Draft ETSI TR 102 546 V1.1.1_2.0.2 (2007-01)

Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics for Professional Wireless Microphone Systems (PWMS); System Reference Document

Reference
DTR/ERM-RM-053

Keywords
audio, SRDoc

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Introduction

The purpose of producing the present document is to lay a foundation for industry to quickly bring innovative and useful products to the market while avoiding any harmful interference with other services and equipment.

PWMS are intended for use in the entertainment and installed sound industry by Professional Users involved in stage productions, public events, TV programme production, public and private broadcasters installation in conference centres / rooms, city halls, musical and theatres, sport / event centres or other professional activities / installation.

PWMS have traditionally been in use in broadcast bands III, IV and V, since 1957. The transition to digital TV has eroded the availability of spectrum. The growth of theatrical and musical productions along with the requirements of "wireless" microphones in all forms of media, plus the growth of independent television and film productions, has resulted in the plethora of uses outlined in annex A.1. The Chester conference of 1997 set the spectrum allocation for digital television and simulcasting. There is a danger that this will result in the displacement of wireless microphones from their traditional spectrum. Continued erosion of spectrum availability will result in the loss of programme, media and film production within Europe, contrary to the EU Recommendation of 50% of all programme making being within the EU [18].

Previous CEPT investigations [9] and [11] identified the frequency range 1 785 MHz to 1 800 MHz, however this designation has proved to have many drawbacks and is not suitable to replace the existing UHF spectrum due to propagation, lack of spectrum for multi-channel use, etc. This frequency range is also being considered by ECC for flexible band usage which is incompatible with PWMS usage.

1 Scope

The present document describes the requirements for radio frequency usage for PWMS in the frequency ranges up to approximately 1 800 MHz.

These systems are constant-carrier devices, with 100 % duty cycle, for use by Professional users and are, as a rule, high quality wireless audio transmission systems, including, but not limited to, wireless microphones, back-channel equipment (in-ear monitoring), wireless equipment for sound mixing panels, wireless equipment for news reporting (e.g. news reporters and their teams) and audio link test, correction and optimization equipment. The professional nature of the intended system users differentiates these systems from "consumer" systems.

The present document includes necessary information to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT).

Additional information is given in the following annexes:

- detailed market information (annex A);
- technical information (annex B);
- expected compatibility issues (annex C);
- PWMS path loss model (attachment 1);
- receiver parameters below 1 GHz (attachment 2).

2 References

For the purposes of the present document the following references apply:

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

[1] CEPT Report 005 (2004): "Final report by the ECC in response to the EC Mandate to CEPT on SRD Radio Spectrum harmonization".

[2] CEPT/ECC Report 2 (February 2002): "SAP/SAB (incl. ENG/OB) spectrum use and future requirements".

[3] CEPT/ERC Recommendation 25-10 (2003): "Frequency ranges for the use of temporary terrestrial audio and video SAP/SAB links (incl. ENG/OB)".

[4] CEPT/ERC Recommendation 70-03 (2005): "Relating to the use of short range devices (SRD)".

[5] CEPT/ERC Recommendation 74-01 (1999): "Unwanted emissions in the spurious domain".

[6] CEPT/ERC Report 7 (December 1991): "Compatibility between certain mobile Radiocommunications systems operating in adjacent bands".

[7] CEPT/ERC Report 25 (2004): "The European table of frequency allocations and utilizations covering the frequency range 9 kHz to 275 GHz".

[8] CEPT/ERC Report 38 (May 1995): "Handbook on Radio Equipment and Systems Video Links for ENG/OB Use".

[9] CEPT/ERC Report 42 (October 1996) "Handbook on Radio Equipment and Systems Radio Microphones and Simple Wide Band Audio Links".

[10] CEPT/ERC Report 58 (January 1998): "DSI Phase II (900 MHz Issues) Services Ancillary to Program Making".

[11] CEPT/ERC Report 63 (May 1998): "Introduction of radio microphone applications in the frequency range 1 785 MHz to 1 800 MHz".

[12] CEPT/ERC Report 88 (February 2000), "Compatibility and Sharing Analysis Between DVB-T and Radio Microphones in Bands IV and V".

[13] The Chester 1997 Multilateral Coordination Agreement relating to Technical Criteria, Coordination Principles and Procedures for the introduction of Terrestrial Digital Video Broadcasting (DVB-T) Chester (25 July 1997).

[14] EBU press release (Geneva, 24 May 2006): "The Eurovision Song Contest 2006".

[15] EBU, SPB 495 18th January 1995: "Technical Bases for T-DAB planning".

[16] EC RSPG Opinion #5 (2006), "Radio Spectrum Policy Group Opinion on The Introduction of Multimedia Services in particular in the frequency bands allocated to the broadcasting services".

NOTE: As of October 2006, EC RSPG Opinion #5 is still under consideration by the EC. This reference will be updated on final publication of this document.

[17] EU Authorization Directive 2002/20/EC EU A

[18] European Parliament decision on levels of programme making in Europe.

[19] CEPT Report (2006): "Final Report from CEPT in response to the Second EC Mandate to CEPT to develop a strategy to improve the effectiveness and flexibility of spectrum availability for Short Range Devices (SRDs)".

NOTE: As of October 2006, this CEPT report is still in draft. This reference will be updated on final publication of this document.

[20] ETSI EN 300 422 (V1.3.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics and test methods for wireless microphones in the 25 MHz to 3 GHz frequency range; Wireless microphones in the 25 MHz to 3 GHz frequency range".

[21] ETSI EN 300 454 (V1.1.1) (all parts): "ElectroMagnetic Compatibility and Radio Spectrum Matters (ERM); Wide band audio links".

[22] ETSI EN 301 357 (V1.3.1) (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Cordless audio devices in the range 25 MHz to 2 000 MHz".

[23] ETSI EN 301 489-9 (V1.1.1): "ElectroMagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 9: Specific conditions for wireless microphones and similar Radio Frequency (RF) audio link equipment".

[24] ETSI EN 301 840: " ElectroMagnetic Compatibility and Radio Spectrum Matters (ERM); Digital radio microphones operating in the CEPT Harmonized band 1 785 MHz to 1 800 MHz".

[25] Global Standardization Collaboration (GSC) 11th Meeting, Chicago, Illinois, USA, 28 May to 2 June 2006.

[26] ITU-R Recommendation P.372-8 (2003): "Radio noise".

[27] ITU-R Recommendation SM.328-10 (1999): "Spectra and bandwidth of emissions".

[28] ITU-R Working Party 3J /15-E: United Kingdom: Recent measurements of man-made noise in the United Kingdom

[29] ITU-R Working Party 3J /43-E: Israel (State of): Noise level measurements at VHF + UHF for recommendation ITU-R P.372-8: Radio Noise.

[30] ITU-R Working Party 3J /89-E: Norddeutscher Rundfunk (NDR): ITU-R Input Document: "Man-Made Noise in the VHF and UHF Frequency Bands: Results of Indoor Measurements".

[31] ITU Radio Regulations (2004).

[32] Radiocommunications Agency study (2 April 1998): "Investigation into the implementation of digital techniques for Radiomicrophones".

[33] Resolution GSC-11/23 (2006): (GRSC) "Radio Microphones and Cordless Audio Standardization".

[34] The Society of London Theatre: "The Wyndham Report" (1998).

