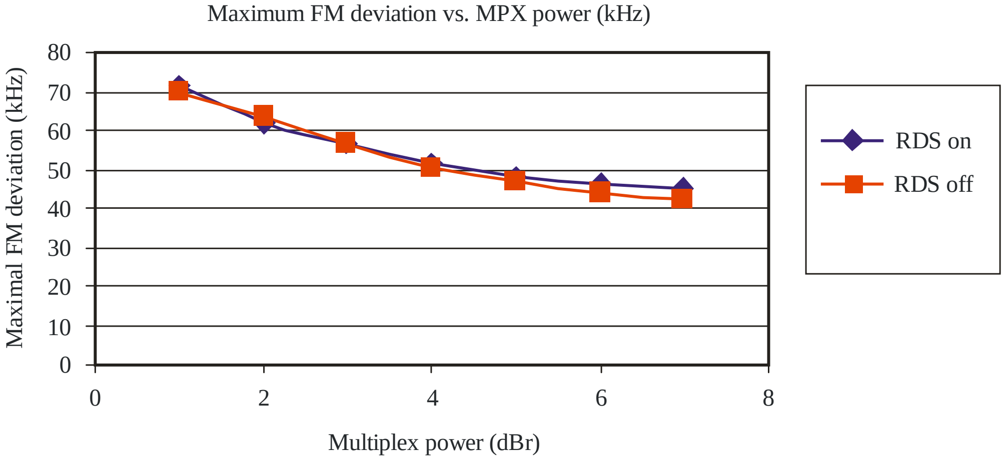
TABLE 3

Peak deviations for different MPX power values

Maximum applicable FM deviation (kHz)		
Multiplex power (dBr)	**RDS on**	**RDS off**
1	71.5	69.7
2	61.5	63.3
3	56.8	56.8
4	51.6	50.4
5	48	46.9
6	46.3	43.9
7	45.1	42.2

FIGURE 5

Applicable peak deviations that can compensate the effect of the higher MPX power of the unwanted transmitter



Report BS.2213-04

The measurements were carried out both in the "on" and "off" state of the RDS signal. It was found that this causes only a very slight difference.

The above results can be expressed in the reduction of the peak deviation – relative to the nominal 75 kHz – as well.

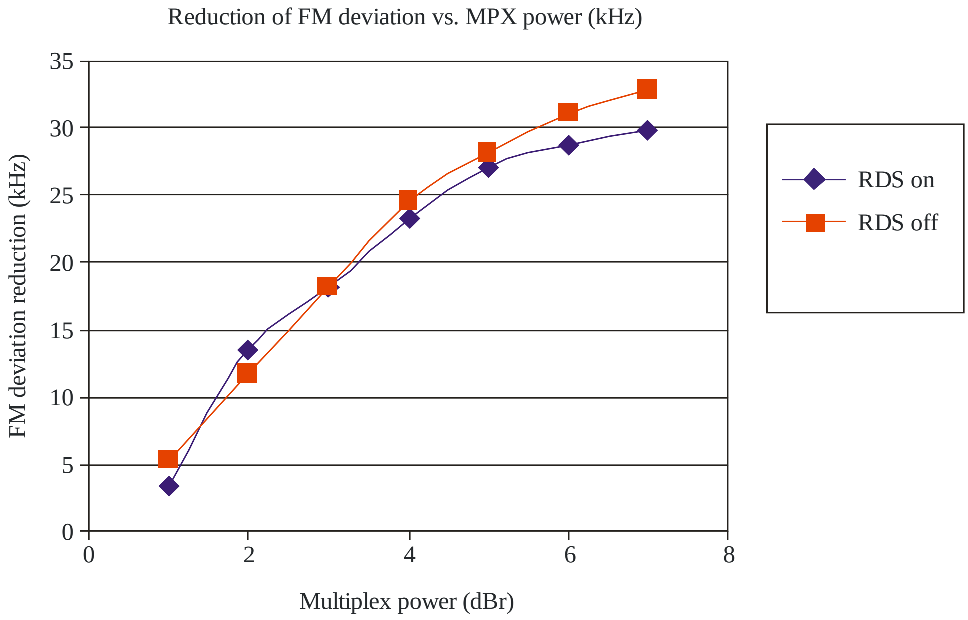
TABLE 4

Reduction of the peak deviations that can compensate the effect of the higher MPX power of the unwanted transmitter (relative to 75 kHz)

Reduction of the peak FM deviation (kHz)		
Multiplex power (dBr)	**RDS on**	**RDS off**
1	3.5	5.3
2	13.5	11.7
3	18.2	18.2
4	23.4	24.6
5	27	28.1
6	28.7	31.1
7	29.9	32.8

FIGURE 6

Reduction of the peak deviations that can compensate the effect of the higher MPX power of the unwanted transmitter (relative to 75 kHz)



Report BS.2213-05

Conclusion

The laboratory measurements confirmed that FM broadcast signals with higher multiplex power can cause higher degradation in the quality of the interfered FM broadcast signal. This degradation can be compensated by decreasing either the RF level or the peak deviation of the interferer signal. The above described measurements provide quantitative figures for the amount of these reductions.

Attachment
to Annex 1

List of instruments

TABLE 5

List of instruments

No.	Equipment/type	Serial or Reg. No.
1	CD player (in an industrial PC)	L0064576
2	RDS coder	
3	Audio processor Orban 5300 FM	53000135
4	Function generator Tektronix AFG 3252	
5	Stereo coder R&S MSC-2	890340/017
6	Signal generator Marconi 2031 (wanted transm.)	119848/053
7	Signal generator R&S SMR-20 (unwanted transm.)	11040002.20
8	Modulation (and MPX) meter Audemat Aztek FM-MC4	L0062277
9	High power directional coupler C5091 (Werlaton)	10279
10	Step attenuator 8496A 10 dB	3308A14564
11	Step attenuator 8494A 11 dB	3308A32544
12	Resistive power splitter Aeroplex1870A	8134
13	50/75 Ohm match RAM	100131
14	Radio set Sony S-master CMT-CPZ1	122234
15	Radio set Denon DN-U100	
16	UPL Audio Analyzer R&S DC…110 kHz	100091
17	UPA Audio Analyzer R&S 10 Hz 100 kHz	

Signal and instrument settings

Signal level of the wanted transmitter at the receiver input: 49 dB(μV)

Pilot signal: 9%

FM deviation caused by the RDS signal: 3 kHz

UPL audio analyzer

Low-pass filter: on (15 kHz)

Detector: quasy-peak

Weighting filter: on (weighting characteristics according to Recommendation ITU-R BS.468-4)

UPA audio analyzer

Low-pass filter: on (22 kHz)

Detector: quasy-peak

Weighting filter: on (weighting characteristics according to Recommendation ITU-R BS.468-4)

Audemat Aztec FM-MC4 modulation (and MPX) analyzer

Mode of operation: MPX Analysis Mode (In this mode the averaging time is automatically set to 200 ms and the MPX processing mode to “linear”).

Orban 5300 FM audio processor

Applied factory preset: “Extreme”.

Annex 3

Results of measurements performed in France on the protection levels against interferers with exceeded MPX power in the FM sound broadcasting

1 The bench test

The French Administration has carried out a bench test using 26 receivers to study the impact of the increase of multiplex power on protection ratios. The results of these measurements carried out in France to quantify the impact of multiplex power over protection ratios (PR) when the limit of 0 dBr is exceeded are included in this Annex, which provides quantitative figures of required protection ratios, according to the values of multiplex power (MPX) used by some broadcasting FM stations.

2 Measurement results

2.1 Statistical figure for the measurement analysis

The ninth decile statistical figure has been chosen in order to show a representative analysis of the measurement results. It was more representative than the median or the average to describe the statistical behaviour of receivers during the experimentation.

Furthermore, the statistical ninth decile figures represent protection ratios of a theoretical receiver which is less efficient than the 90% of the sample receivers tested.

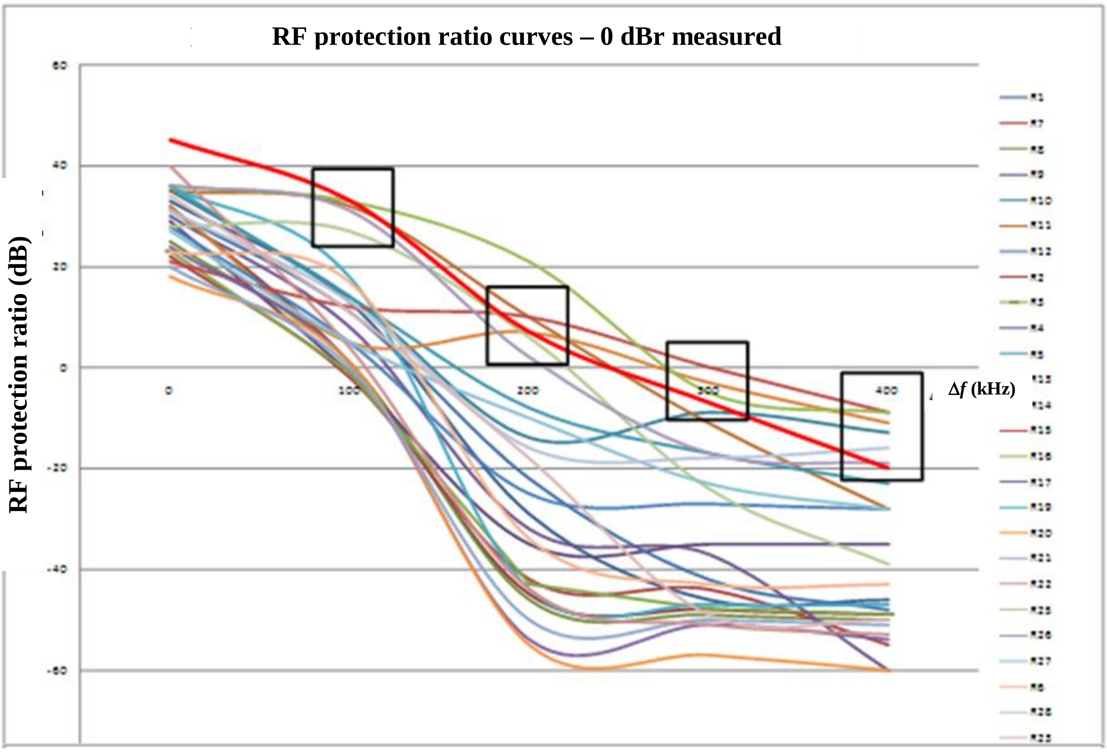
The PR values taken as reference are given in Recommendation ITU-R BS.412-9 (§ 2.3.2, Table 3: Stereophonic mode and steady interference).

2.2 Results

As shown in Fig. 7 below, some receivers (more than 10%) are protection ratio values close to those found in Recommendation ITU-R BS.412-9, where no multiplex power applies to the interfered signal at 100, 200, 300 and 400 kHz of the carrier frequency spacing.

FIGURE 7

RF protection ratios for 0 dBr multiplex power and carrier frequency spacing difference values for the 26 receivers tested



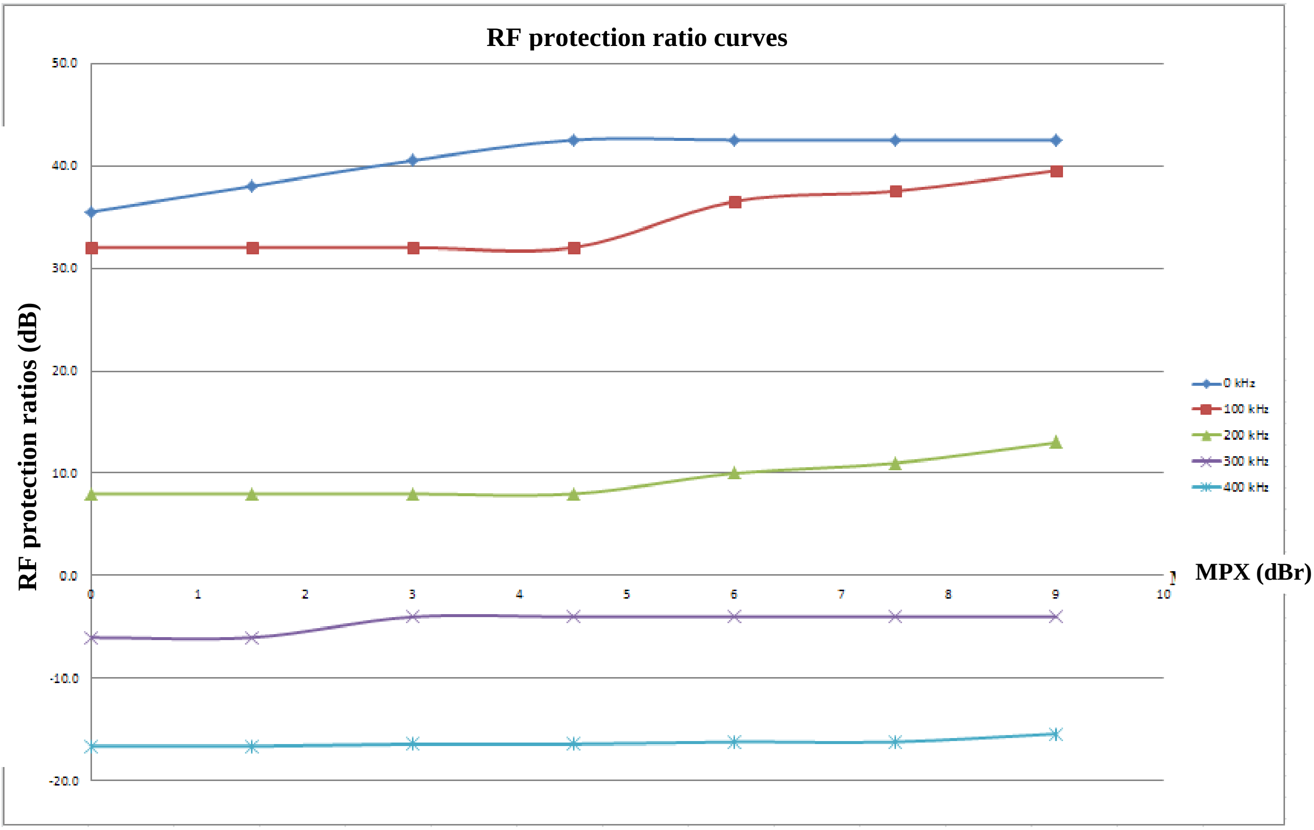
The bold red curve represents the PR in Recommendation ITU-R BS.412-9.

Figure 7 shows that the protection ratios given in Recommendation ITU-R BS.412-9 are still relevant even if a lot of receivers have better protection ratios.

Figure 8 below shows several protection ratios measured for different values of multiplex power. As indicated in § 2.1, the following curves represent a theoretical receiver which ensures that 90% of the sample receivers tested will work properly.

FIGURE 8

RF protection ratio curves for several multiplex power values using frequency carrier spacing values (by steps of 100 kHz)



As shown in Fig. 8, it is important to note that at 300 kHz and 400 kHz of the carrier frequency spacing, the differences between the PR measured at 0 dBr multiplex power and at 9 dBr are very low.

Thus, only carrier frequency spacing of 0 kHz, 100 kHz and 200 kHz are taken into account for the final results.

Table 6 shows the value of the PR measured for different values of multiplex power applied to the interfered signal at different carrier frequency spacings: 0, 100 and 200 kHz.

TABLE 6

RF protection ratios for different multiplex power and frequency difference values

MPX	**< 5 dBr**	**6 dBr**	**7.5 dBr**	**9 dBr**	**Rec. ITU-R 412-9**
Δ*f*	RF protection ration measured (dB)				
0 kHz	42.5	42.5	42.5	42.5	**45**
100 kHz	32.0	36.5	37.5	39.5	**33**
200 kHz	8.0	10.0	11.0	13.0	**7**

According to the measurements made on receivers, for a multiplex power less than 5 dBr, the PR obtained does not exceed: 42.5 dB at 0 kHz of the carrier frequency spacing, 32 dB at 100 kHz and 8 dB at 200 kHz.

But for a multiplex power greater than 5 dBr, the PR measured keeps growing as the multiplex power increases.

Compared to the PR values mentioned in Recommendation ITU-R BS.412-9, the decrease of RF power that can counterbalance the effect of a higher multiplex power of the unwanted transmitter is shown in Table 7.

TABLE 7

Decrease of RF power that can compensate the effect of the higher MPX power of the unwanted transmitter

MPX	**< 5 dBr**	**6 dBr**	**7.5 dBr**	**9 dBr**	**Rec. ITU-R 412-9**
Δ*f*	RF protection ration measured (dB)				
0 kHz	+2.5	+2.5	+2.5	+2.5	45
100 kHz	+1.0	–3.5	–4.5	–6.5	33
200 kHz	–1.0	–3.0	–4.0	–6.0	7

The negative figures represent the necessary decrease of RF power that can compensate the effect of multiplex power to ensure the protection of the wanted signal.

The positive figures show that PR values of Recommendation ITU-R BS.412-9 can be decreased by each value according to the case considered. For example, for a carrier frequency spacing of 0 kHz, the trial has shown the possibility to use 42.5 dB of protection ratio (between a wanted signal which did not use the multiplex power and an unwanted signal which did use the multiplex power) instead of 45 dB as indicated in Recommendation ITU-R BS.412-9.

3 Conclusion

The test bench results performed in France in 2012 have confirmed that FM broadcast signals with higher multiplex power are degrading protection ratios and can worsen the quality of the interfered FM broadcast signal. However, by widening the amount of receivers taken into account in the measurements, the figures of the protection ratio obtained in Annex 1 are slightly different.

The main conclusion is that PRs in Recommendation ITU-R BS.412-9 are still relevant for multiplex power that do not exceed 5 dBr for any frequency spacing between the wanted and the unwanted signals. For signals that exceed 5 dBr, it is necessary to reduce the transmitter RF power according to the values shown in Table 7.

Furthermore, the measurements show better performance for receivers put into market after 2010 (35% of the tested receivers). This could be due to a majority of 2010's FM receivers using digital components. This trend could enable the use of a lower protection ratio in the long term and a possible revision of Recommendation ITU-R BS.412 if a new measurements campaign assessed it.

Attachment
to Annex 3

Measurement protocol

1 Introduction

The bench test is based on Recommendation ITU-R BS.641 used to set protection ratios according to the multiplex power variations and the spacing of carrier frequencies. The bench test involved a representative sample of 26 receivers.