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

audio links: wireless microphones with a transmitter output power level above 50 mW

dBc: decibels relative to the unmodulated carrier power of the emission

NOTE: In the cases which do not have a carrier, for example in some digital modulation schemes where the carrier is not accessible for measurement, the reference level equivalent to dBc is decibels relative to the mean power P.

professional user: person operating in the following employment segments:

- TV / Radio Broadcasting and production
- SAB/SAP
- ENG/OB
- Stage production
- "PA Rentals": companies who rent audio equipment to touring bands, artists, conferences, corporate events, exhibitions and fairs
- Performing artists
- Installations: conference / sport / event centres; city halls, etc.

Service Ancillary to Broadcasting: services that support the activities of broadcast service companies carried out in the production of their programme material

NOTE: See ECC Report 2 [2].

Services Ancillary to Programme making: services that support the activities carried out in the making of programmes

EXAMPLE: Film making, advertisements, corporate videos, concerts, theatre and similar activities not initially meant for broadcasting to general public.

NOTE: See ECC Report 2 [2].

UHF TV Band IV: 470 MHz to 606 MHz

UHF TV Band V: 614 MHz to 790 MHz

wireless microphones: all radio microphones with a transmitter power level up to 50 mW

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AF	Audio Frequency
CEPT	European Conference of Postal and Telecommunications administrations
dB	deciBel
dBm	deciBel relative to one milliwatt
DVB	Digital Video Broadcast
e.i.r.p.	equivalent isotropically radiated power
e.r.p.	effective radiated power
ECC	Electronic Communications Committee
ENG/OB	Electronic News Gathering / Outside Broadcast
GSC	Global Standardization Collaboration
IEM	In-Ear Monitor
IM	Intermodulation Product
ITU-R	International Telecommunication Union - Radiocommunication sector
PAMA	Professional Audio Manufacturers Alliance
PEP	Peak Envelope Power
PMSE	Programme Making and Special Events (UK term)
PWMS	Professional Wireless Microphone System
Rec	Recommendation
RF	Radio Frequency
RR	Radio Regulations [31]
Rx	Receiver
SAB	Service Ancillary to Broadcasting
SAP	Services Ancillary to Programme making
T-DAB	Terrestrial Digital Audio Broadcasting
TV	Television
Tx	Transmitter
UHF	Ultra High Frequency
VCO	Voltage controlled oscillator
VHF	Very High Frequency

4 Executive summary

Introduction

The present document describes the spectrum requirements of Professional Wireless Microphones Systems (PWMS).

Wireless microphone systems for professional applications are used by public and private broadcasters or other professional entities (e.g. content creators) including commercial applications like installations in sport / events centres, musical and theatres, conference centres and city halls. Such applications normally include in-ear monitoring or a simultaneous stereo return channel to the artist and have high audio quality requirements. This means among others AF bandwidth, 100 % duty cycle, very low distortion, smallest transmission delay, transmission quality oriented on studio requirements, Interference-free transmission. In addition, wireless microphone systems for professional applications have an extremely high probability of usage at a given time and location which essentially differentiates them from non-professional wireless microphone usage.

Issue

Before the advent of Digital Video Broadcasting TV services (DVB-T), PWMS used the spectrum in the gaps between analogue TV channels. During the change-over to DVB-T this spectrum is diminishing, whilst at the same time increasing demand is being made on the numbers of PWMS channels deployed, the technical quality of the content and the density of the sites utilizing PWMS. When the digital switch-over has taken place and the released spectrum re-farmed for other services, there will be substantially less spectrum available for PWMS. The recent push, within the EC, for more multimedia content production will only exacerbate the problem with production companies looking to use wireless means to produce programming material.

New solutions need to be identified to satisfy demand. It is proposed that the "tuning range" concept is maintained so that a flexible solution is adopted with spectrum made available where it is needed [10].

Conclusions

The combination of antenna size, equipment size and propagation characteristics mean that UHF spectrum is the only solution for practical PWMS applications in the vast majority of scenarios. VHF can be used, but the antenna and equipment sizes preclude its use in all but a minority of cases.

The existing "tuning ranges" identified in EN 300 422 [20] need to be retained, augmented by the new candidate bands:

- 1 452 MHz to 1 559 MHz ("L band"); and
- 1 785 MHz to 1 800 MHz (presently identified for analogue and digital PWMS).

The close proximity of PWMS transmitters and receivers (e.g. wireless microphone and IEM) means that wide frequency separations are needed to avoid intermodulation products and inter-system interference. The availability of L Band and the 1,8 GHz band will provide that wide separation and ultimately reduce the overall spectrum required at any one site.

Changes may be required to CEPT/ERC Recommendation 70-03 [4], EN 300 422 [20] and perhaps EN 300 454 [21].

4.1 Status of the present document

The present document was created by ETSI TG17 WP3 in July 2006. It has been in the ERM RM consultation process between October and December 2006 with changes being incorporated following comments from ETSI members. ERM RM has received delegation of authority by ERM for the final approval of the document as an ETSI Technical Report. The present document was formally approved for publication as an ETSI Technical Report by ERM RM on 24 December 2006 and is now submitted to WG-FM and WG-SE for consideration.

4.2 Related ETSI and GSC initiatives

Inside ETSI, ERM TG17 has the responsibility to define the user requirements for PWMS. It is planned that EN 300 422 [20], ranging from 25 MHz to 3 GHz, will be revised with new requirements for spectrum masks above 1 GHz.

NOTE: EN 300 454 21 is the applicable standard for Audio Links.

The Global Standardization Collaboration (GSC) agreed on a common global standard for professional audio microphones at their eleventh meeting in June 2006 [25]. It resolved "to facilitate a strong and effective global radio standards collaboration on Radio Microphones and Cordless Audio standardization in a technology-neutral environment" [33]. See http://www.itu.int/itu-t/gsc/index.html for GSC documents.

4.3 Technical system description

For detailed technical information, see annex B.

4.4 Market Information

"The professional radio microphone market continues to expand year on year but the market size is limited due to the high cost of professional equipment (some thousands of Euro per channel). Due to the disparate nature of users and long life of equipment (above 20 years) it is difficult to provide detailed data, but the data collected by the Wyndham Report [34] gives an indication for the UK theatre industry which will be repeated in other European Countries. It is reasonable for the entertainment industry to include within its benefits to GDP the associated direct income from tourism." (Final Report from CEPT in response to the Second EC Mandate on SRDs, clause 6.1.12 [19]).

For detailed market information, see annex A.

5 Current regulations

PWMS are only covered by CEPT/ERC Recommendation 70-03 [4], annex 10 and are referenced by ERC Recommendation 25-10 [3], annex 2. There is no other ECC Decision or Recommendation on PWMS in existence today.

The present document contains existing frequency ranges covered by CEPT/ERC Recommendation 70-03 [4], annex 10, as well as a proposal for a new frequency ranges between 1 452 MHz and 1 559 MHz.

Other frequency bands covered in CEPT/ERC Recommendation 70-03 [4], annex 10 are from 174 MHz to 216 MHz, as well as from 1 785 MHz to 1 800 MHz. However, the range 174 MHz to 216 MHz is considered more and more as being too noisy for fulfilling the high audio quality requirements. Studies in Israel, Germany and the UK have shown the noise levels encountered in the VHF and UHF bands [26], [30], [29] and [28]. It is also to noted that DAB & DVB-T usage is foreseen in the future in this range. In addition, this band is being withdrawn for PWMS in some EU member states to facilitate the further roll-out of T-DAB. See annex C.1.5.

Many European countries use the band 174 MHz to 216 MHz for mobile applications on a primary basis (RR [31] 5 235).

The frequency range from 1 785 MHz to 1 800 MHz is considered too small to completely satisfy demand, the number of available channels not being high enough. In addition, other usage is foreseen in some European countries. Some non-commercial professional audio production applications use this frequency range.

At present the spectrum around 1,8 GHz can be used as follows:

- EN 301 840 [24] is for 1 785 MHz to 1 800 MHz, professional systems, but **digital only.**
    - There are problems with transmission delays, involving both coding delays and forward-error-correction delays. The typical limit for permissible delay is 2ms for live stage performances, etc. This is not possible with today's technology.
    - The available band gives 25 digital channels at 600 kHz. This is not sufficient for even modest stage productions. See annex A.3.1.
    - Not all channels can be used -gaps are needed to avoid mutual interference. This point is illustrated for UHF systems by figure A.2 in annex A.2.2.
- EN 301 357 [22] is for 1 795 MHz to 1 800 MHz analogue and digital, but is for license-exempt cordless audio.
    - There are problems with co-channel interference with license-exempt systems.

Table C.1, in Annex C.1.2, shows an extract from the ECA. Table [7] for the frequency bands in question and Table C.2 shows the current situation regarding national arrangements for PWMS applications for UHF TV bands IV and V.

6 Proposed regulations

The following frequency tuning ranges are proposed:

1) 470 MHz to 790 MHz (used by PWMS on licensed sharing basis with broadcast services);
2) 790 MHz to 862 MHz (possible suggestion for a harmonized PMWS band e.g. on sharing principle);
3) 1 452 MHz to 1 492 MHz (new candidate band);
4) 1 492 MHz to 1 530 MHz (new candidate band);
5) 1 533 MHz to 1 559 MHz (new candidate band); and
6) 1 785 MHz to 1 800 MHz (possible suggestion for a harmonized PMWS band for ENG to avoid conflict potential with PWMS at UHF).

The various typical PWMS users have been categorized as follows:

Table 1: PWMS user categories

User Group 1:	TV / Radio Broadcast stations Media production, including film, video and DVD
User Group 2	TV / Radio productions ENG/OB
User Group 3:	Musical / Theatre installations Fixed installations Conference venues / universities
User Group 4:	"PA Rentals": companies who rent audio equipment to professional touring bands or artists and to large corporate and political events
User Group 5:	Other professional users, such as touring bands or artists who own their own audio equipment

The proposed bands would be utilized as follows:

Table 2: Proposed regulations

Frequency band	Maximum mean power and mean power density	Duty cycle	Channel spacing (see note 5)	Remarks
470 MHz to 790 MHz	50 mW e.r.p.	No restriction	200 kHz	All user groups individual license required (see notes 1 & 2).
790 MHz to 862 MHz	50 mW e.r.p.	No restriction	200 kHz	All user groups individual license required (see notes 1 & 2).
1 452 MHz to 1 492 MHz See NOTE 7	50 mW e.i.r.p.	No restriction	Up to 600 kHz	New candidate frequency band proposed to be added in CEPT/ERC Recommendation 70-03, annex 10 All user groups individual license required.
1 492 MHz to 1 530 MHz and 1 533 MHz to 1 559 MHz	50 mW e.i.r.p.	No restriction	Up to 600 kHz	New candidate frequency band proposed to be added in CEPT/ERC Recommendation 70-03, annex 10 All user groups individual license required. For indoor installations only.
1785 MHz to 1 800 MHz	50 mW e.i.r.p.	No restriction	Up to 400 kHz	All user groups individual license required (see notes 3 and 4).

NOTE 1: 608 MHz to 614 MHz is not usable for PWMS because of difficulties caused by the protection afforded to a Radio Astronomy by Footnote 5.149.
NOTE 2: Some European countries (including the Czech Republic, Belgium, Denmark, France, Germany, Luxembourg, Norway) allow individual license exempt operation by professional entities in this band (or part of it).
NOTE 3: A common radiated power level is proposed for all professional usage cases, whether hand held or body-worn.
NOTE 4: In the Netherlands this band is already licence-exempt.
NOTE 5: The PWMS channel is always at least at a distance of channel spacing/2 from the respective band edge.
NOTE 6: EN 301 840 supports up to 600 kHz bandwidth.
NOTE 7: It should be noted that CEPT is planning to create a project team that will study the options and possibilities for application of mobile multimedia services in the band 1452-1479.5 MHz in accordance with the mandate from the RSC, and provisions for indoor reception, as well as options for the future use of the band 1479.5-1492 MHz

The following points should be noted:

- That consideration should be given to establishing a core harmonized band for PWMS. Harmonization of spectrum usage has two key advantages in this area. Firstly, cross border circulation of professional wireless microphone system equipment is better facilitated and secondly, economy-of-scale in the production line will decrease equipment manufacturing costs.

- The frequency band 470 MHz to 862 MHz is covered by CEPT/ERC Recommendation 70-03 [4], annex 10, which specifies "professional use only -individual licence required". However, it is proposed to change this requirement, in the case of professional broadcasters and professional production companies, to a "lighter licensing" regime. This "lighter licensing" regime is planned to be used during broadcast productions whereas individual licensing is considered more suitable for special event scenarios. This "lighter licensing" regime may include a defined channel planning approach using specific limited spectrum. In this context, article 5 of the EU Authorization Directive [17] which declares preference to license-exempt (or in more general terms a "lighter licensing") usage should be taken into account.

- To ensure portability of equipment and flexibility in frequency assignment, it would be considered an advantage if common utilization conditions for PWMS were to be applied equally to each identified 1,5 GHz band.

- It is proposed that analogue PWMS be permitted in the band 1 785 MHz to1 800 MHz, on a tuning range basis. The band does not completely satisfy the need for spectrum, but would provide a useful number of analogue channels that are well separated in frequency from the UHF and L Bands. That means the frequency separation requirements (e.g. between microphone and in-ear monitor) are already satisfied reducing the amount of spectrum neutralised in any one installation. If this band was not made available, the total spectrum used would be much higher as frequency separation would be needed between physically adjacent systems.

- Following "digital switchover" all DVB-T services will be concentrated in one part of the UHF "TV" spectrum. Together with the increasing demand for, and deployment of, PWMS, this puts an increasing strain on the remaining spectrum and reduces the scope for the operation of PWMS. This is illustrated by figure 1 .