This document explains the methodology and the means used to carry out the bench test.

2 Bench test design

This first part explains how to get some technical elements required for the bench test:

1) the coloured noise signal;

2) the equipment that enables the multiplex power variations.

After that, the bench test is set up according to the diagram of measuring given in Recommendation ITU-R BS.641.

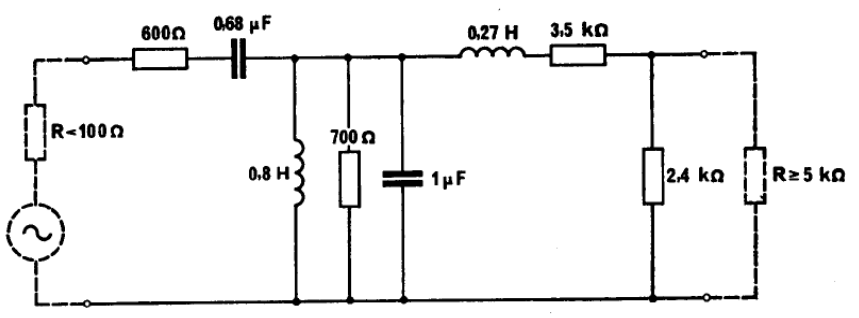
The second part describes the bench test configuration, which is adapted in order to match with the modern metrology methods.

2.1 Filtered white noise according to Recommendation ITU-R BS.559-2

The multiplex power variations depend on the noise modulating signal given in Recommendation ITU-R BS.559-2. In order to obtain the coloured noise signal spectrum as defined in the recommendation "*…the spectral amplitude distribution of which is fairly close to that of modern dance music…*", it is necessary to use a filtered white noise signal proceeding from an AF generator signal according to the diagrams below (Figs 9 and 10).

FIGURE 9

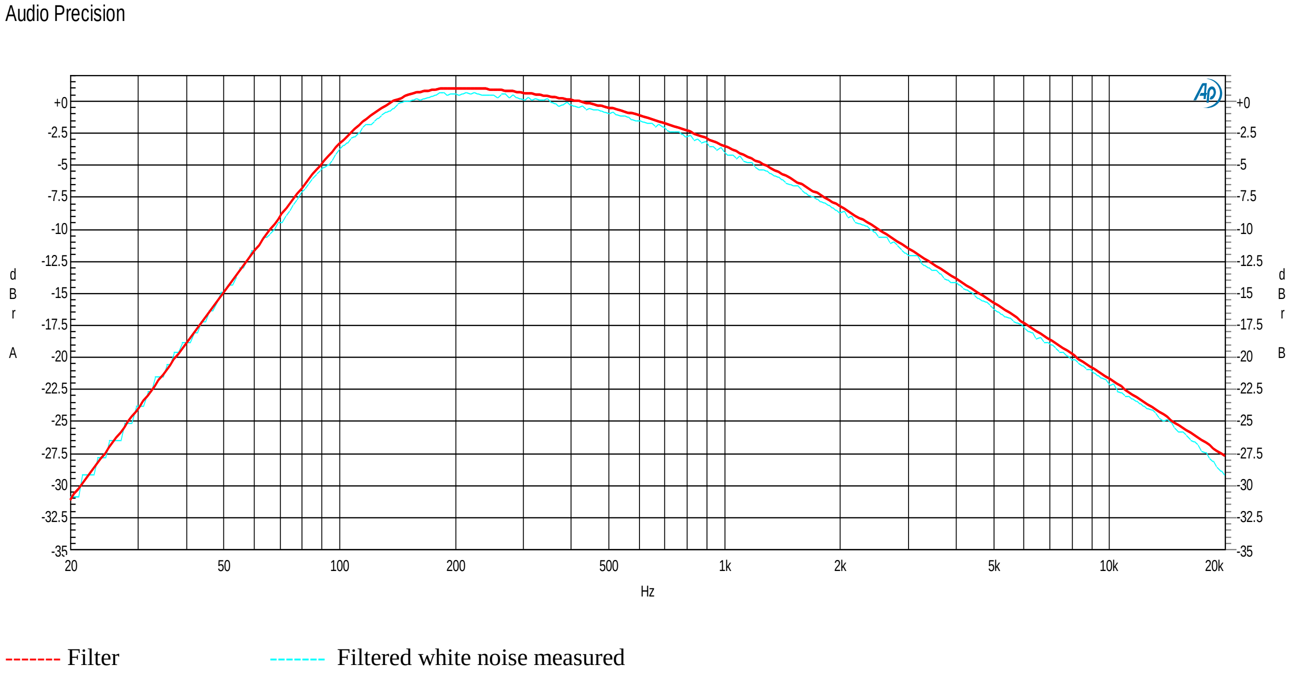
Recommendation ITU-R BS.559-2 Filter diagram



Frequency/Amplitude AF measured

FIGURE 10

Weighted (coloured) noise defined by Recommendation ITU-R BS.559-2



The coloured noise obtained was recorded in a specific VX222HR audio card from DIGIGRAM.

This file was saved in a PCM (48 kHz – 16 bit) format and can be read by any professional audio card. It just requires a digital or analog audio output.

The device SYSTEM TWO from AUDIO PRECISION was selected to provide a white noise signal. (Set up: Noise – White Pseudo).

2.2 Multiplex power (MPX) variations on interfering transmitter

A Principle

The MPX variation is achieved by using a sound processing system often used in the FM sound broadcasting service.

The device selected is an OMNI ONE FM. It consists of a stereo coder, which embeds processing and optimization sound features, used in FM sound broadcasting.

The OMNIA ONE FM can achieve the following functionalities:

1 Filtering at 15 kHz

2 Pre-emphasis of 50 µs

3 Limitation and optimization of level composite output in order to comply with the maximal level fixed at 8.72$V_{c/c.}$ This condition ensures that the maximum frequency deviation of ±75 kHz would not be exceeded.

The audio processing is based on AF signals dynamic compression techniques. The processing is achieved by a set of cells working in a specific frequency band. Each audio frequency band, cut out beforehand, is handled by a set of functions: dynamic compressor and limiter.

Then, the audio spectrum is reconstructed in order to be injected in the stereo coder. This last function includes a clipper, which eliminates the over-shoot. This handling ensures to keep the MPX in a tension range (8.72 $V_{c/c}$) and the maximum frequency deviation less than 75 kHz.

Therefore, the AF signal dynamic range could be reduced according to the device settings. This reduction increases the MPX of the signal.

The RF wanted signal is generated by a FM THOMSON-LGT RAMSES II transmitter. The stereo coder integrated is put into operation.

B Interfering signal line

The bench test interfering signal line consists of the following devices:

– A PUC 2 YELLOWTEC card, which generates a coloured noise as a AES/UER signal

– A set up Mono OMNIA ONE FM

– A FM RVR PTX 100LCD transmitter.

Concerning the measurement in static mode, the following settings are used:

– The control of the maximum deviation is achieved by the FMA of Rohde & Schwarz;

– The spectrum analyser E4402B of HP shows the J0 carrier cancellation;

– The modulating signal MPX is measured with the ADFM02 analyser.

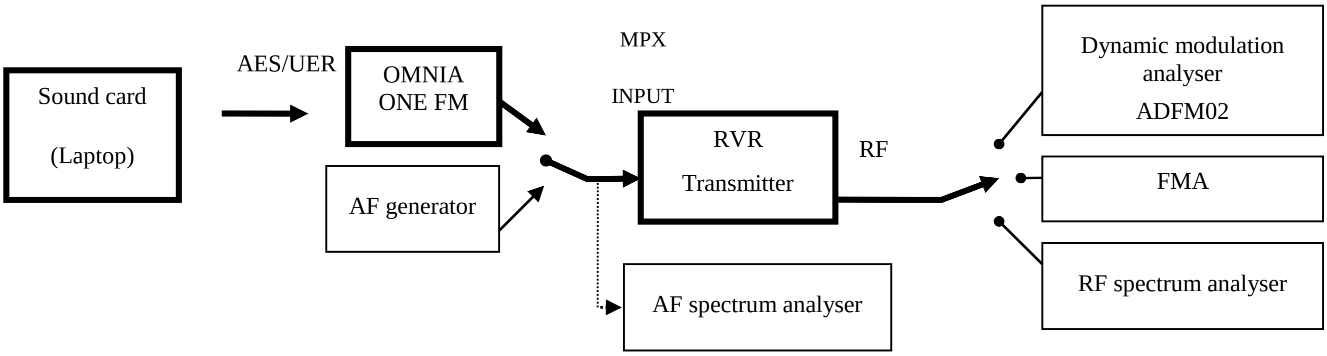
Concerning the measurement in dynamic, following settings are used:

– MPX variations and frequency deviations are analysed with the ADFM02.

This part of the bench test and its measurements modes are shown on Fig. 11.

FIGURE 11

Diagram of the interfering signal line



2.3 Bench test description

The bench test is built according to the diagram of measuring apparatus reproduced below:

FIGURE 12

Diagram of the measuring apparatus

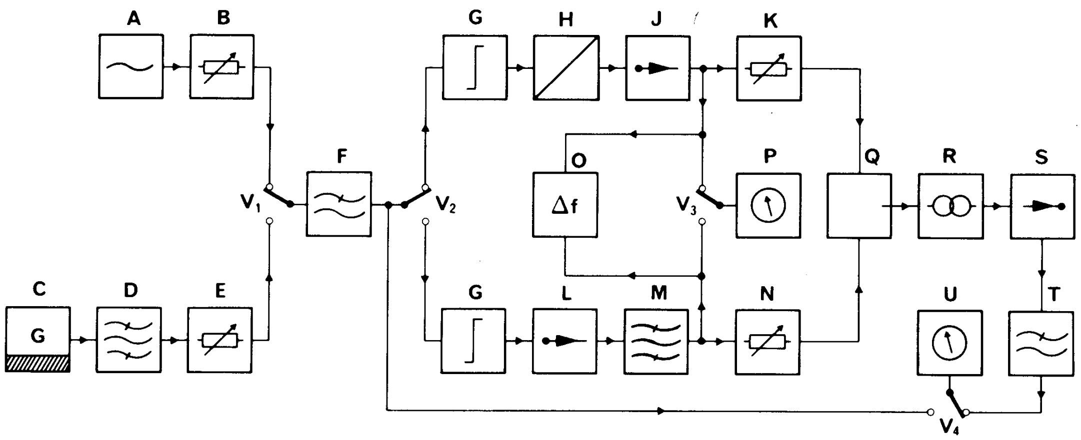


FIGURE 1 – *Diagram of the measuring apparatus*

A: 500 Hz AF generator (for transmitter line-up procedure)
B: calibrated AF attenuator
C: noise generator
D: noise shaping filter complying with Recommendation 559
E: calibrated AF attenuator
F: 15 kHz low-pass filter
G: pre-emphasis network
H: stereo coder
J: signal generator (wanted signal)
K: calibrated RF attenuator
L: signal generator (unwanted signal)
M: RF band-pass filter (tuneable)
N: calibrated RF attenuator
O: frequency-meter for measuring the frequency difference between signal generators J and L
P: frequency-deviation meter
Q: coupling device
R: matching network
S: receiver under test
T: 15 kHz low-pass filter
U: psophometer (switchable weighting network)
V_1: selector switch for the modulation
V_2: selector switch for modulating one or other of the signal generators
V_3: selector switch for the frequency-deviation meter (J and L generators)
V_4: selector switch for measuring the AF signal levels

D01-sc

A modern version of this bench test is presented below. It contains, in a macroscopic model, all the elements given in the reference diagram (Recommendation ITU-R BS.641). A correspondence between the diagram given in the recommendation and the new version is shown below (Letters "A" to "U").

The tested equipment (the receiver) is put in a Faraday cage that shields the receiver from any radio interferences around.

FIGURE 13

Proposed bench test diagram

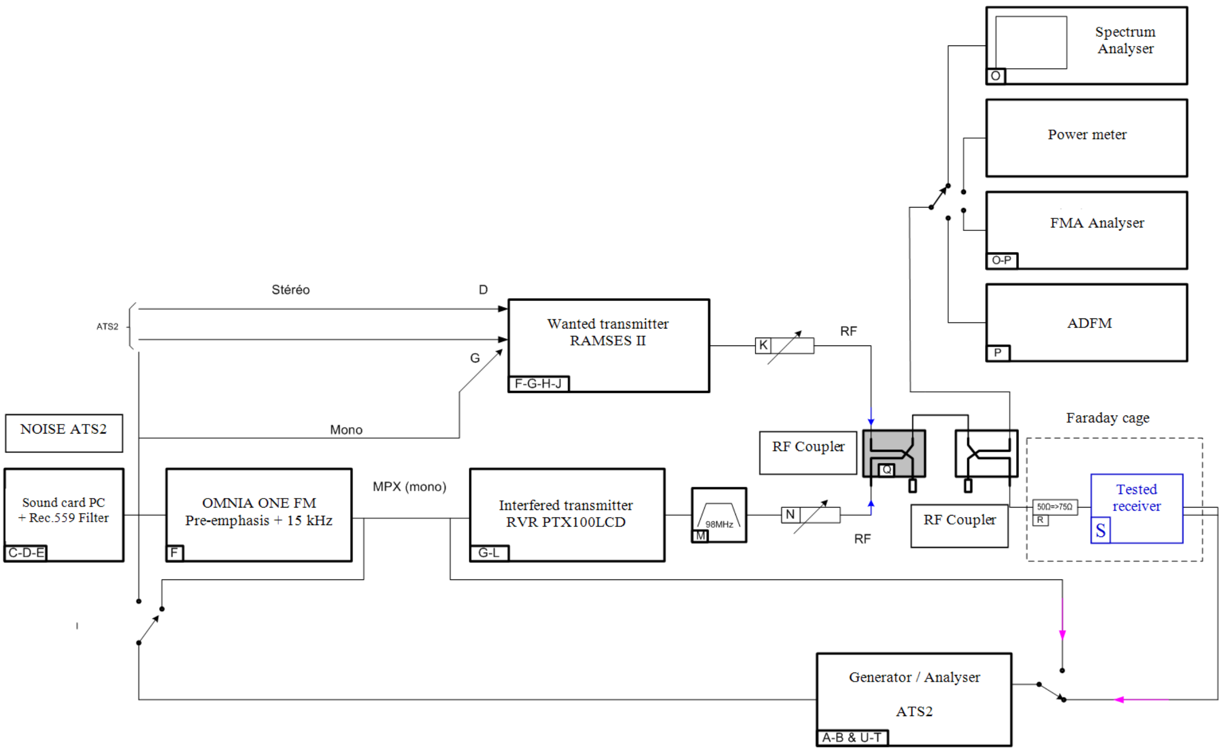
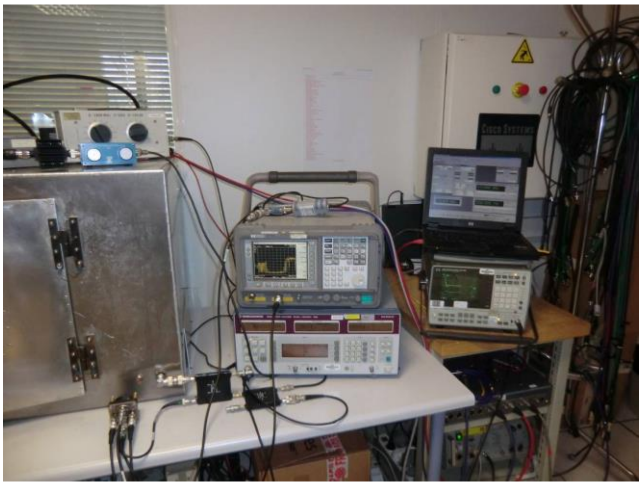


FIGURE 14

Wanted and interfering transmitters, clipper/Faraday Cage (at left) – measuring devices (At right)



2.4 Measuring process

The measurement process used for the bench test follows exactly the methodology described in Recommendation ITU-R BS.641.

The protection ratio is obtained when the following calculation is achieved:

$$PR = (P_U - Att_U) - (P_B - Att_B)$$

where:

P_U is the RF wanted transmitter power

Att_U is the RF wanted transmitter attenuation that enables to fix the S/N at 56 dB, when the interfering transmitter is not activated, as recommended

P_B is the RF interfering transmitter power

Att_B is the RF interfering transmitter attenuation that enables to fix the S/N at 50 dB, when the interfering transmitter is activated.