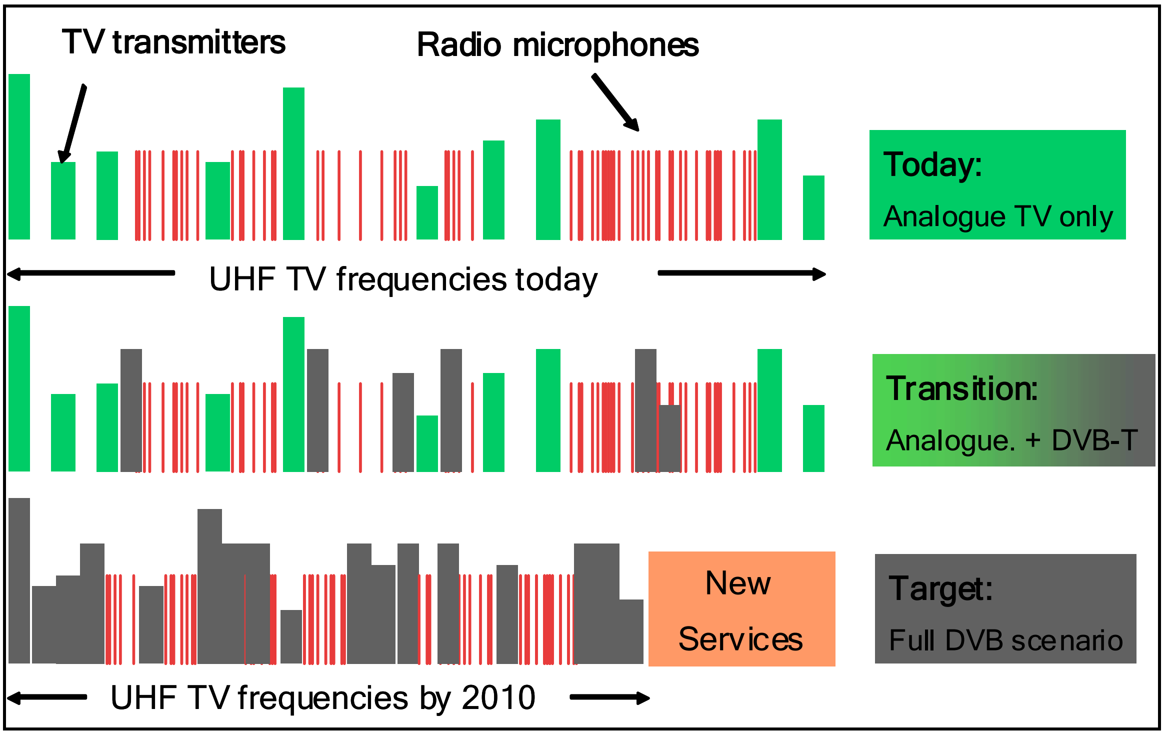


Figure 1: PWMS spectrum availability following digital switch-over

- PWMS traditionally operate in non-primary, non- protected spectrum, however they do require protected spectrum due to the 100% duty cycle and are typically connected to vast sound systems or recorded for radio or TV transmission. To date this protection has been provided by the licensed use of the TV bands 3, 4 and 5 on a geographical restricted basis, but with the switchover to digital TV there is an impending crisis in the industry as the only other spectrum available for large multi-channel systems is in the 1 785 MHz band but does not provide equivalent propagation characteristics or sufficient spectrum.
(Final Report from CEPT in response to the Second EC Mandate on SRDs, clause 6.1.12 [19])

- Frequencies above about 1 800 MHz are unusable due to higher propagation losses and body absorption. There are no PWMS above 1 800 MHz in existence today. Use of spectrum above this band will have EMF implications for users.

- RSPG Opinion #5 [16] on the introduction of multimedia services in broadcasting bands concluded that in the band 1 452 MHz to 1 479,5 MHz (L band), the Maastricht Special Arrangement (introduction of Digital Audio

Broadcasting) seems unduly restrictive and should therefore be reviewed urgently to ensure that other technologies and services are not unduly precluded from use of the band.

- A recent European Parliament decision [18] was made that at least 51 % of programming should be made in Europe. Similar legislation is believed to be proposed for France.
- Various estimates put the present level of European programme making as low as 10 %. This decision would, therefore, herald a dramatic increase in the use of radio microphones for SAB and SAP within Europe as well as a similar increase in the roaming requirements for these devices.
- Occasionally radiated powers in excess of 50mW are needed, for instance to cover sporting events or productions within buildings with highly absorbent walls. In these cases Audio Links are required and these are authorized on a case-by-case basis by the relevant national regulatory authority. This situation exists at present and no changes are envisaged.
- The growth of digital TV broadcasting in the UHF band creates much more difficult intermodulation scenarios for PWMS. In fact, wireless microphone applications operate in small gaps between multi carrier TV channels and have to bear more than about 13000 intermodulation carriers close to these gaps. It is this interference model that has to be considered by future radio frequency resource planning. In consequence, intermodulation in receivers means that the channels in use must be separated, which increases the frequency requirement. On the other side, a continuous band usage for PWMS is easier to handle than multiple smaller bands with digital TV in the adjacent frequencies, especially in terms of intermodulation scenarios and hardware requirements.

7 Main conclusions

PWMS are intended for use in the entertainment industry and installation industry by professional bodies involved in Musical / Theatre / stage productions, public events, sporting events, programme production (including television, multimedia, video, MP3, CD and DVD), public and private broadcasters or other professional entities.

The spectrum available for PWMS following digital switch-over will be vastly reduced and the demands on PWMS systems, both in terms of the required numbers of channels and the system capacity, are increasing.

PWMS can operate in non-primary, non-protected spectrum, but do require exclusive use of the radio spectrum at the site of operation, due to their 100 % duty cycle and the conditions of operation.

Consideration should be given to establishing a harmonization band for PWMS to better facilitate cross border circulation of professional wireless microphone system equipment and to increase economies-of-scale in production .

Extra Tuning Ranges should be identified in the L Band frequency range for use by PWMS.

The 1,8 GHz wireless audio band should be retained for PWMS, but it should also be recognized that this cannot, on its own, satisfy the demand for PWMS channels.

That power levels of all PWMS should be the same as those in the new revision of CEPT/ERC Recommendation 70-03 [4].

8 Expected ECC and ETSI actions

ETSI requests ECC to consider the present document, which includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT).

It is proposed that ECC considers the proposed regulation in clause 6 and identifies includes the proposed new frequency tuning ranges as indicated in CEPT/ERC Recommendation 70-03 [4], annex 10.

Furthermore, it is proposed that the ECC creates a revision of the ERC Recommendation 25-10 [3] to further ensure that the radio spectrum requirements for professional audio microphones are met now and in the future.

Sharing studies for the indicated new candidate band for professional wireless audio microphones in the bands from 1 452 MHz to 1 492 MHz, 1 492 MHz to 1 530 MHz and 1 533 MHz to 1 559 MHz are proposed.

ETSI would appreciate if the ECC could finalize the new deliverable(s) by mid 2007.

ETSI would revise EN 300 422 [20] and EN 300 454 21 to encompass parameters and spectrum identified by the sharing studies.

Annex A: Detailed market information

A.1 Applications

PWMS are intended for use in the entertainment industry by professional bodies involved in stage productions, public events, TV programme production, public and private broadcasters or other professional entities.

The quality requirements for the audio coverage are very high starting with CD quality.

A.1.1 Application categories

The difference between Professional and General (consumer) applications is defined as follows:

Table A.1: Application categories

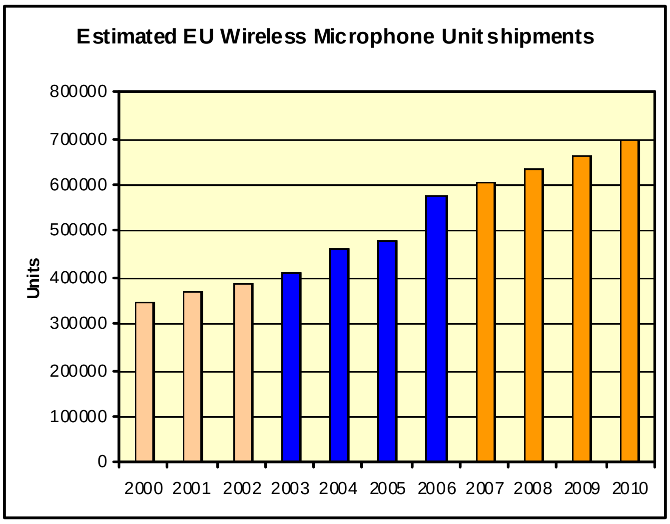
Attribute	PWMS	General audio applications
Application type	High quality, real-time and time-synchronized sound and voice recording including talk-back links (IEMs) with very high reliability	Sound and voice recording with reduced quality and reliability on used frequency band
Quality and performance of radio frequency channels	License-based operation by radio frequency assignment Based on The Chester Agreement [13] operation in the VHF and UHF broadcast bands on secondary basis Careful planning of large events and Early involvement of the responsible authorities	License-exempt operation on harmonized or ISM frequency bands e.g. 863 MHz to 865 MHz, 1 785 MHz to1 800 MHz or 2 400 MHz License free bands due to national regulations (e.g. Germany) or designated frequencies (like UK shared CH69) Quality of radiofrequency link not guaranteed
Quality requirements	The usable quality permits high-quality audio production	The available quality permits high-quality audio production only in few cases. Nevertheless the distribution of voice and music is well possible
Duty cycle	100 % - Frequency sharing impossible	Up to 100 % - Reduced frequency sharing is conceivable
Delay (back to back)	As short as possible (<20ms)	Typically up to 300ms
Investment opportunity	Users ready to invest, depending on: the application configuration the perceived value of the system	Users reluctant invest because of: low cost environment based on standardized set-ups low perceived value of systems
Typical production	Individual manufacturing up to series production. Expensive auxiliary components guarantee sound quality and reliability	Series production up to mass-market production. Careful component selection permits favourable prices
Support from manufacturer and/or distributor (pre and after sales)	Often intensive co-operation between manufacturer and customer is established during an extended period of planning and execution Individual assistance with installation and sound check of the system Support for maintenance and service	General application instructions and assistance for customer Standardized information e.g. user manuals, via Internet, etc.

Attribute	PWMS	General audio applications
User's competence	Often expert users, though perhaps with limited knowledge of radio frequency technology Assistance often available through specialized application experts Sometimes specialist rental companies are used, who take care of the customer's application	Mainly interested in just using the wireless microphone for the application in hand Users set up equipment themselves
Examples for typical areas of application	- Broadcast and TV production - Events with high public interest and/or large audience - Large corporate and political events - Live music events - National and international sport events "News gathering teams" - Presenters in large conference venues - Spectacles, operas, musicals or concerts in theatres and churches	- Churches - Coach trips - Conferences - Corporate events - Daily business applications - Events with low public interest and/or small audience - Exhibitions and fairs - Internet audio recording - Residential environment - Sales meetings - Tour guide systems

Note: Some applications could be assigned both columns.
For PWMS number of simultaneously used channels and number of spectators are typically higher. However the used frequency band and license principle limits the sound quality.

A.2 Market size

1997 UK theatre receipts: 589 million Euro. For London the increase in tourist expenditure was calculated at 618 million Euro. These figures are borne out by similar studies in New York.
(Final Report from CEPT in response to the Second EC Mandate on SRDs, clause 6.1.12 [19])



NOTE 1: Results of market research initiatives executed by PAMA, the Professional Audio Manufacturers Alliance (http://www.pamalliance.org), show an estimated total of 1 924 431 wireless microphone unit shipments for the European Union over the past four years. The estimated annual growth for the years before 2003 and after 2006 is 5 %.

NOTE 2: This figure shows quantities of shipped wireless microphones, working licensed based (e.g. in the UHF band) or under licence exemption in harmonized and ISM bands.

Figure A.1: Estimated EU Wireless Microphone Unit Shipments

A.2.1 Markets covered

The primary markets initially targeted are in Europe. A European solution could be an example for the world wide harmonization process.

A.2.2 Market forecast

For the foresee-able future there will continue to be a requirement for analogue PWMS.

It is possible that combined wireless microphone / IEMs will be developed in the future, which will be covered by existing standards.

A.2.2.1 In-Ear Monitors

A few years ago it was thought that there would be a top limit to the number of frequencies used in one location. This would be governed by the number of channel faders on the mixing desk! However, two things have changed that.

1) Musical shows particularly are moving towards 1 IEM for each artist. Sometimes it may be a case of one frequency with dozens of receivers (Olympic opening ceremony for instance), more often though each artist wants their own individual feed.

2) "In Vision" presenters prefer an IEM over a walkie-talkie for their cue feed. A lot of presenters use "open" talkback and the bandwidth of an IEM (approximately 200 kHz) is easier to listen to for long periods than a walkie-talkie (12,5 kHz). For loud sports the feed is in both ears using custom moulded earpieces. 12,5 kHz quality would be impossible in that sort of situation.

NOTE: Source: Charter Broadcast UK.

A.2.2.2 Wireless Microphones

A.2.2.2.1 Present

The limit on the number of frequencies used to depend on the size of the mixing desks (i.e. the larger the mixing desk, the smaller the paying audience), but modern mixing systems are now usually computer controlled so removing this limitation. The nature of TV production has also changed dramatically from fixed stage productions to, for instance, "manor house" productions, like "Fame Academy". In this case, various manor houses have been used, and usually the walls are thick enough that 6 or more receive sites would only just cover all the areas covered by cameras. If you have 12 artists you are in a situation where each receive site needs separate channels on the mixing desk, meaning that you need 72 microphone channels on the mixing desk. Figure A.2 illustrates the effect on the spectrum required to operate multi-channel PWMSs, whilst sharing with analogue TV systems, taking into account intra-PWMS intermodulation products.

The majority of wireless microphone use is for live performances. These by their very nature cannot be repeated and therefore it is now common for major artists to carry more than one wireless microphone to provide backup in case of equipment failure.

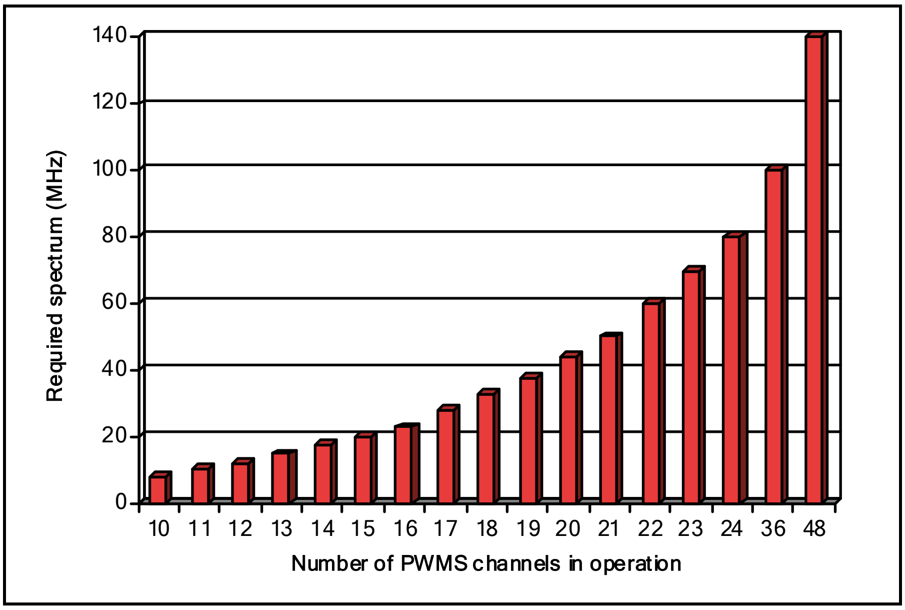


Figure A.2: Required spectrum vs. numbers of channel in Intermodulation free operation

In addition, many programmes are now covered by more than one Broadcast channel. As an example, in the UK, most BBC1 programmes feature on BBC3 and ITV reality programmes (e.g. "Big Brother") are broadcast on ITV1 and ITV3. Separate presenters are used for each and they all require a personal wireless microphone , an IEM, *and* a hand-held wireless microphone for one-to-one interviews. Some programmes, whilst not shared with other TV channels, are also "streamed" to the web and so require similar facilities.