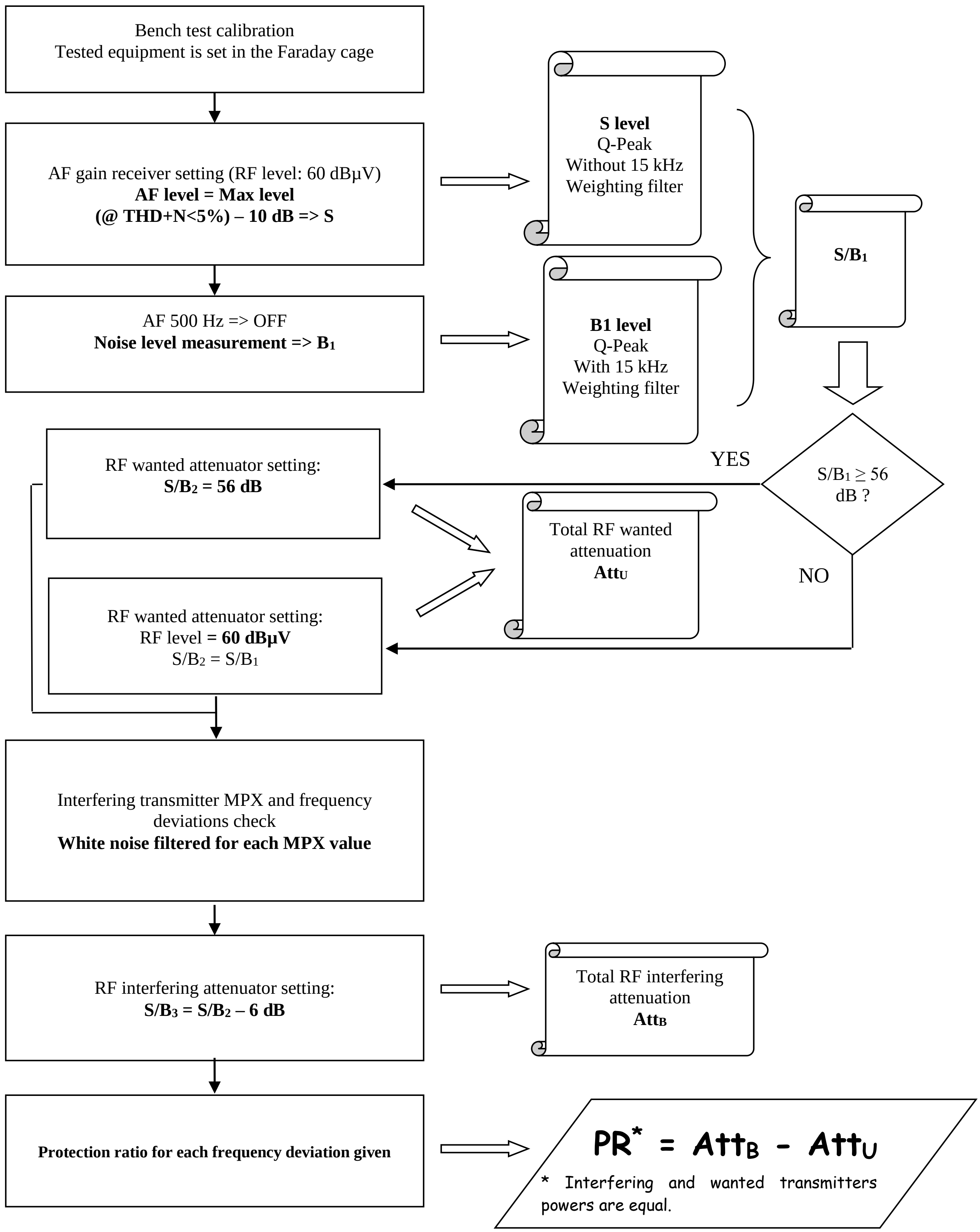
In order to ease the protection ratio calculation, the power level of wanted and interfering signal is the same.

So the protection ratio is: $PR = Att_B - Att_U$.

This measurement process is also described in Fig. 15.

FIGURE 15

Diagram of the measurement process



Annex 4

Impact of multiplex power levels higher than 0 dBr on the RF protection ratio of sound broadcasting emissions in VHF band II

1 Introduction

The RF protection ratios given in Recommendation ITU-R BS.412 are valid for MPX power not exceeding 0 dBr and a maximum frequency deviation of ±75 kHz. Annexes 2 and 3 of this Report investigate the impact on a wanted signal from an interfering unwanted FM modulated signal whose MPX power is higher than 0 dBr, i.e. up to 7.5 dBr or 9 dBr respectively:

- Annex 2: Results of measurements performed in Hungary on the protection levels against interferers with exceeded MPX power in the FM sound broadcasting
- Annex 3: Results of measurements performed in France on the protection levels against interferers with exceeded MPX power in the FM sound broadcasting

For 0 kHz, 100 kHz and 200 kHz frequency difference between wanted and unwanted signal, Annex 2 shows an increase of the measured RF protection ratios when increasing MPX power beyond the values given in Recommendation ITU-R BS.412. (In this Annex frequency differences of 50 kHz, 150 kHz and 250 kHz are assumed to be irrelevant in practice, since only 100 kHz steps are used in Band II.)

Annex 3 also shows an increase of the protection ratios with increasing MPX power but far less than Annex 2.

Although it is mentioned that the measurement was executed according to Recommendation ITU-R BS.641, it seems to be conspicuous that the measured protection ratios for 0 dBr are remarkably low. For example, all measured protection ratios for 0 kHz frequency difference are between 19 dB and 40 dB though experience in Germany is that nearly all receivers show values between about 43 dB and 47 dB with a very low deviation between different receivers. The same applies for the values for 100 kHz frequency difference: the measured values are in a very wide range between –5 dB and 33 dB. Experience in Germany is that the majority of receivers show values around 30 dB with a deviation between different receivers of about 3 or 4 dB, but not much more (when measured in stereo).

For comparison, Fig. 16 shows the data from Annex 2 and measurement results in § 3 of this Annex.

Figure 17 shows the data from Annex 2 compared with the results from Annex 3 and with measurement results in § 3 of this Annex.

FIGURE 16

Measurement results from Annex 2 compared with measurement results in Germany shown in Fig. 21

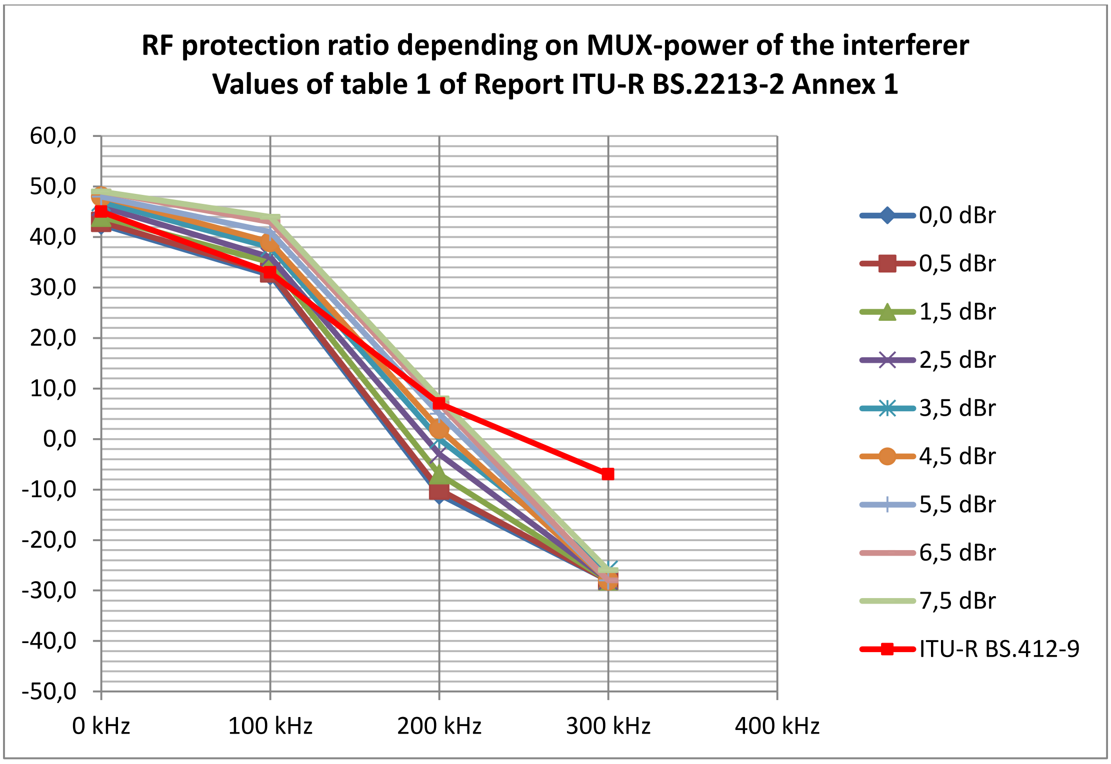
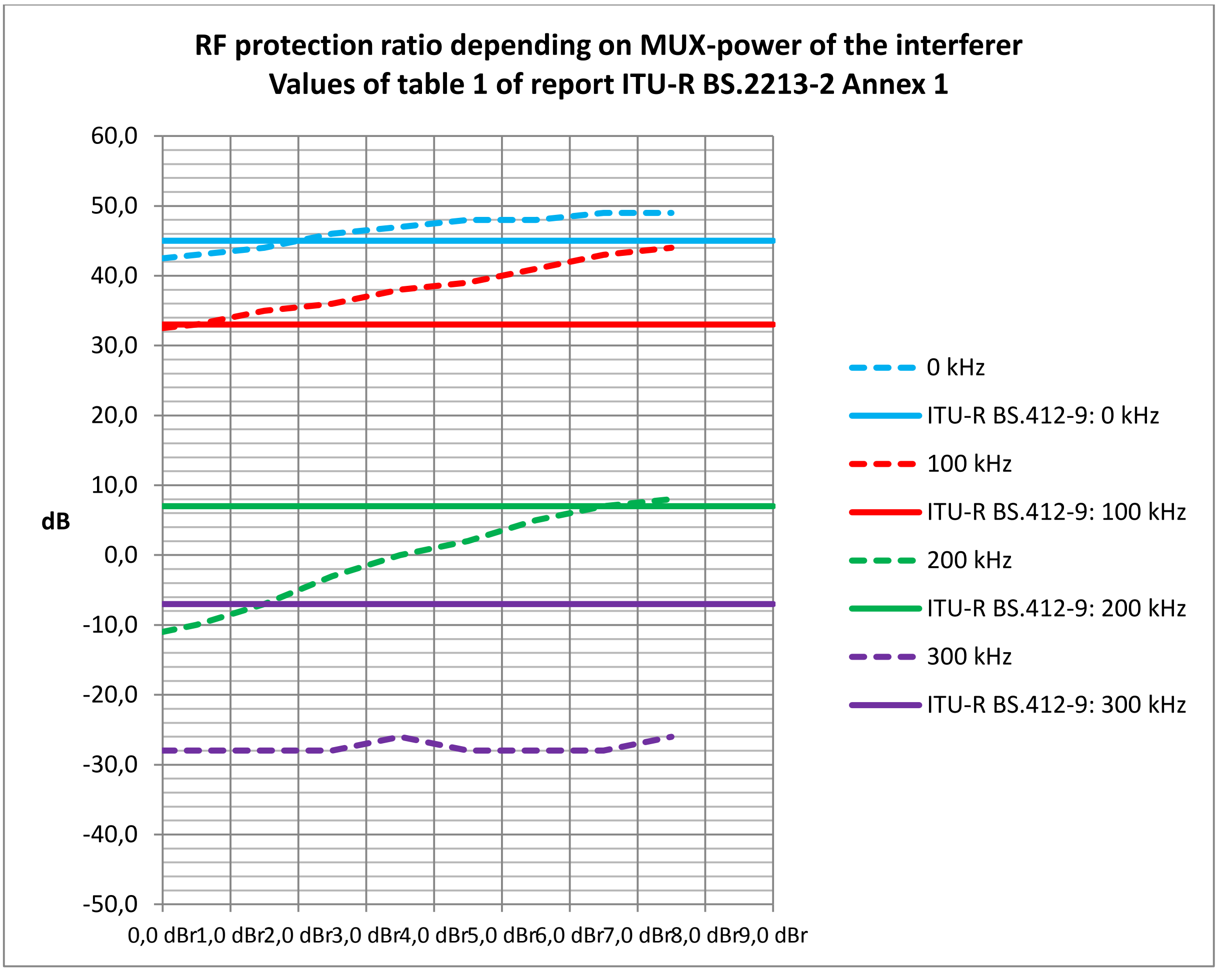


FIGURE 17

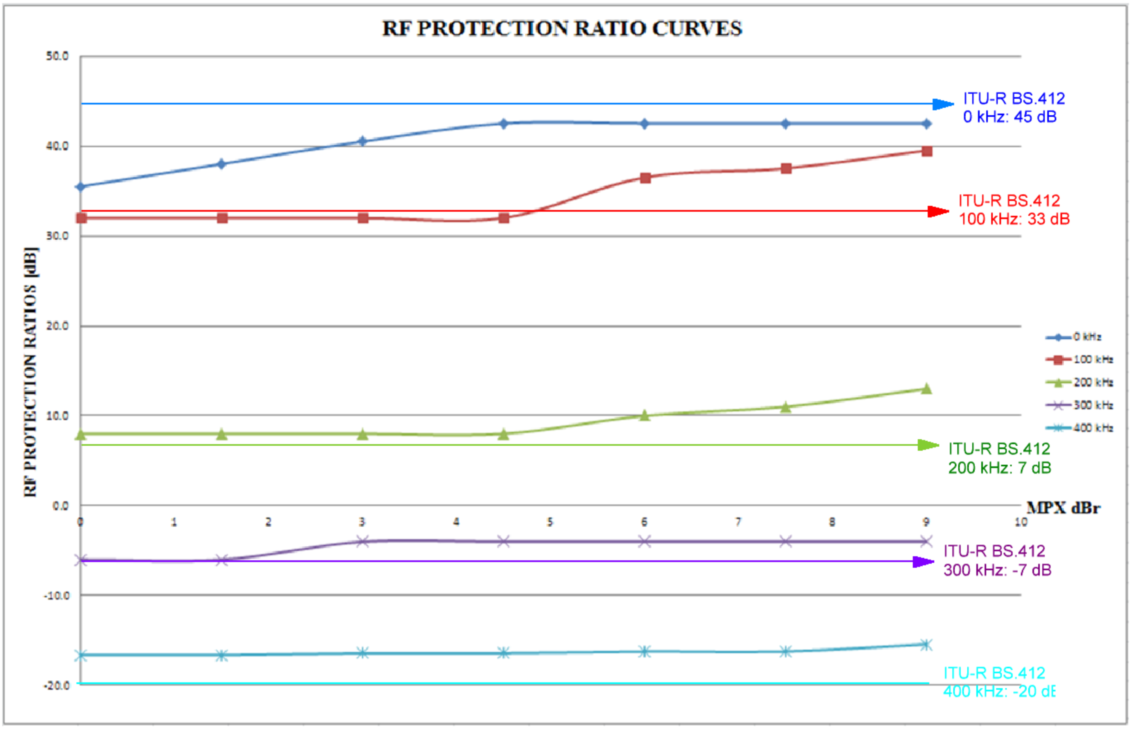
Data from Annex 2 compared with measurement results of Annex 3 and measurement results shown in Fig. 22



In effect, Annex 3 weakens the results of Annex 2 by far and led us to make some own check measurements to find out which values are more reliables.

FIGURE 18

Copy of the results of Fig. 7 of Report ITU-R BS.2213-2 Annex 2 with inserted values given from Recommendation ITU-R BS.412 for comparison with Fig. 2 and Fig. 6



It is noticeable that the measured values for 0 kHz and 100 kHz seem to be too low (see text), while the measured values at 200 kHz, 300 kHz and 400 kHz seem to be too high and are generally above the values from Recommendation ITU-R BS.412.

2 Measurement setup and measurement methods

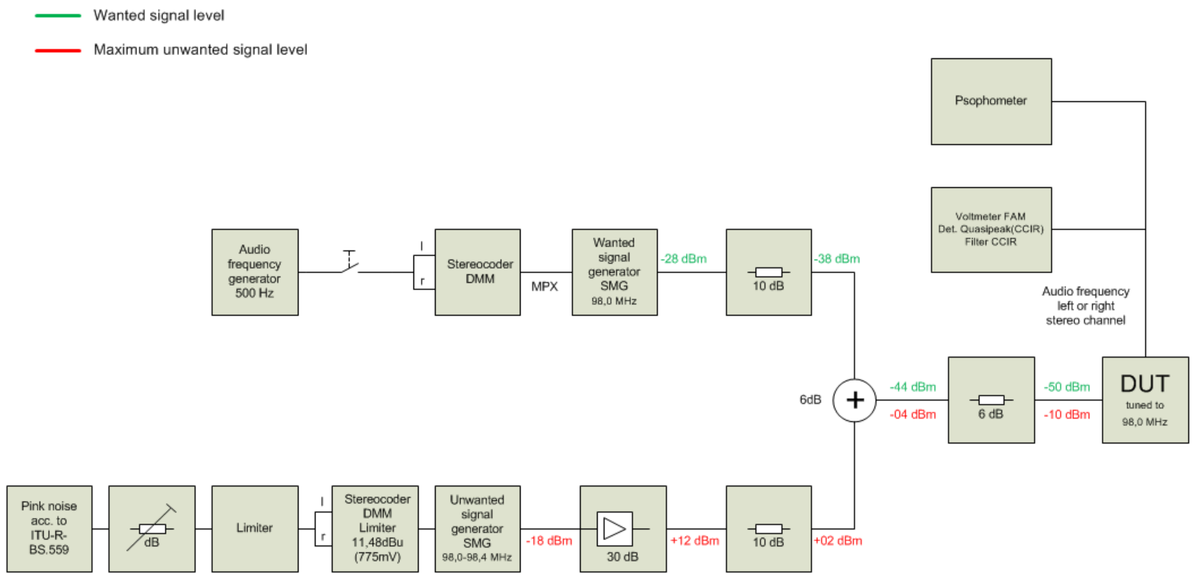
The measurements were carried out based on Recommendation ITU-R BS.641 except for the unwanted signal with multiplex power more than 0 dBr: the transmitter of the unwanted signal was modulated from a CD player with pink noise according to Recommendation ITU-R BS.559. This AF signal was clipped by a limiter (2 anti-parallel diodes). The limiting rate was adjusted by an adjustable attenuator before the clipper. With this method it was possible to generate signals with a multiplex power from 0 dBr to 9 dBr in steps of 1 dB with a maximum deviation not exceeding ±75 kHz, clipped by a depth modelling mode stereo coder (see Fig. 19). Unfortunately it was forgotten to switch off the stereo pilot tone of this stereo coder. So, differing to Recommendation ITU-R BS.641 the unwanted signal included a stereo pilot tone (19 kHz) with ±6.8 kHz frequency deviation, with left channel = right channel like a mono signal. But comparisons with former measurements showed a negligible influence of the stereo pilot tone.

The wanted signal was a stereo signal (19 kHz pilot with ±6.8 kHz deviation) with no further modulation or with additional 500 Hz respectively (±75 kHz sum deviation).

Figure 19 shows the complete measurement arrangement.

FIGURE 19

Measuring arrangement with signal levels



3 Measurement results

Table 8 and Fig. 20 show the results of all eight measured receivers. In principle the measurement could have been enlarged to examine further receivers. But after the tendency was clear and very consistent we saw no need to do that at the moment.

It can be seen that there is a very low deviation of the measured protection ratio for 0 kHz frequency difference (43 dB to 47 dB) and also for 100 kHz (25 dB to 32 dB).

In Fig. 20 it can be seen that all receivers meet the values of Recommendation ITU-R BS.412.

It is clear that the average values in Table 8 are not really representative for all receivers of the listeners at home or in cars though that was not the intention of the measurements. Instead it is intended to measure the impact of a more compressed unwanted signal.

TABLE 8

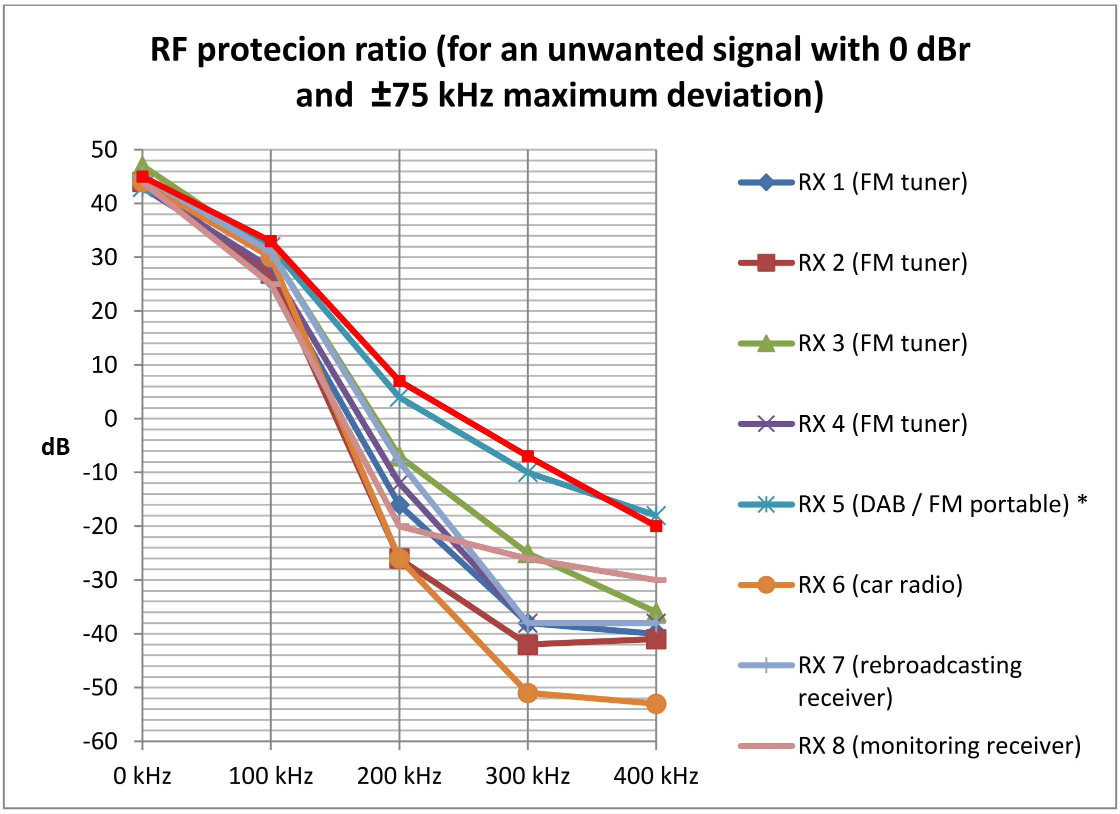
Measured receivers (all in stereo) and the measured protection ratio for an unwanted signal with 0 dBr and ±75 kHz maximum deviation

Frequency difference (kHz)	0 kHz	100 kHz	200 kHz	300 kHz	400 kHz
RX 1 (FM tuner)	44 dB	26 dB	–16 dB	–38 dB	–40 dB
RX 2 (FM tuner)	44 dB	27 dB	–26 dB	–42 dB	–41 dB
RX 3 (FM tuner)	47 dB	31 dB	–7 dB	–25 dB	–36 dB
RX 4 (FM tuner)	43 dB	28 dB	–12 dB	–38 dB	–38 dB
RX 5 (DAB / FM portable) *	43 dB	32 dB	4 dB	–10 dB	–18 dB
RX 6 (car radio)	44 dB	30 dB	–26 dB	–51 dB	–53 dB
RX 7 (rebroadcasting receiver)	45 dB	31 dB	–8 dB	–38 dB	–38 dB
RX 8 (monitoring receiver)	44 dB	25 dB	–20 dB	–26 dB	–30 dB
Average values:	**44,3 dB**	**38,8 dB**	**–13,9 dB**	**–33,5 dB**	**–36,8 dB**

* There was only 47 dB *S*/*N* reached. Therefore we measured the RF protection ratio for 40 dB *S*/*N* and added 10 dB for comparison with the other receivers.

FIGURE 20

Measured receivers and the measured RF protection ratio for an unwanted signal with 0 dBr and maximum frequency deviation of ±75 kHz



* There was only 47 dB *S*/*N* reached. Therefore we measured the RF protection ratio for 40 dB *S*/*N* and added 10 dB for comparison with the other receivers.

Figure 21 shows the results when the MPX power of the unwanted signal is increased from 0 dBr to 9 dBr by steps of 1 dB. It can be seen that the major impact happens at 100 kHz frequency difference. Also the values given by Recommendation ITU-R BS.412 are exceeded by far.

Although at 0 kHz frequency difference there is a lesser impact, the values given by Recommendation ITU-R BS.412 are exceeded anyway.

At 200 kHz frequency difference there is also an impact but all values are still under the values given by ITU-R BS.412, so this influence seems not that critical than at 0 kHz and 100 kHz frequency difference.

At 300 kHz and 400 kHz the influence of the MPX power is very low and in practice negligible.

FIGURE 21

Average of measured RF protection ratios of eight receivers (see Table 8) in comparison with the values given by Recommendation ITU-R BS.412

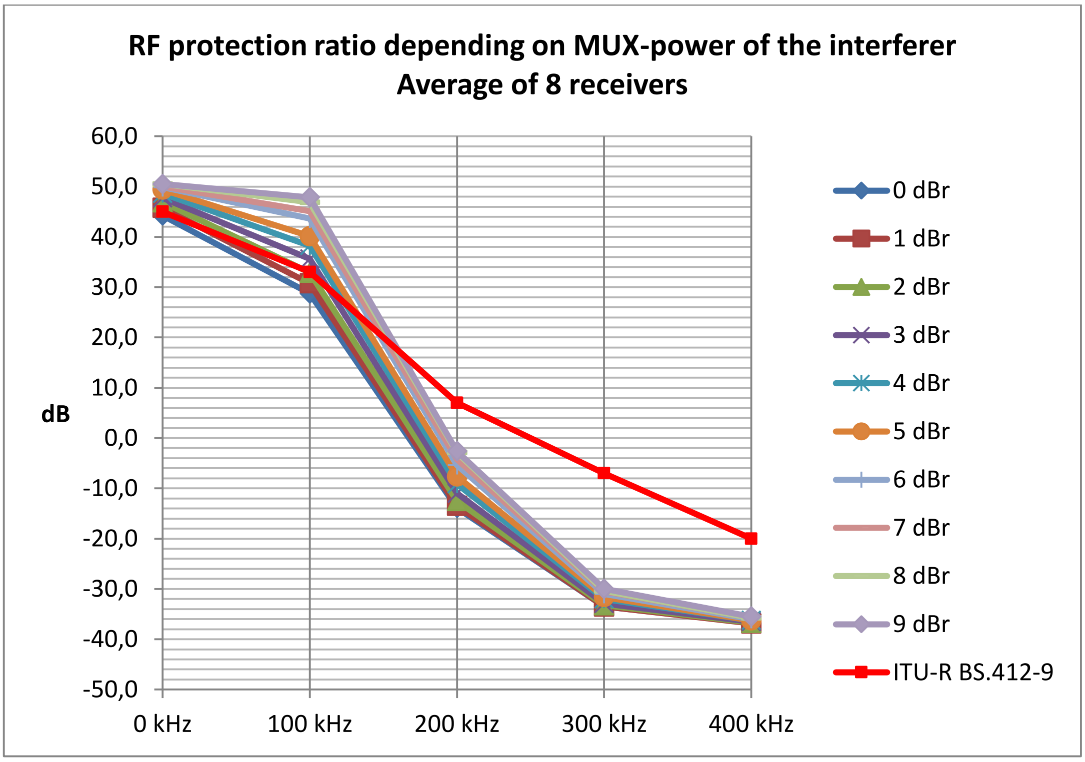
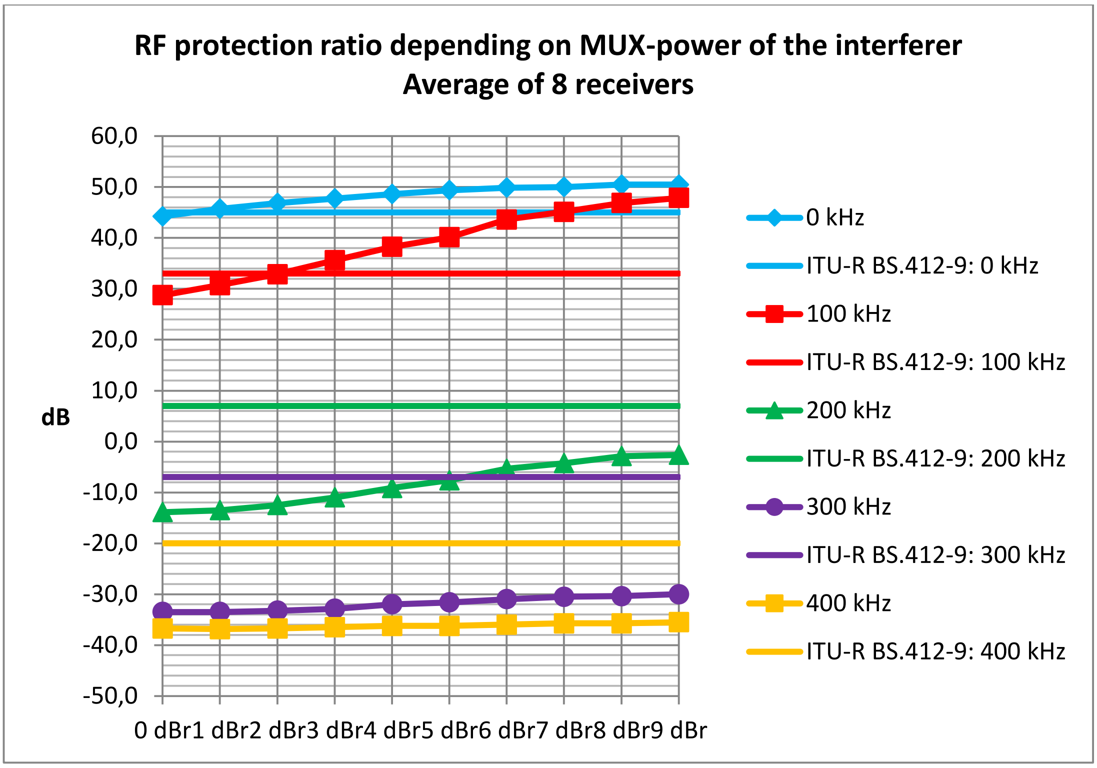


Figure 22 shows the influence of the MPX power more clearly. It can be seen that at 2 dBr the protection ratio given by Recommendation ITU-R BS.412 are reached (100 kHz) though at 0 kHz frequency difference the value of 45 dB (Recommendation ITU-R BS.412) is still exceeded by 2 dB.

FIGURE 22

Average of measured RF protection ratios of eight receivers (see Table 8) depending on multiplex power in comparison with the values given by Recommendation ITU-R BS.412



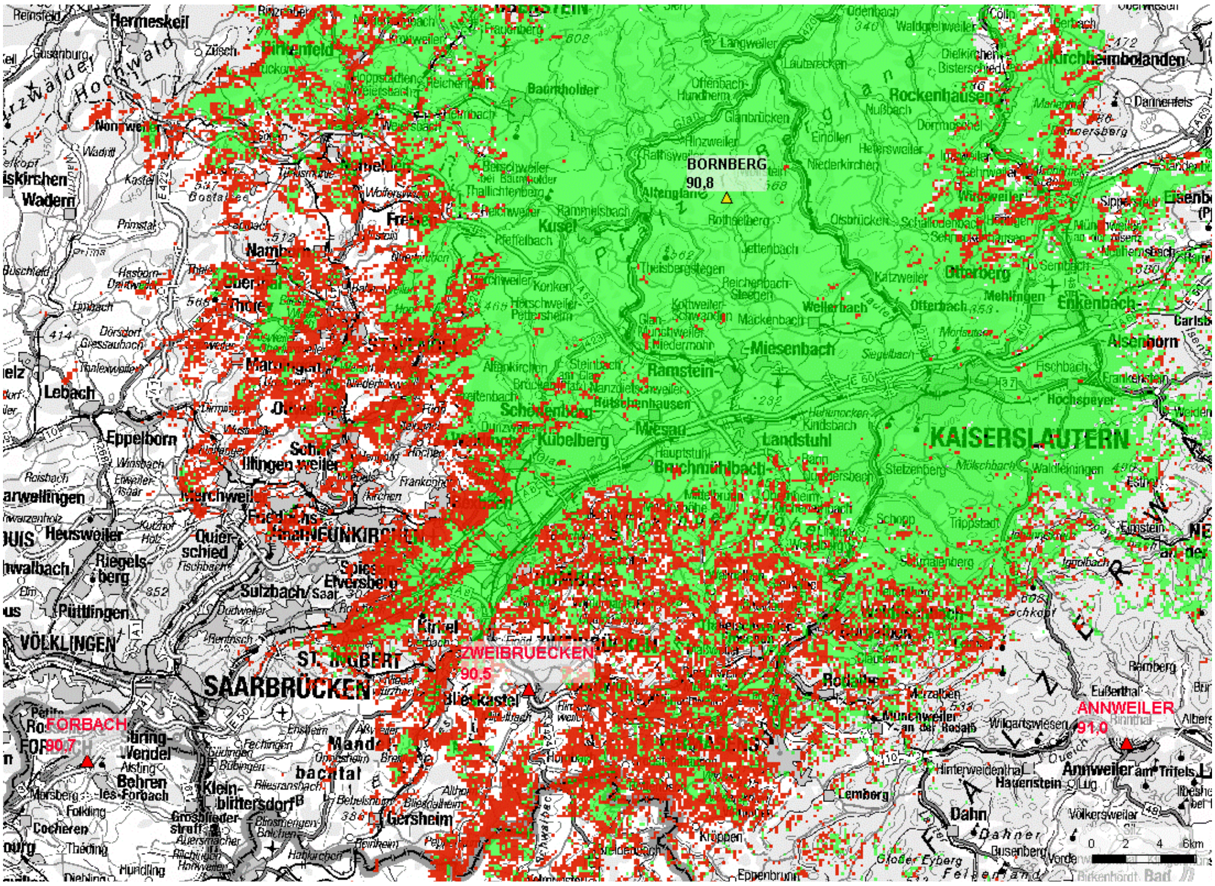
4 Consequences

Figure 23 shows an example of what would happen if a 100 kHz neighbour transmits with 7 dBr instead of 0 dBr multiplex power. Of course a lot of other parameters have their influence, e.g. ERP of all other transmitters, topography, distances etc.

But it can be seen that there is a certain impact if only one of the 100 kHz neighbour transmitters interferes like having 12 dB more RF power.

FIGURE 23

Stereo reception (green region) from transmitter Bornberg 90.8 MHz



NOTE – All relevant interfering transmitters 0 kHz to ±400 kHz have been considered, protection ratios according to Recommendation ITU-R BS.412, directional receiving antenna according to Recommendation ITU-R BS.599 and 54 dB minimum field strength.

The red colored regions change from not-interfered to interfered when the transmitter Forbach 90.7 MHz changes from 0 dBr to 7 dBr multiplex power. This is considered in higher RF protection ratios which have been changed from 33 dB to 45.1 dB (stereo steady) and from 25 dB to 37.1 dB (stereo tropo), see Table 10.

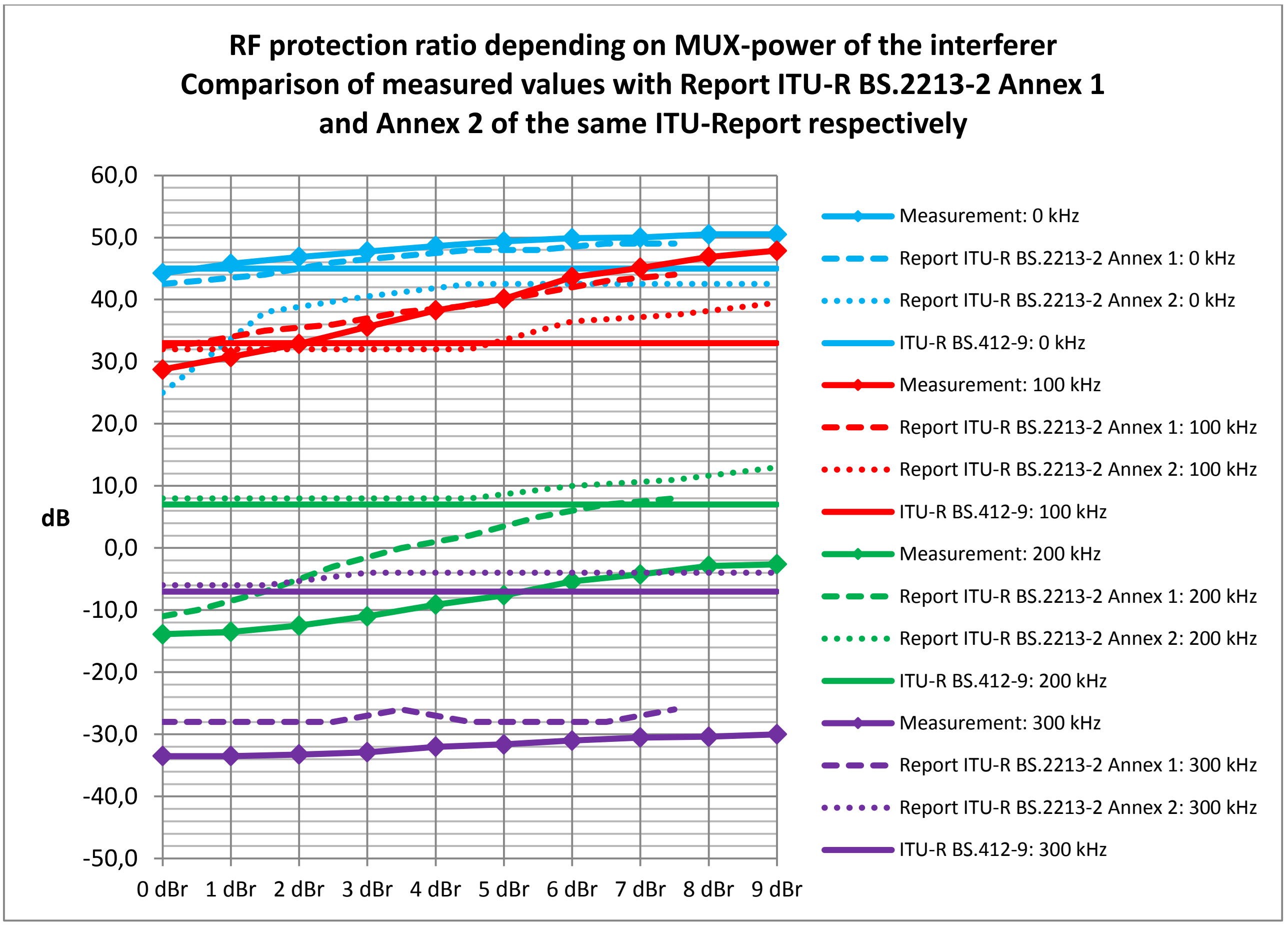
(Underlay map: ATKIS®, DTK500-V; ©Bundesamt für Kartographie und Geodäsie 2004.)