A.2.2.2.2 Future

The high cost of wireless microphones used to limit the number in use in any production. The higher budgets, complexity of production and world-wide distribution of the programmes, means that the original financial restrictions no longer apply and that the number of wireless microphone channels for any individual programme continues to rise. Increasingly, there is a requirement for live sound effects to be picked up (e.g. horse sounds, skiing sounds).

The introduction of high definition TV and its multiple channels sound reproduction also requires additional wireless microphones to achieve the results required by programme makers.

A.2.3 Audio Links

During the initial preparation of wireless microphone standards, it was agreed, due to the national regulation in place, that wireless microphones would be considered devices with a power output of less than 50mW. It was recognized that the range of activities such as outside broadcast, golf, sporting events and similar activities, required a greater range and in some cases, such as golf tournaments, required both a higher power wireless microphone to go to an accompanying vehicle plus a link from that vehicle to the outside broadcast control point. Developments in programme making increasingly require a higher power than 50mW in order to provide coverage in either complex buildings or to provide longer range for the artist.

NOTE: See annex B.4.3 Absorption in walls.

A.3 Traffic evaluation

Wireless audio systems have very high quality requirements. The maximum operating distances are typically not more than 100 metres.

Typical deployment scenarios for special events are illustrated in clause A.3.1. These productions would not be possible without the use of PWMS.

A.3.1 Examples of typical deployment scenarios

The numbers of channels deployed in recent TV productions were as follows:

A.3.1.1 Comic Relief Fame Academy

UK, indoor

- 60 wireless microphone channels - a dozen or so were for use during the performances, the rest for presenters and participants, 2 presenters for BBC1 and 2 different presenters for BBC3. All the "reality" microphones (not used specifically for performance on stage) could be received by any of the 16 pairs of antennas located across 3 floors of the house.
- Each presenter required a separate IEM feed. This is usually done by providing a high power (1Watt) central feed.

A.3.1.2 The Games

UK, indoor / outdoor

- 24 wireless microphones.
- 3 x 1 Watt IEMs.
- Based in a stadium in Sheffield with 12 antennas, covering the pitch, the changing rooms and accommodation. 3 other locations, one of which was in Northampton for water ski-ing, and they originally wanted a wireless microphone on each water skier.

A.3.1.3 The Farm

UK, outdoor

- 24 wireless microphone for contestants over a very large area.
- 2 high power IEMs.

A.3.1.4 Springwatch

UK, outdoor

- 6 wireless microphones.
- 2 IEMS at nearly 2 Watts.
- Coverage of the wireless microphone spreads across a huge area.

A.3.1.5 The Match

UK, outdoor

Has a "reality" part for 2 weeks in one location using:

- 30 transmitters.
- 3 IEMs.
- The "Final" moves to another location.

A.3.1.6 Only Fool on Horses

UK, indoor / outdoor

The programme is being made at an equestrian centre with indoor and outdoor arenas and uses:

- Site Wide IEMS (1 watt).
- 4 wireless microphones for BBC1.
- 4 wireless microphones for BBC3.
- 20 wireless microphones for contestants.
- 12 wireless microphones for horses (yes horse heavy breathing!).
- 16 antennas for site wide coverage.

A.3.1.7 Phantom of the Opera

UK, indoor

- 22 wireless microphones.
- 2 IEMs / talkback channels.

A.3.1.8 Festspiele Bregenz

Austria, indoor / outdoor

- 48-88 wireless microphones.
- 16 IEMs.
- 150000 spectators per year.

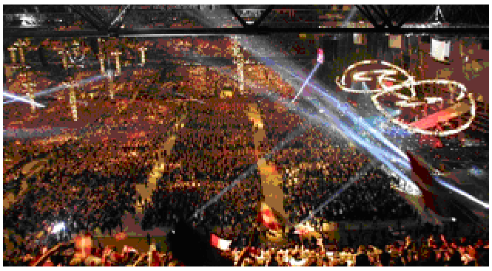
A.3.1.9 Seefestspiele Mörbisch

Austria, outdoor

- 32 wireless microphones.
- 12 IEMs.
- 215 000 spectators per year.

A.3.1.10 Eurovision Song Contest

Places of event:



1) 2001: Kopenhagen, Parken Stadion.
2) 2002: Tallinn, Saku Suurhall.
3) 2003: Riga, Skonto-Olympia Hall.
4) 2004: Istanbul, Abdi Ipekci Spor Salonu.
5) 2005: Kiew, Palats Sportu.
6) 2006: Athens, Olympic Stadium.

- Typically 48 active microphone channels on stage.
- Typically 16 IEM on stage.
- Additional wireless microphones off-stage and outdoor operation.
- Careful frequency planning employed to reduce required UHF resource.
- High potential for high levels of man-made noise due to installed stage effect applications.
- Very high collision potential with "On tour applications".
- Up to 250 million spectators per event.

Figure A.3 shows the web site activity and voting figures for the 2006 song contest and figure A.4 shows the viewing figures in several of the Eurovision countries.

NOTE: Source: EBU Press Release [14].