5 Conclusions

A direct comparison of these measurement results with those of Annexes 2 and 3 are presented in Fig. 24. Although it cannot be expected that the values are identical (because of not measuring the same receivers) these measurements and the results from Annex 1 are much more alike than the results from Annex 3.

FIGURE 24

Comparison of the measured values with the results from Annexes 2 and 3 and the values given by Recommendation ITU-R BS.412



The measured results are very similar to those from Annex 2, especially for frequency differences of 0 kHz and 100 kHz. From this point of view the results from Annex 2 seem to be reliable and can be used for compatibility calculations.

Table 9 shows these values for 0 kHz frequency difference stereo steady protection ratios and also the necessary derived protection ratios for stereo tropo.

Table 10 shows the same values but for 100 kHz frequency difference.

TABLE 9

Comparison of measurement results and the values given by Recommendation ITU-R BS.412 for 0 kHz frequency difference

	Rec. ITU-R BS.412	**0 dBr**	**1 dBr**	**2 dBr**	**3 dBr**	**4 dBr**	**5 dBr**	**6 dBr**	**7 dBr**	**8 dBr**	**9 dBr**
Stereo **Steady**	**45.0**	**45.0**	**45.8**	**46.9**	**47.8**	**48.6**	**49.4**	**49.9**	**50.0**	**50.5**	**50.5**
Stereo **Tropo**	**37.0**	**37.0**	**37.8**	**38.9**	**39.8**	**40.6**	**41.4**	**41.9**	**42.0**	**42.5**	**42.5**

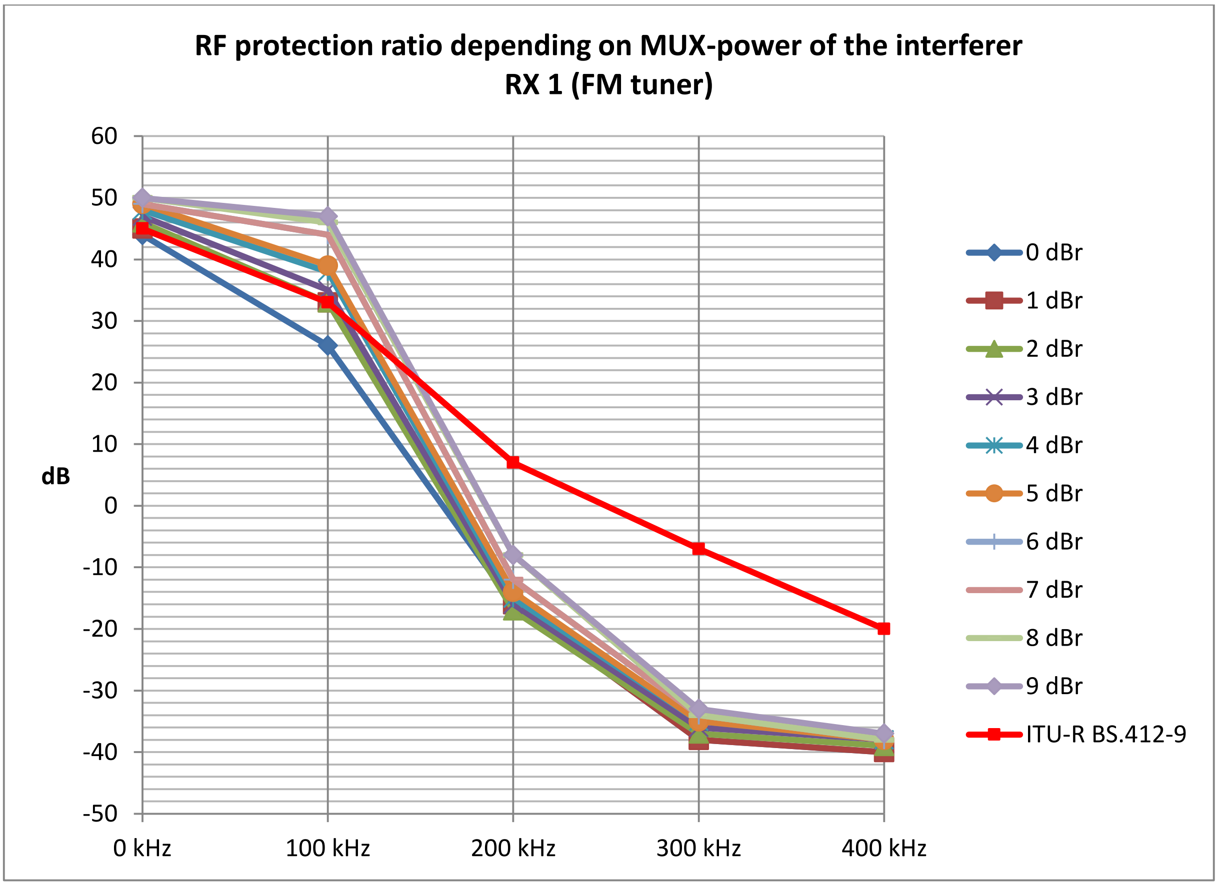
TABLE 10

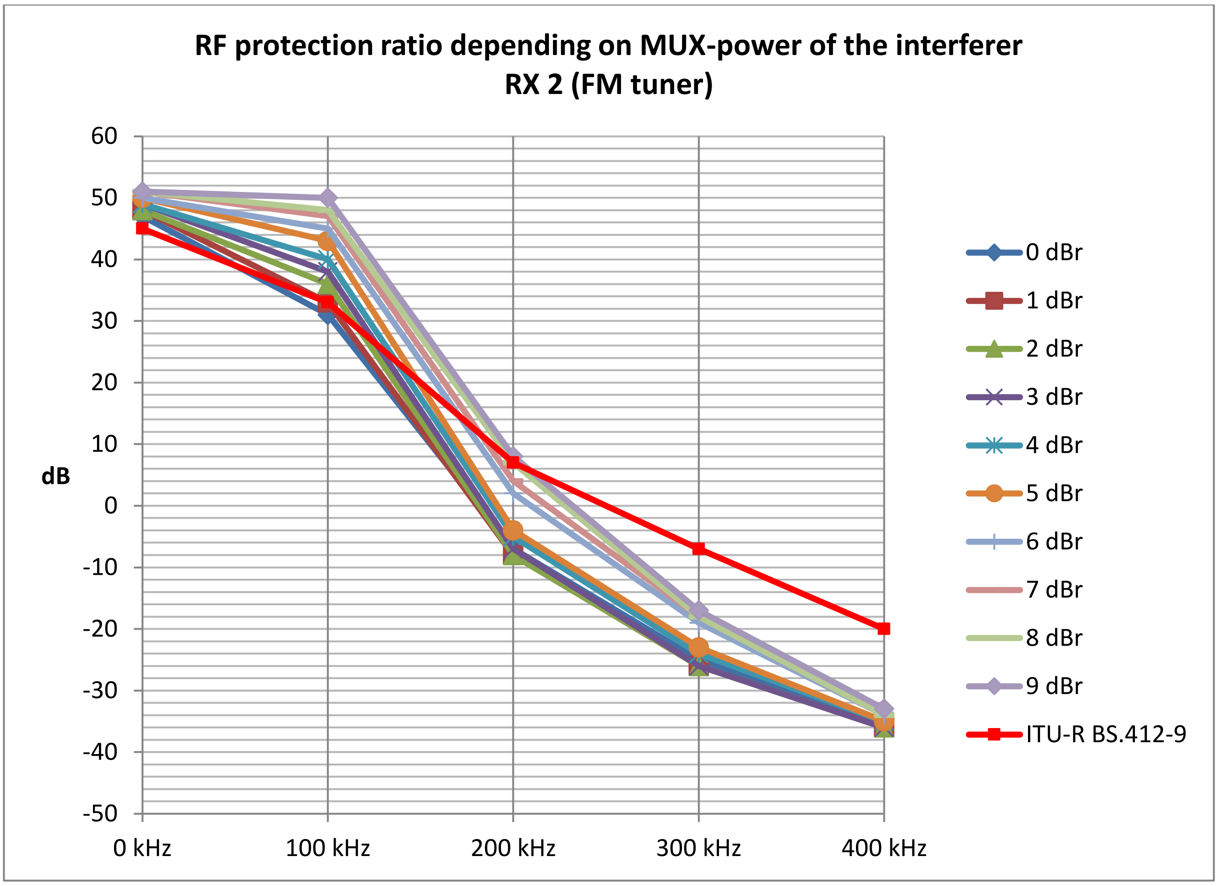
Comparison of measurement results and the values given by Recommendation ITU-R BS.412 for 100 kHz frequency difference

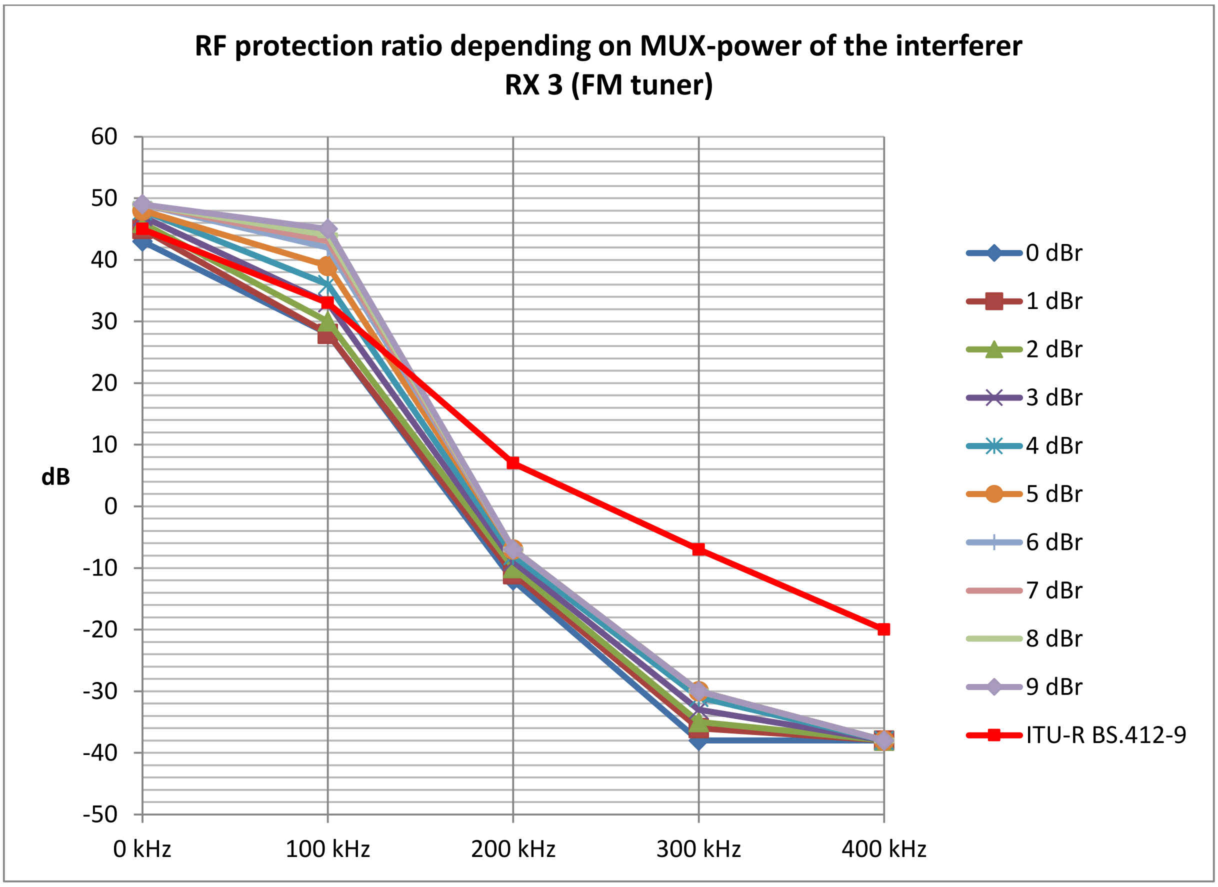
	Rec. ITU-R BS.412-9	0 dBr	1 dBr	2 dBr	3 dBr	4 dBr	5 dBr	6 dBr	7 dBr	8 dBr	9 dBr
Stereo **Steady**	33.0	33.0	33.0	33.0	35.6	38.3	40.1	43.6	45.1	46.9	47.9
Stereo **Tropo**	25.0	25.0	25.0	25.0	27.6	30.3	32.1	35.6	37.1	38.9	39.9