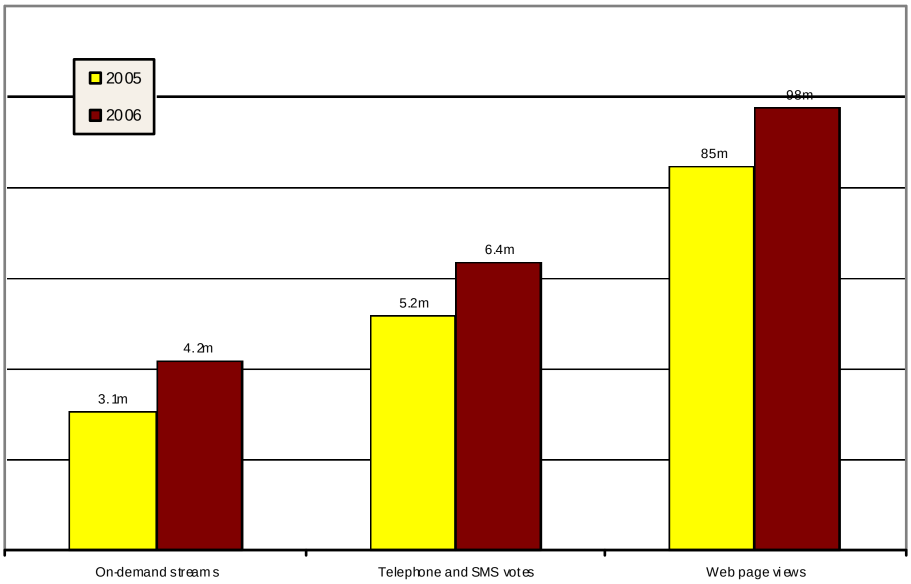


Figure A.3: Eurovision Song Contest Web site statistics

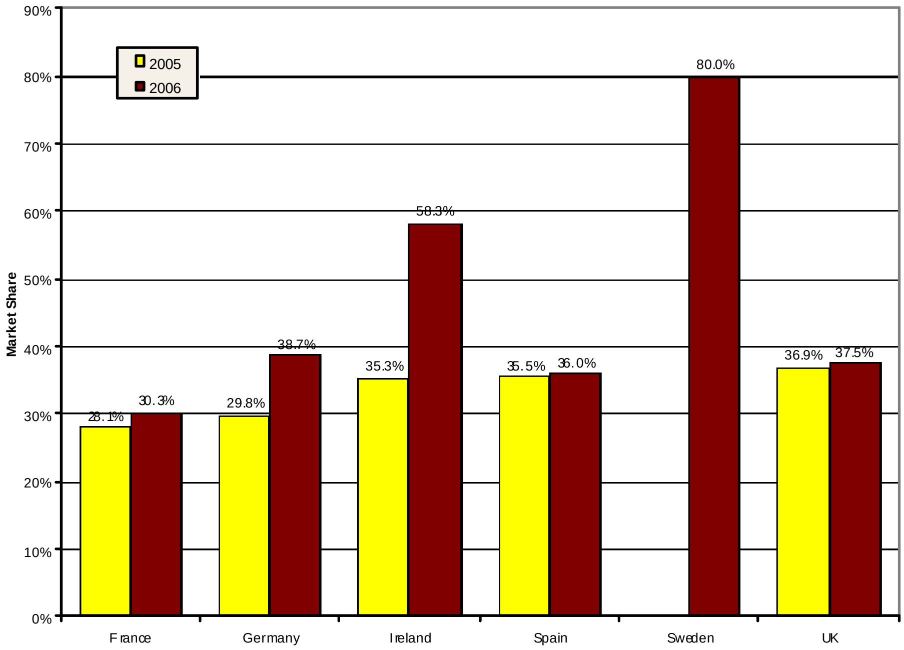


Figure A.4: Eurovision Song Contest Viewing figures

A.3.1.11 Olympics, 2004

Athens, indoor / outdoor

- 3 535 wireless microphones on 527 channels.
- 241 IEMs on 71 channels.
- 976 talkback systems on 423 channels.

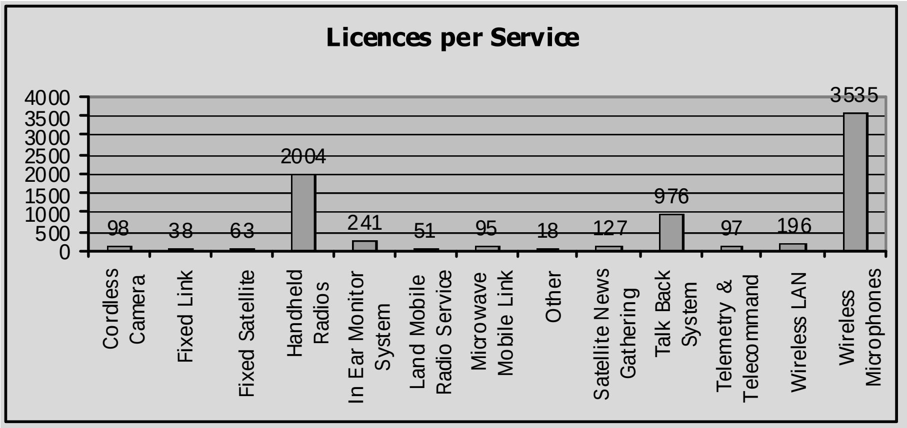


Figure A.5: Licenses per service, Athens Olympics 2004

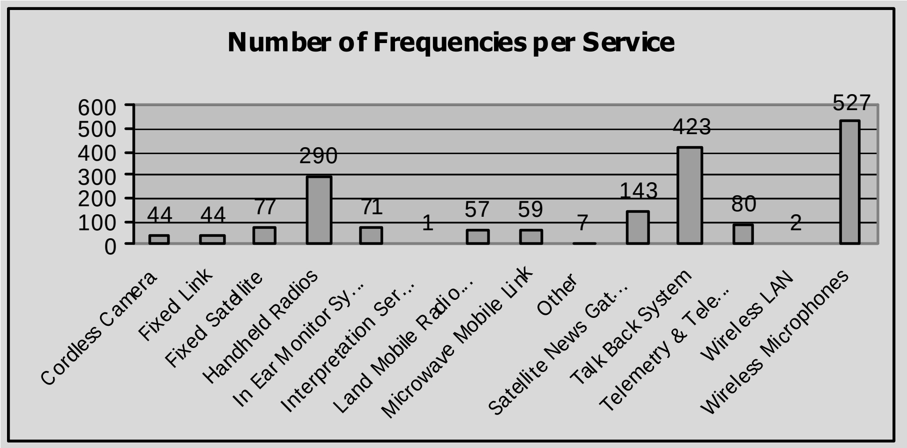


Figure A.6: Number of frequencies per service, Athens Olympics 2004

NOTE: (Final Report from CEPT in response to the Second EC Mandate on SRDs, clause 6.1.12 [19])

A.3.1.12 Domstufen Erfurt

Germany, August 2006, Outdoor, free open-air opera

- 86 wireless microphones simultaneously.
- no IEMs.

A.3.1.13 Musical production Elizabeth / Mamma Mia

Germany, indoor installation

- 36 microphones simultaneously.
- no IEMs.

A.3.1.14 Best of Musical

Germany, indoor - tour throughout Germany

- 25 microphones.
- 10 IEM simultaneously.

A.3.1.15 Deutsche Leichtathletikmeisterschaften

Germany, indoor - tour throughout Germany

- 50 microphones
- 15 IEM simultaneously

A.3.1.16 "News gathering team" at Vienna airport

Austria, indoor / outdoor

- Up to 3 microphones.
- Up to 3 IEM simultaneously.
- Very fast suburban deployment.
- No frequency planning possible.
- Possibility of high levels of local interference.
- Lack of time for frequency planning means there is a high probability of co-channel collision with third parties.
- This application requires a separated frequency assignment to avoid collisions. The best solution would be a Europe-wide harmonized frequency band.

A.3.1.17 "Production on tour" (e.g. production of documentary films)

Germany, indoor / outdoor

- Up to 5 microphones.
- No IEMs.
- Very fast suburban deployment.
- Only simple frequency planning possible.
- Possibility of high levels of local interference.
- Lack of time for frequency planning means there is a high probability of co-channel collision with third parties.

- This application requires a separated frequency assignment to avoid collisions. The best solution would be a Europe wide harmonized frequency band.

A.3.1.18 BRITs 2006

UK, indoor

- On stage:
  - 12 microphones.
  - 6 IEMs.
- In studio:
  - 14 Microphones.
- "Red Carpet":
  - 4 microphones.

A.3.1.19 Comic Relief 2005

UK, indoor / outdoor

- 34 microphone channels.
- 6 IEM channels.
- 3 duplex studio talkback channels.
- 4 simplex studio talkback channels.

A.3.1.20 HRH Birthday Party @ The Palace 2006

UK, outdoor

- 43 microphones.
- 3 IEMs.