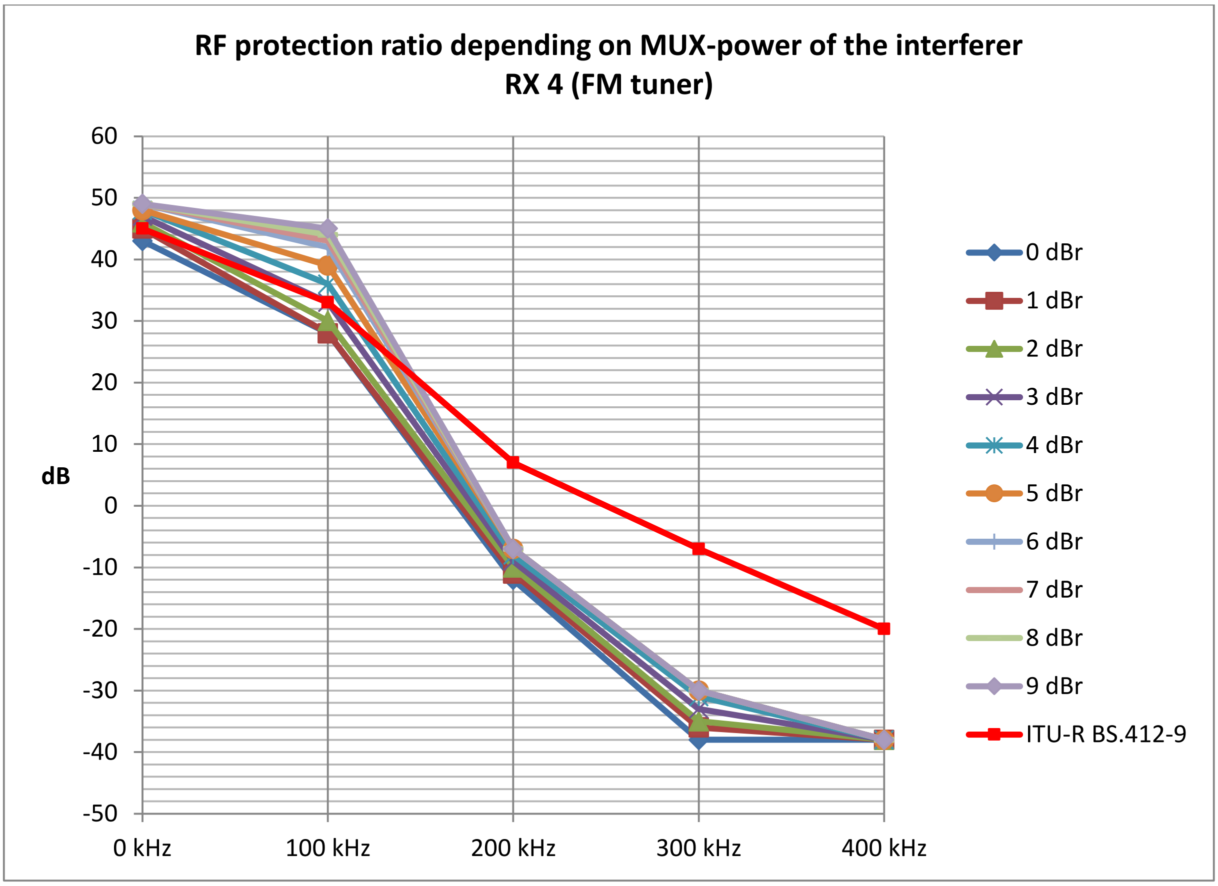
Attachment 1
to Annex 4

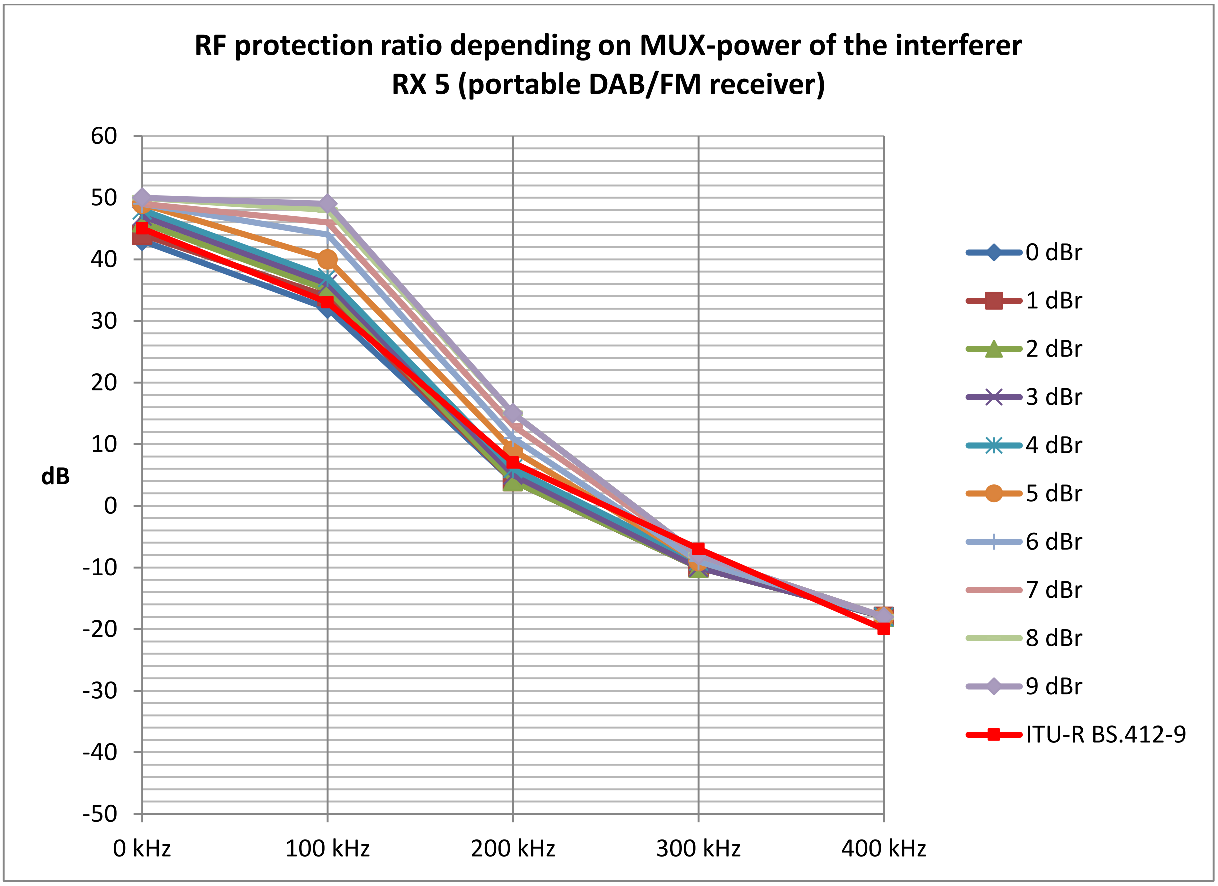
Single results of the measurements



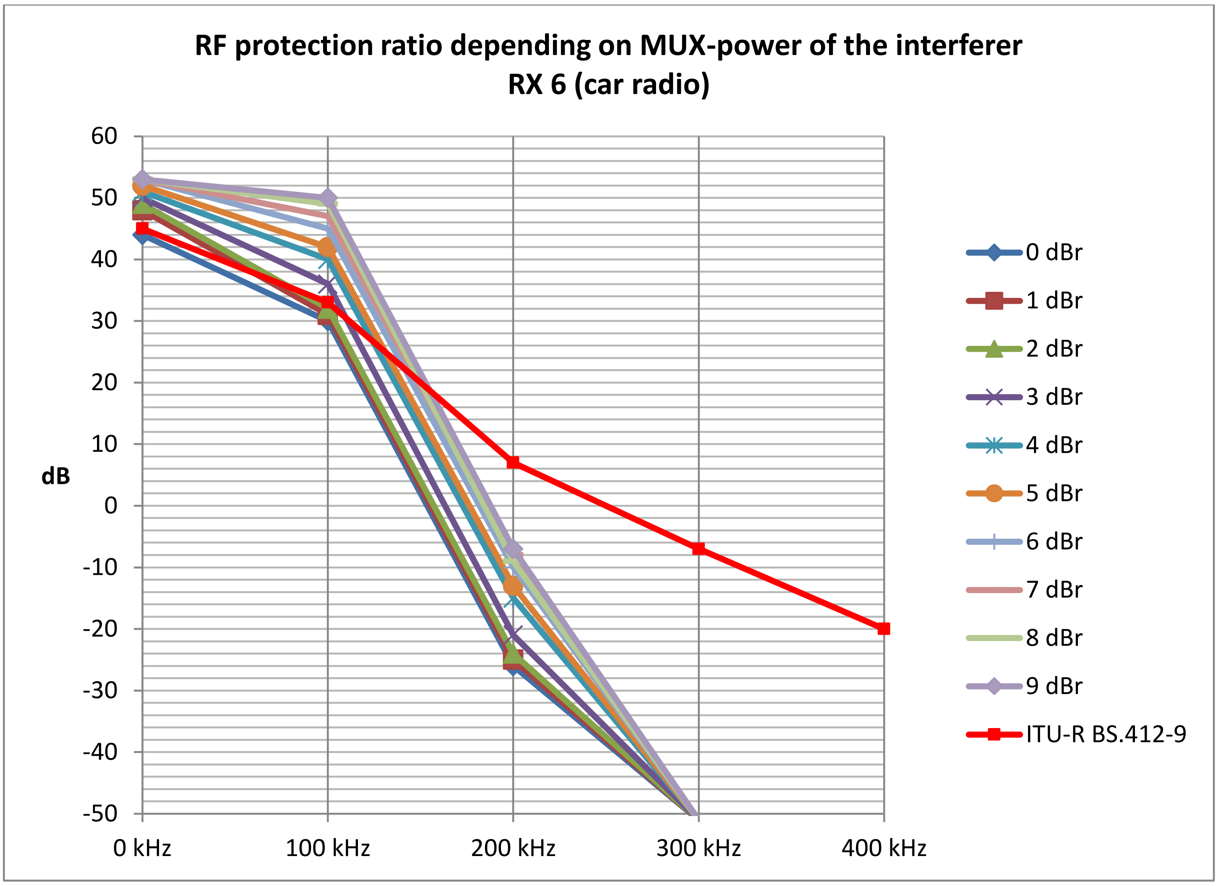

RF protection ratio depending on MUX-power of the interferer
RX 2 (FM tuner)
dB
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
0 kHz
100 kHz
200 kHz
300 kHz
400 kHz
0 dBr
1 dBr
2 dBr
3 dBr
4 dBr
5 dBr
6 dBr
7 dBr
8 dBr
9 dBr
ITU-R BS.412-9

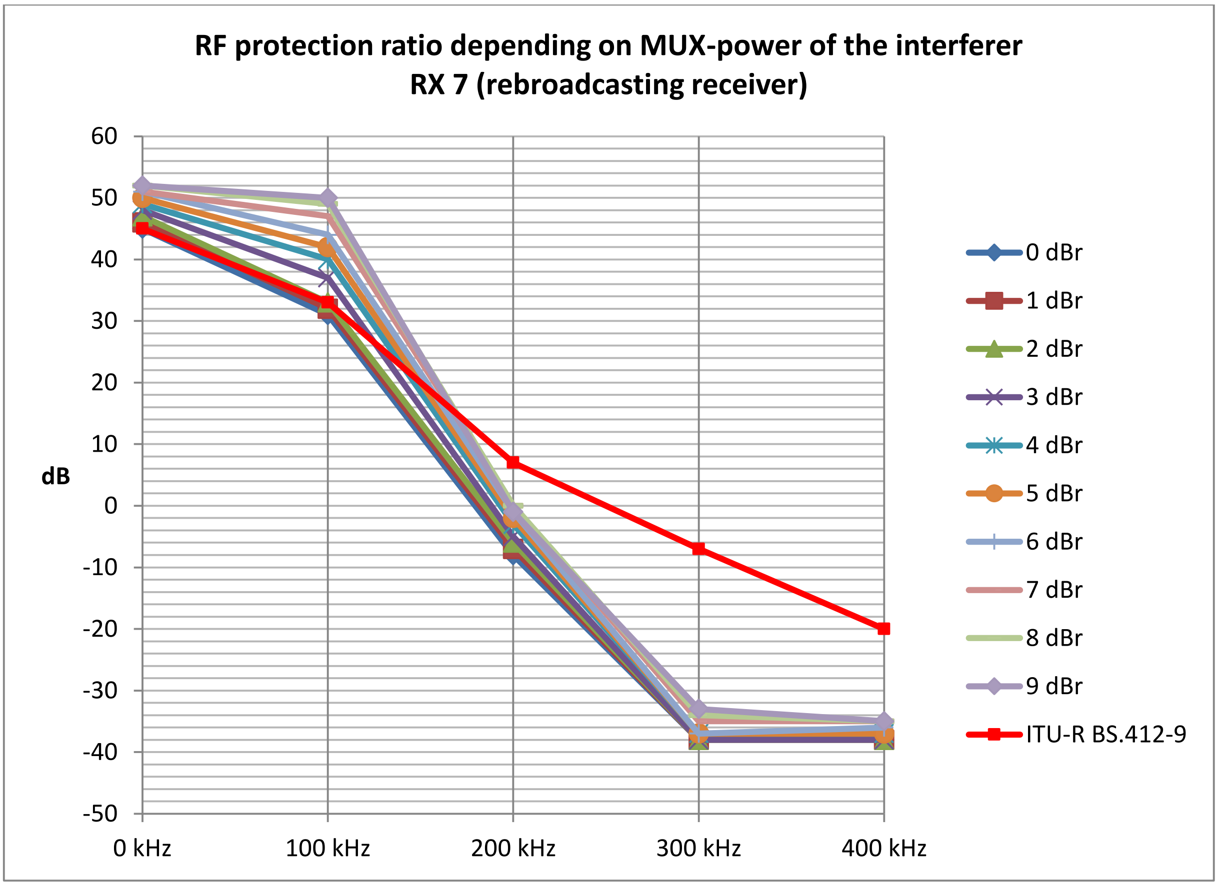

RF protection ratio depending on MUX-power of the interferer
RX 3 (FM tuner)
dB
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
0 kHz
100 kHz
200 kHz
300 kHz
400 kHz
0 dBr
1 dBr
2 dBr
3 dBr
4 dBr
5 dBr
6 dBr
7 dBr
8 dBr
9 dBr
ITU-R BS.412-9

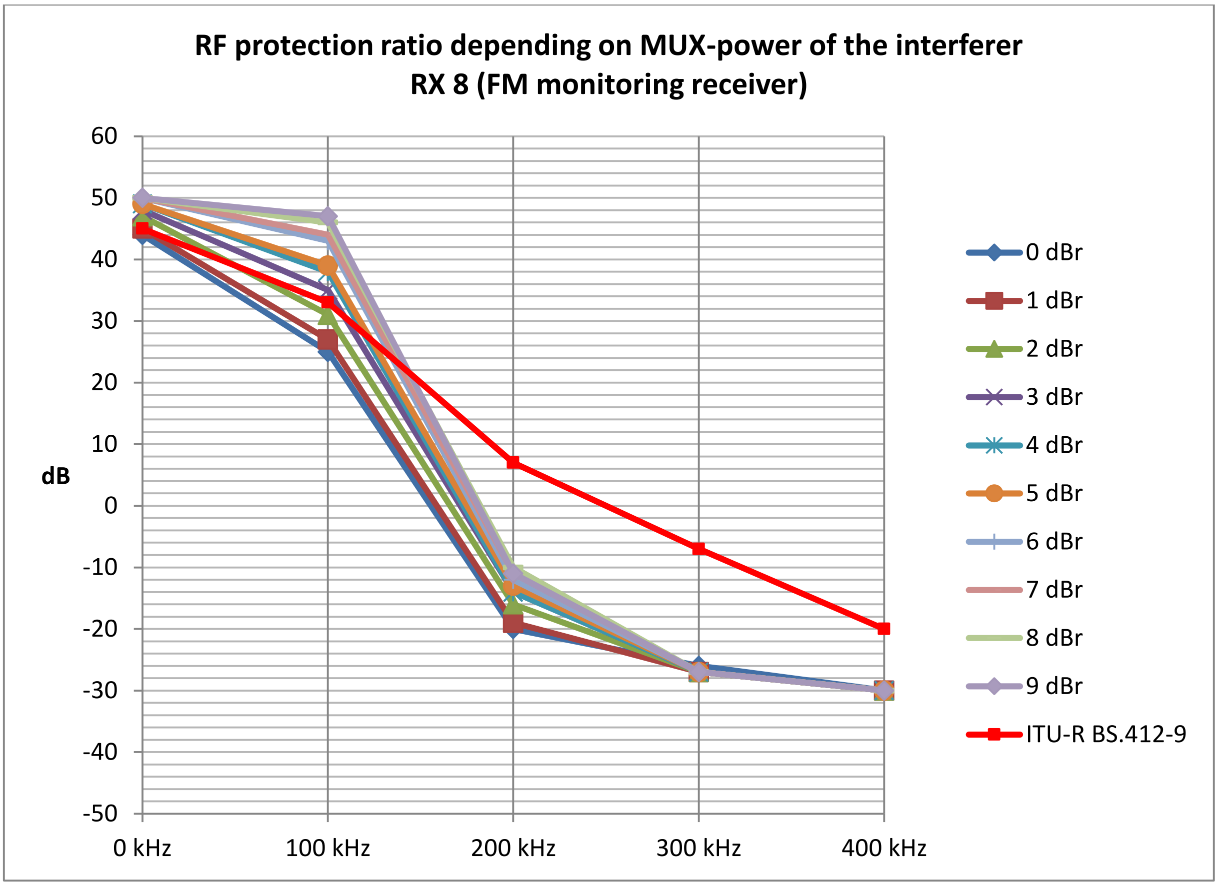




Note to RX 5: There was only 47 dB *S*/*N* reached. Therefore we measured the RF protection ratio for 40 dB *S*/*N* and added 10 dB for comparison with the other receivers.

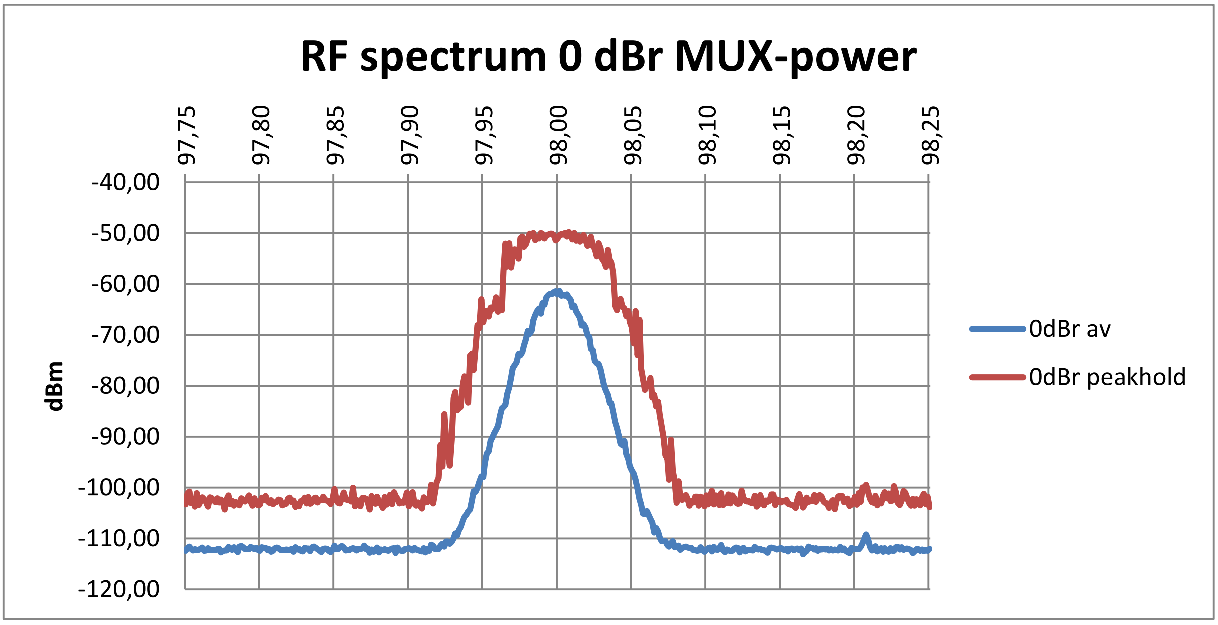

RF protection ratio depending on MUX-power of the interferer
RX 6 (car radio)
dB
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
0 kHz
100 kHz
200 kHz
300 kHz
400 kHz
0 dBr
1 dBr
2 dBr
3 dBr
4 dBr
5 dBr
6 dBr
7 dBr
8 dBr
9 dBr
ITU-R BS.412-9

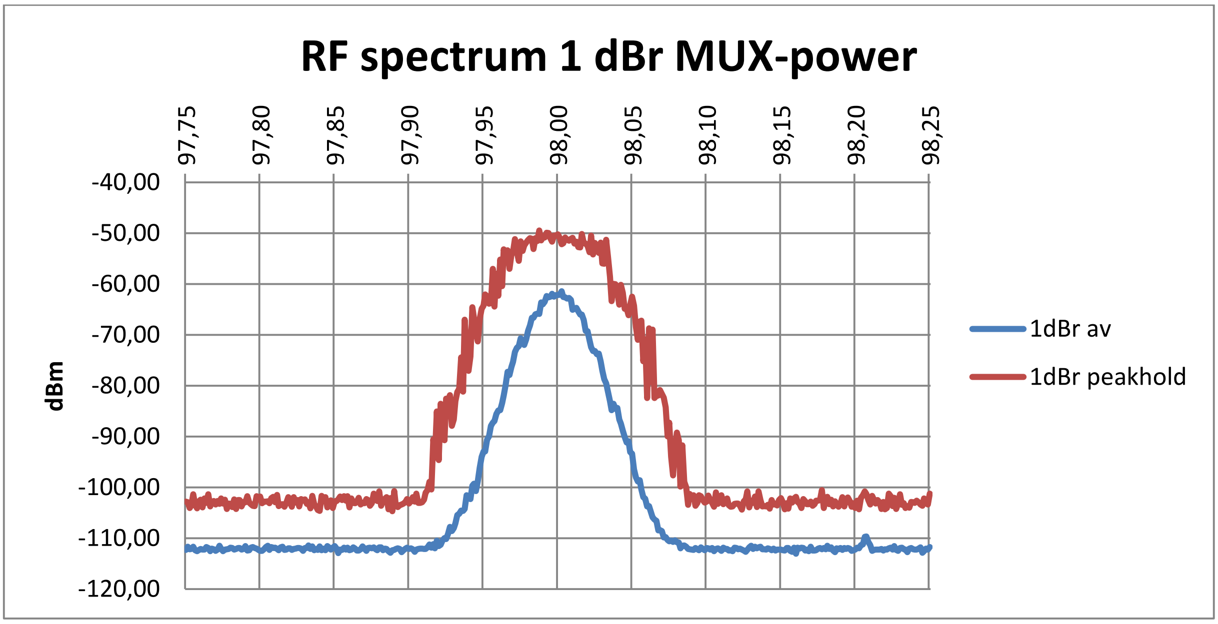

RF protection ratio depending on MUX-power of the interferer
RX 7 (rebroadcasting receiver)
dB
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
0 kHz
100 kHz
200 kHz
300 kHz
400 kHz
0 dBr
1 dBr
2 dBr
3 dBr
4 dBr
5 dBr
6 dBr
7 dBr
8 dBr
9 dBr
ITU-R BS.412-9

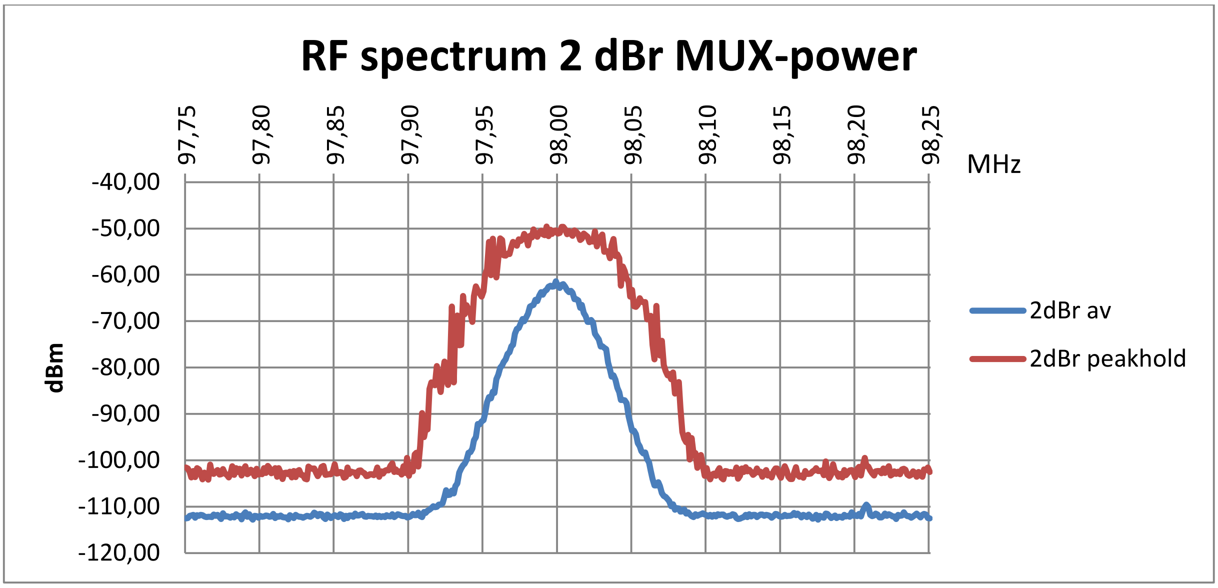

RF protection ratio depending on MUX-power of the interferer
RX 8 (FM monitoring receiver)
dB
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
0 kHz
100 kHz
200 kHz
300 kHz
400 kHz
0 dBr
1 dBr
2 dBr
3 dBr
4 dBr
5 dBr
6 dBr
7 dBr
8 dBr
9 dBr
ITU-R BS.412-9

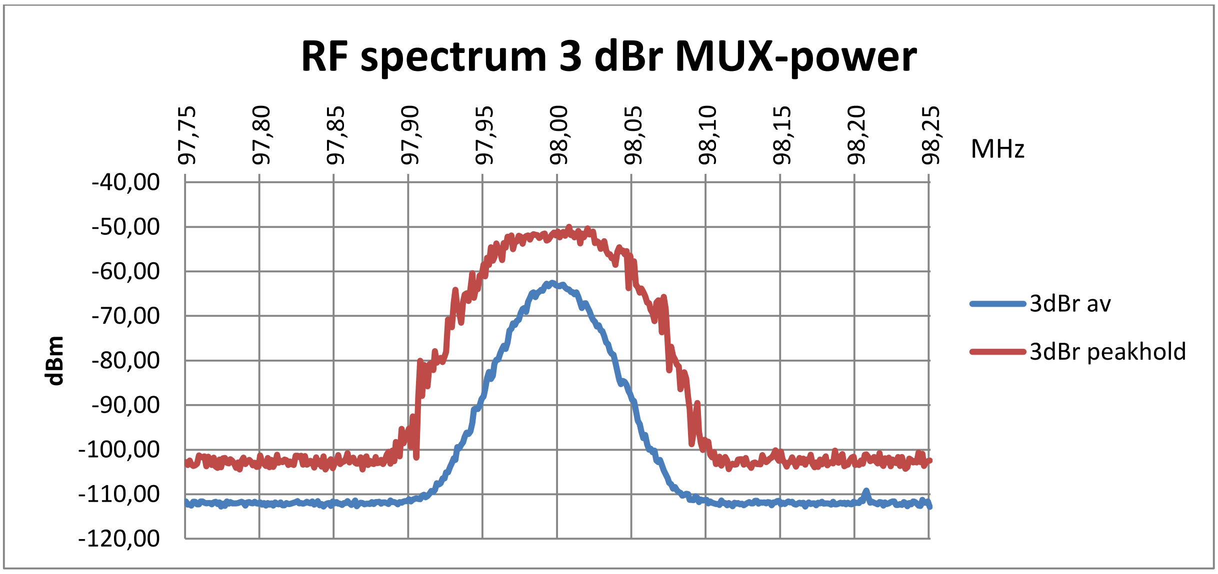
Attachment 2
to Annex 4

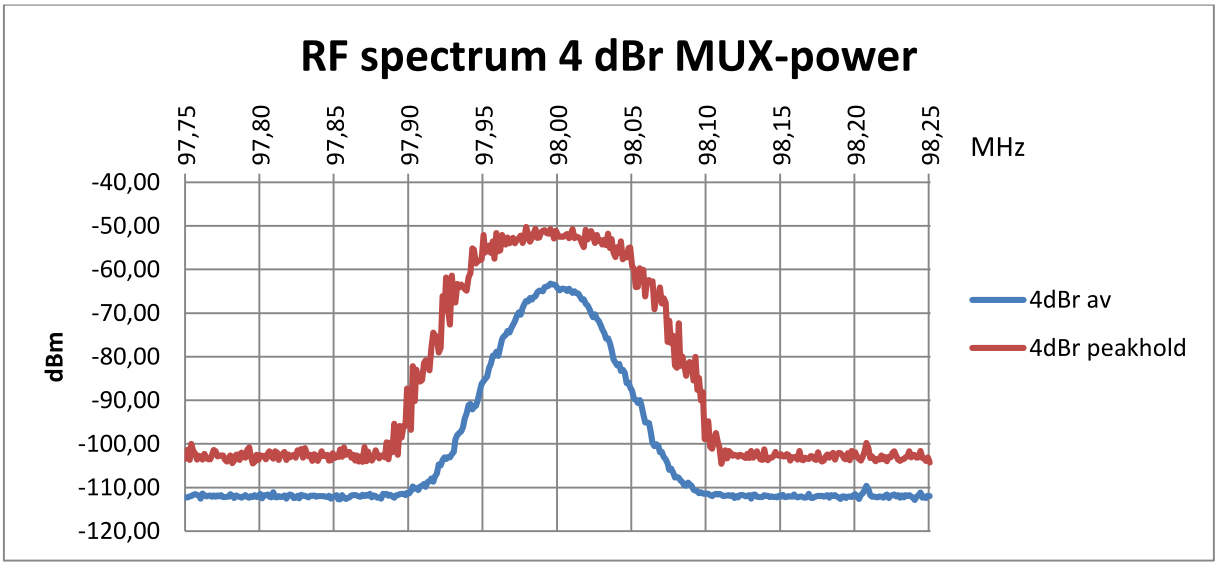
Spectrum plots of the unwanted signal

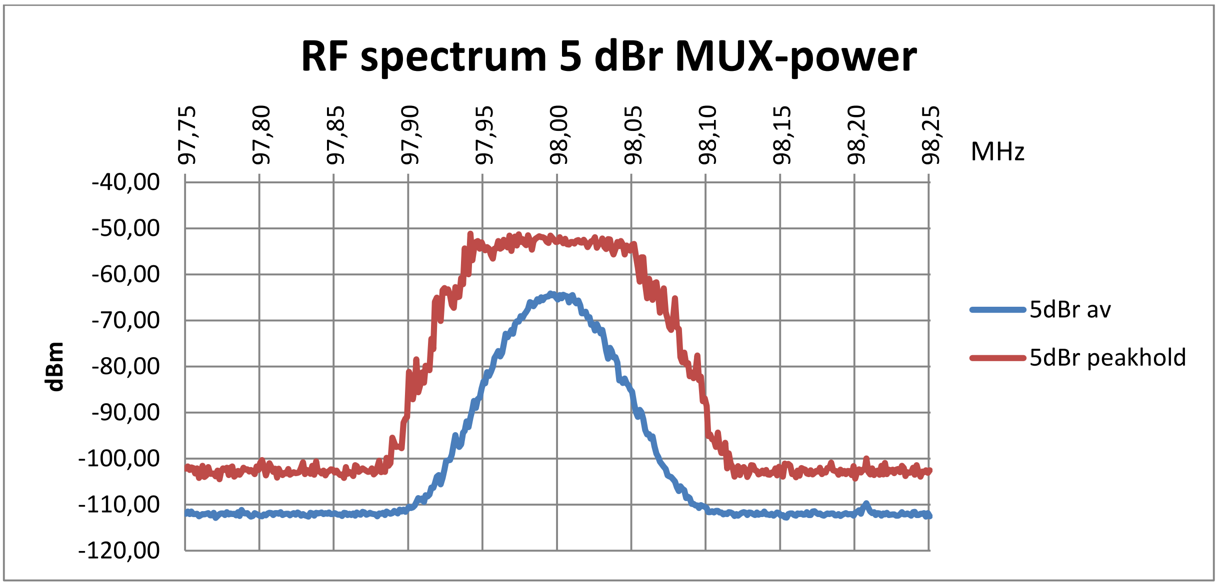


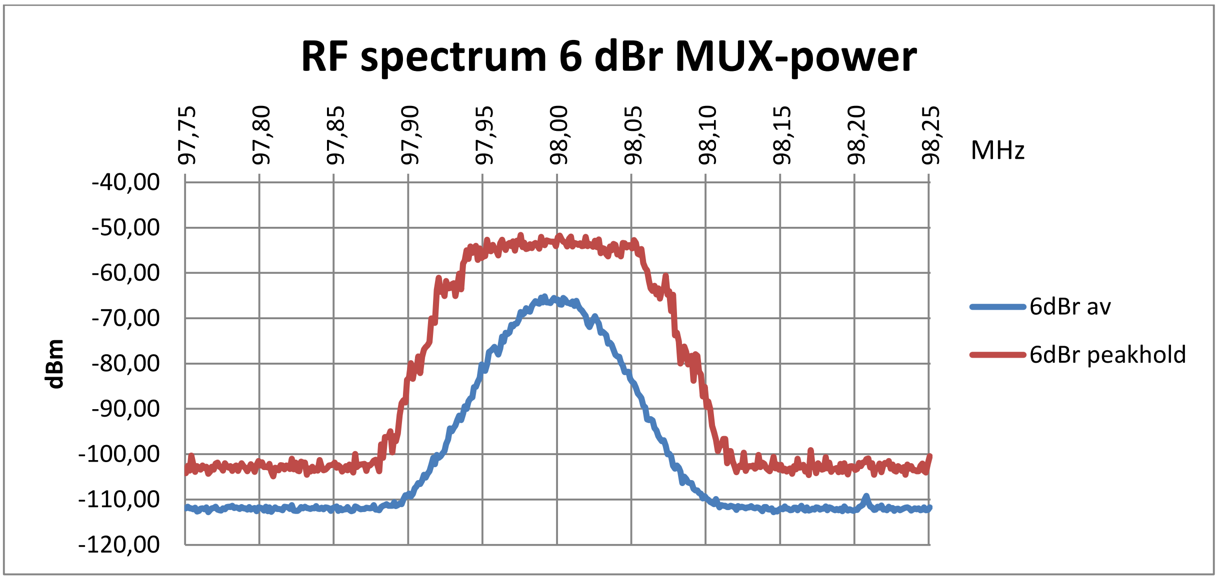


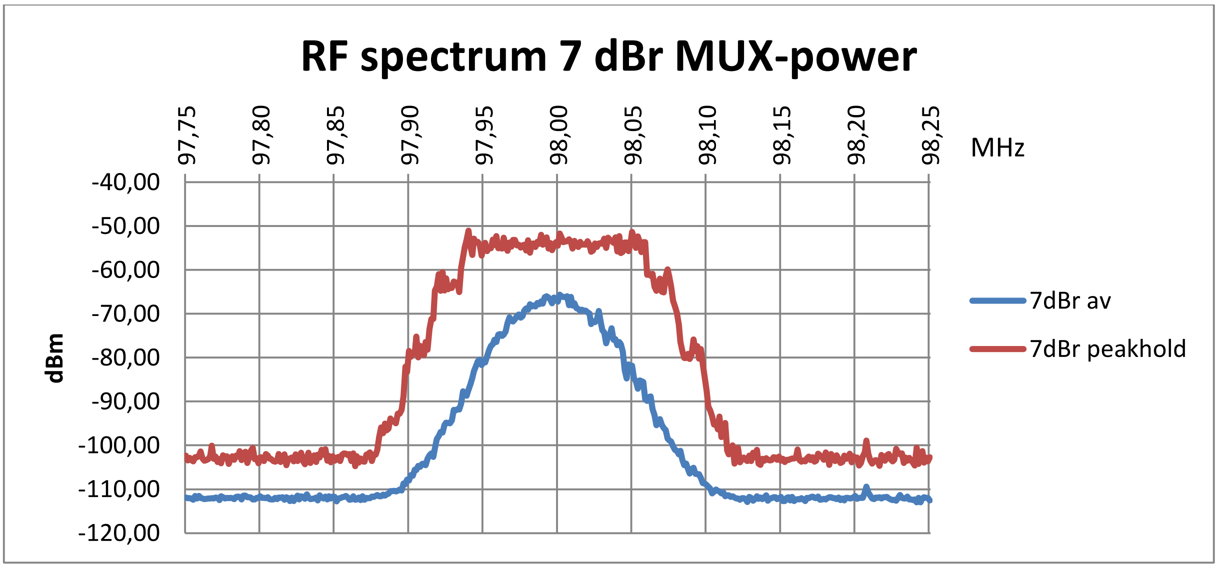

RF spectrum 2 dBr MUX-power
97,75
97,80
97,85
97,90
97,95
98,00
98,05
98,10
98,15
98,20
98,25
MHz
-40,00
-50,00
-60,00
-70,00
-80,00
-90,00
-100,00
-110,00
-120,00
dBm
2dBr av
2dBr peakhold

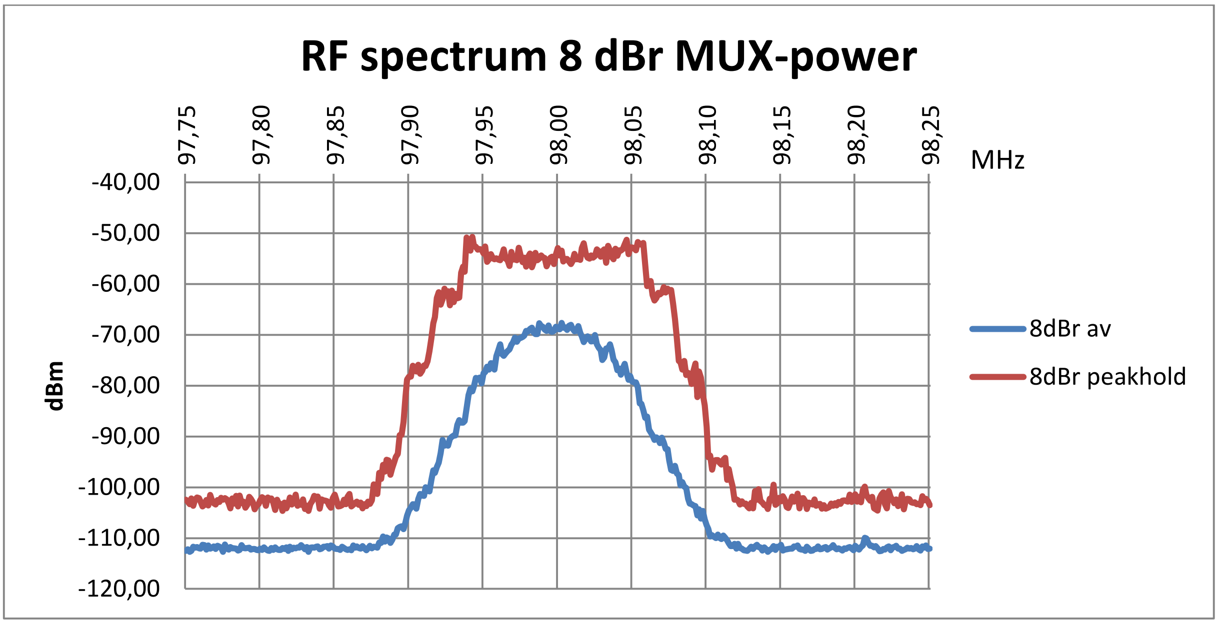

RF spectrum 3 dBr MUX-power
97,75
97,80
97,85
97,90
97,95
98,00
98,05
98,10
98,15
98,20
98,25
MHz
-40,00
-50,00
-60,00
-70,00
-80,00
-90,00
-100,00
-110,00
-120,00
dBm
3dBr av
3dBr peakhold

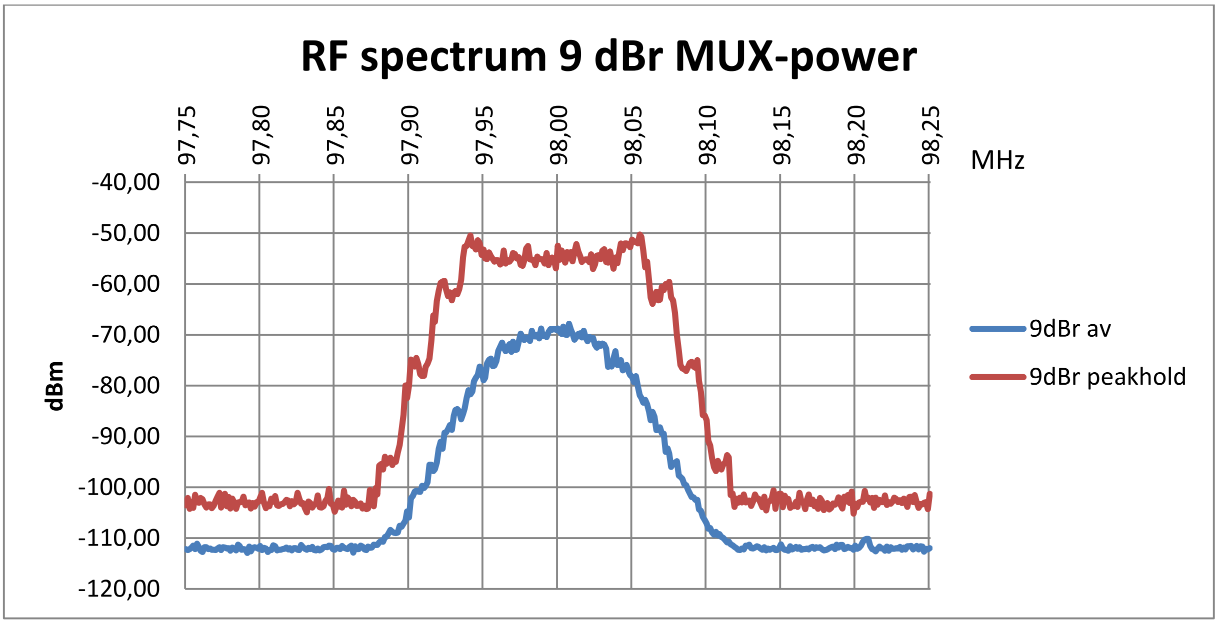

RF spectrum 4 dBr MUX-power
97,75
97,80
97,85
97,90
97,95
98,00
98,05
98,10
98,15
98,20
98,25
MHz
-40,00
-50,00
-60,00
-70,00
-80,00
-90,00
-100,00
-110,00
-120,00
dBm
4dBr av
4dBr peakhold


RF spectrum 5 dBr MUX-power
97,75
97,80
97,85
97,90
97,95
98,00
98,05
98,10
98,15
98,20
98,25
MHz
-40,00
-50,00
-60,00
-70,00
-80,00
-90,00
-100,00
-110,00
-120,00
dBm
5dBr av
5dBr peakhold


RF spectrum 6 dBr MUX-power
97,75
97,80
97,85
97,90
97,95
98,00
98,05
98,10
98,15
98,20
98,25
MHz
-40,00
-50,00
-60,00
-70,00
-80,00
-90,00
-100,00
-110,00
-120,00
dBm
6dBr av
6dBr peakhold


RF spectrum 7 dBr MUX-power
97,75
97,80
97,85
97,90
97,95
98,00
98,05
98,10
98,15
98,20
98,25
MHz
-40,00
-50,00
-60,00
-70,00
-80,00
-90,00
-100,00
-110,00
-120,00
dBm
7dBr av
7dBr peakhold


RF spectrum 8 dBr MUX-power
97,75
97,80
97,85
97,90
97,95
98,00
98,05
98,10
98,15
98,20
98,25
MHz
-40,00
-50,00
-60,00
-70,00
-80,00
-90,00
-100,00
-110,00
-120,00
dBm
8dBr av
8dBr peakhold


RF spectrum 9 dBr MUX-power
97,75
97,80
97,85
97,90
97,95
98,00
98,05
98,10
98,15
98,20
98,25
MHz
-40,00
-50,00
-60,00
-70,00
-80,00
-90,00
-100,00
-110,00
-120,00
dBm
9dBr av
9dBr peakhold

Annex 5

Measurements of the relationship between loudness and multiplex power in FM radio performed in France

1 Introduction

The multiplex power is a broadcast parameter whose value influences the reception quality and the loudness of the received signal: the loudness increases with the multiplex power. In France, this parameter is not regulated and no consensus exists for its value. Each radio operator fixes the value of this parameter according to his own criteria.

By using high multiplex power, some radio operators pretend extending their coverage area, preserve their audio “signature”, satisfy their audience and compete in the worldwide radio market. These practices have many harmful consequences. One of these is a radio landscape with heterogeneous loudness between radio stations. It can damage the audio quality of the program with high multiplex power, but also disturb the good receiving of other program and increases the risks on the hearings health, particularly when using headphones. The imbalance in the practices leads to conflicts between radio operators.

In this context, Conseil Supérieur de l’Audiovisuel (CSA), the French regulatory body for broadcasting, thought about regulating the multiplex power in France, and an international harmonization on the use of MPX power could be a way forward for avoiding difficulties among countries at border level.

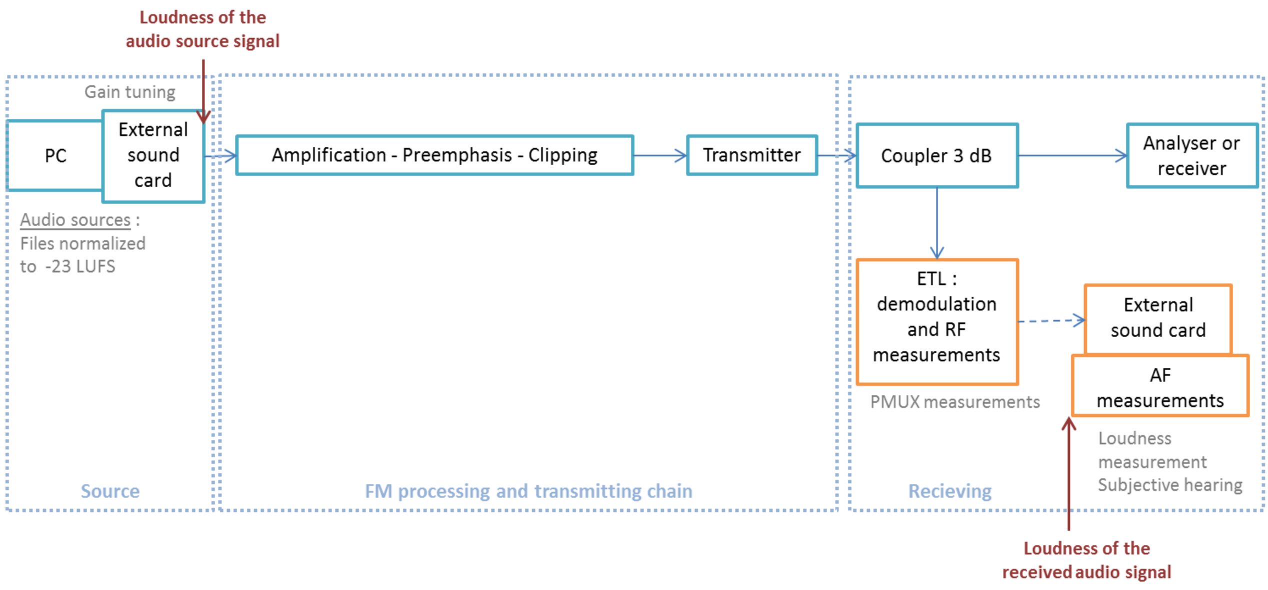
1. A previous experimentation has been led in 2012, which has allowed estimating the impact of the multiplex power on the protection ratios in FM broadcasting (see Annex 2). It has seemed interesting to evaluate the impact of the multiplex power from the ‘loudness’ point of view.
2. This analysis presents the measurements realized in 2015 in France by the CSA, which aimed at establishing the dependence between multiplex power and loudness and concluded on the degradation of the quality of a signal due to the use of high multiplex powers.

2 Experimentation system

Figure 25 describes the test bench for the experimentation.

FIGURE 25

Experimentation system



3 Database description

The database is initially composed of three audio tracks which are a good representation of content usually broadcasted in FM radio:

– an information sequence (speech voice);

– a pop music sequence (singing voice and acoustic instrument);

– a rap music sequence (speech and singing voices, percussions and electronic music).

Each audio track is compressed with two different levels (3 dB and 6 dB). All audio files are normalized to –23 LUFS. The tests are made on the three versions (0 dB, 3dB and 6 dB compression) of each track. More information about the audio files is available in the Annex of the document.

4 Experimental protocol

The experimentation respects the following protocol for each audio track:

1 Submit of the audio source signal to the modulation chain[2];

2 Tuning of the gain of the audio source signal in order to reach the target multiplex power by controlling the frequency deviation[3];

3 After stabilization of the multiplex power:

- measurement of the gain applied to the audio source signal (which allows to obtain the loudness),
- measurement of the loudness of the received signal,
- recording of the received signal,
- recording of the RF spectrum over one minute.

[2] The signal is looped until a stable multiplex power is reached.

[3] The frequency deviation is controlled to the value of 63,9 kHz, which corresponds to the deviation of a composite stereo signal of 75 kHz to which the carrier and the RDS signal are removed.

Each audio track is tested for the values of the multiplex power of 0, 3, 5, 7 and 9 dBr.

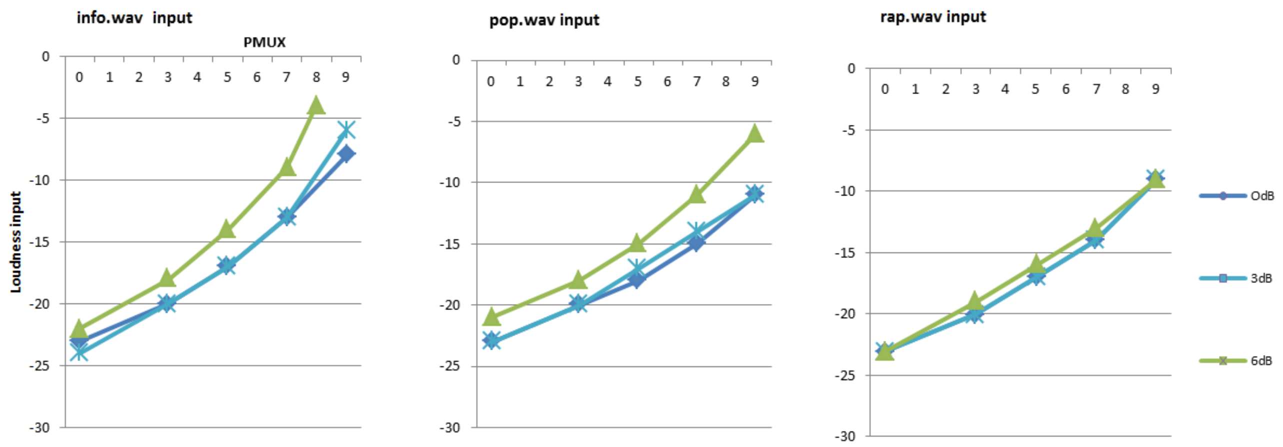
5 Results

5.1 Effect of the multiplex power increase on the loudness of the source audio file

The curves in Fig. 26 show that the loudness of the source audio signal (measured after the amplifier and before the pre-emphasis) exponentially grows when the multiplex power increases. The loudness of the source audio signal can meet an increase of up to 20 dB in the worst case (speech) for a multiplex power that is gradually raised from 0 to 9 dBr. In this case, the maximum peak is –3 dBTP[4] with a loudness of –4 LUFS, which lets only a small headroom for a given signal.

FIGURE 26

Loudness of the emitted audio files as a function of the multiplex power for the three tested audio files



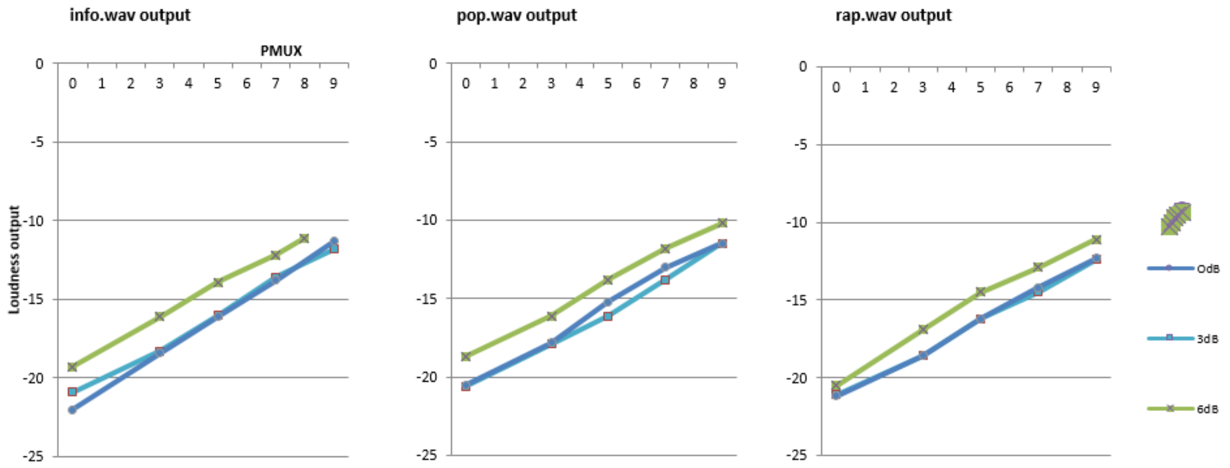
5.2 Effect of the multiplex power increase on the loudness of the received audio file

The graphics in Fig. 27 show that the loudness of the received audio signal (measured after the demodulation) linearly grows when the multiplex power increases. With a loudness in production at –23 LUFS and a multiplex power range from 0 and 9 dBr, the loudness of the received audio signal is never higher than –10 LUFS. On the other hand, the maximum peak can range until –3 dBTP.

4 The dBTP (dB True Peak) is the unit of measurement used for the measurement of the maximum peak; more details are available in Recommendation ITU R-BS.1770-3.

FIGURE 27

Loudness of the received audio file as a function of the multiplex power for the three tested audio files

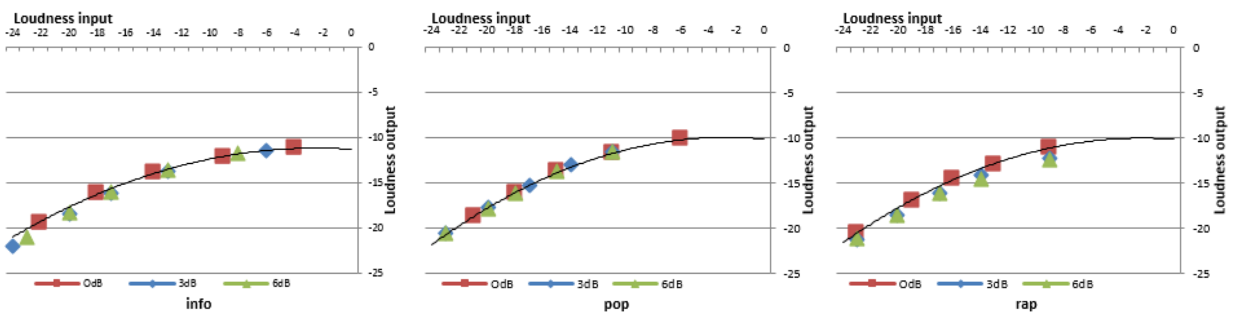


5.3 Effect of the FM transmission chain on the loudness

The curves in Fig. 28 show that when the loudness of the input signal is increased in order to raise the mutiplex power, the loudness of the received audio signal evolves as a logarithmic function with regard to the loudness of the audio source signal. Therefore, when the multiplex power increases, the loudness of the received signal increases more slowly than the loudness of the audio source signal. The inflection point is reached for a multiplex power between 5 dBr and 7 dBr depending on the content.

FIGURE 28

Loudness of the received audio signal as a function of the loudness of the audio source signal when the input loudness is increased in order to raise the multiplex power



5.4 Synthesis

The results of this experimentation allow bringing better knowledge on the multiplex power effects on the audio signal:

– The loudness of the received audio signal evolves as a quasi-linear function of the multiplex power.

– The loudness of the transmitted audio signal evolves as an exponential function of the multiplex power.

– When the multiplex power increases by raising the loudness of the source audio signal, the loudness of the received signal evolves as a logarithmic function of the loudness of the audio source signal.

This experimentation has been lead with a modulating monophonic signal. In stereophonic mode, for each FM radio with a high multiplex power, the spectrum of the resulting FM signal is more spread out in spite of the control of the frequency deviation (±75 kHz).

6 Conclusions

This experimentation has proved the negative effect of a high multiplex power on the audio quality of the signal itself. More precisely, it is shown that an increase of the multiplex power higher than 5 dBr causes some raise and degradation of loudness.

To conclude, the results of the experimentation allow:

– to demonstrate the relationship between the multiplex power and the loudness;

– to show an important degradation of the audio signal itself caused by a multiplex power higher than 5 dBr.

Attachment to Annex 5

Measurements

Database description:

– Sampling frequency: 44.1 kHz

– Resolution: 16 bits

– Duration: 30 s

File	Content	Integrated loudness	Max True Peak	Max Short-term Loudness	Max Momentary Loudness
info	Speech of the type “information” without dynamic compression	−23.3	−3.4	−20.4	−16.8
info_3 dB	Speech of the type “information” with 3 dB dynamic compression	−23.1	−2.9	−21.7	−20.6
info_6 dB	Speech of the type “information” with 6 dB dynamic compression	−23.1	−3.5	−22.1	−21.1
rap	Music of type “rap” in two parts: – rapper voice – singer voice	−23.1	−9.5	−21.5	−19.9
rap_3 dB	Music of type “rap” with 3 dB dynamic compression	−23.0	−4.1	−22.1	−21.2
rap_6 dB	Music of type “rap” with 6 dB dynamic compression	−23.0	−4.4	−22.3	−21.4
pop	Music of type “pop”	−23.2	−7.3	−21.0	−18.7

File	Content	Integrated loudness	Max True Peak	Max Short-term Loudness	Max Momentary Loudness
pop_3 dB	Music of type “pop” with 3 dB dynamic compression	−23.0	−6.9	−21.6	−20.2
pop_6 dB	Music of type “pop” with 6 dB dynamic compression	−23.0	−7.4	−21.7	−20.8

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