A.3.1.21 "How Do You Solve a Problem Like Maria"

Episodes 6 - 8 and 11 - 12,

UK, indoor

- 33 microphones.
- 3 IEMs.
- 2 duplex studio talkback channels.
- 3 simplex studio talkback channels.

A.3.1.22 "Prince's Trust" Concert 2006

UK, outdoor

- 44 microphones

A.3.1.23 Tour de France

France, outdoor
(Source: http://www.letour.fr/2005/presentationus/chiffres.html)

The Tour by numbers

1) **Followers**
   - 4 500 accompanying people
   - 1 500 vehicles
2) **Organization**
   - 60 permanent staff
   - 200 temporary staff
   - 180 service providers
   - 14 medical staff
   - 1 200 rooms reserved daily
3) **Security**
   - 13 000 "gendarmes"
   - 45 "gardes républicains"
   - 9 000 police staff & CRS
   - 3 000 government officials from the Ministère de l'Équipement
   - 10 policemen for the Permanent Mission
4) **Publics**
   - 15 million spectators
   - Men: 68 % - Women: 32 %
   - 71 % under 50
   - 42 % under 34
   - 76 % of French people have once attended the Tour
   - Brand recognition: 96 % in France, 90 % in Europe
   - 3 0% of foreign spectators in the mountain stages
   - 22 various nationalities

5) **Publicity caravan**

- 200 vehicles
- 40 brand names represented
- 11 million gifts distributed

6) **Media**

- 2 300 accredited journalists
- 1 200 journalists, photographers, cameramen & TV directors
- 1 100 technicians or chauffeurs
- 528 various media

7) **TV broadcasting**

- 78 channels in 170 countries
- 2 billion viewers
- 2 400 hours of TV coverage

8) **Internet**

- 350 million pages viewed (+17 % vs. 2003)
- 7,7 million visitors

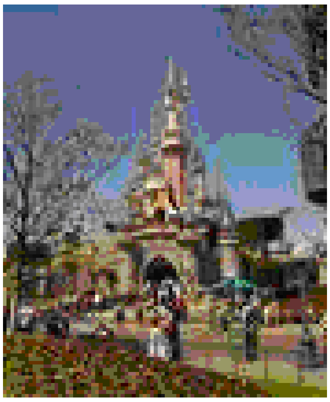
9) **Radio frequency resources**

- At least 1 000 wireless microphones used daily.

A.3.1.24 La Plaine Saint Denis

- France, indoor
- High concentration of TV studios
- 40 studios at the same place!
  It is the hottest fixed spot in France for RF microphones.
- Producing the biggest TV shows in France, like Star Academy.
- An average of 400 wireless microphones are used daily.

A.3.1.25 Disneyland Paris



- France, indoor & outdoor
- Located in Marne la Vallée.
- Wireless microphones are used all over the Theme Parks
  to produce music shows, outside animation, the daily parade…
- 200 wireless microphones are used daily.

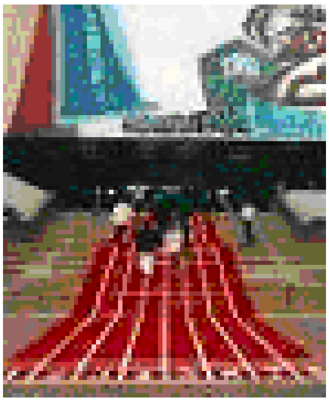
A.3.1.26 14th of July event

- France, outdoor
- Hundreds of military troops are playing music along the boulevard.
- Yearly event on the Champs Elysées in Paris.
- Big challenge because of the Eiffel Tower broadcasting 450 kW in UHF band.
- Around 150 wireless microphones at the same place.
- High ENG operation activities

A.3.1.27 Johnny Hallyday tour in France

- France, indoor
- Biggest concert in France.
- 100 concerts around the French territory.
- 80 wireless microphones and ear monitors

A.3.1.28 Cannes film festival



- France, indoor
- Yearly event in Cannes in May. TV crews from around the world.
- 80 wireless microphones minimum
- High ENG operation activities

A.3.1.29 SFP TV production

- France, indoor
- TV production company.
- Located in Bry sur Marne.
- At least 50 microphones used daily for TV production.

A.3.1.30 Palais des congrès de Lyon

- France, indoor
- 40 wireless microphones, used daily for congress.

A.3.1.31 Musical "Heidi Walenstadt"

Switzerland, outdoor

- 22 microphone channels
- 4 IEM channels

A.3.1.32 "Tell Festspiele Altdorf"

Switzerland, indoor

- 32 microphone channels

A.3.1.33 Jazz Festival Montreux

Switzerland, indoor

- 60 microphone channels
- 20 IEM channels

A.3.1.34 Phil Collins European Tour

Switzerland, indoor

- 16 microphone channels
- 10 IEM channels

A.3.1.35 Theater Basel

Switzerland, indoor

- 16 microphone channels
- 10 IEM channels

A.3.1.36 Theater Bern

Switzerland, indoor

- 20 microphone channels

A.3.1.37 Casino Theater "Winterthur"

Switzerland, indoor

- 16 microphone channels

A.3.1.38 Fêtes des vignerons Vevey

Switzerland, outdoor

- 80 microphone channels

A.3.1.39 FIFA Zürich

Switzerland, outdoor

- 20 microphone channels

A.3.1.40 SwissRe Zürich

Switzerland, indoor

- 50 microphone channels

A.3.1.41 "Novartis Basel

Switzerland, indoor

- 50 microphone channels

A.3.1.42 WEF Kongresszentrum Davos

Switzerland, indoor

- 28 microphone channels

A.3.1.43 Universitäten Fribourg, Bern, Basel Genf, St. Gallen, Luzern Yverdon, Lausanne

Switzerland, indoor / outdoor

- 1500 microphone channels

A.3.1.44 Conclusion

The challenges for all of these type of jobs is to find enough available spectrum to fit in the number of channels required on an intermodulation-free basis. Each location is different so there is no standard set of channels. For multi-location jobs (e.g. The Games) it is not always possible to use the same frequencies in each location - this means more equipment.

After digital switch-over it will become even more difficult to find useable channels.

A.3.2 Audio links

The other area in which there is growth, is audio links (high power wireless microphones). Quite often 1 watt transmitters are used, mainly at sporting events. Golf was once covered with effects microphones at every hole, which meant a cable to every hole. Now this is done by radio. Sometimes 2 receive sites are used but generally hi-gain antennas on a well sighted elevated platform will cover the entire course. Local radio also use high power wireless microphones for soccer or horse racing, and they have been used for radio coverage at Chelsea and other Flower shows.

NOTE 1: See annex B.4.3 Absorption in walls.

NOTE 2: See annex B.1 Detailed technical description .

Annex B: Technical information

B.1 Detailed technical description

See attachment 2: "Receiver Parameters Below 1GHz ".

For the purposes of wireless microphones, a minimum building attenuation of 6dB should be considered.

Table B.1: System parameters, wireless microphones (up to 88 simultaneous channels)

Parameter	Value	Comments
Frequency stability	20 ppm below 1GHz, 15 ppm between 1 GHz and 2 GHz and 10 ppm above 2 GHz.	As in EN 300 422 [20] (current new draft) Derived from limit in EN 300 422 [20]
Maximum radiated power	Below 1 GHz: 50 mW e.r.p. Above 1 GHz: 50 mW e.i.r.p.	Typical operating distance up to 200 m
Antenna beam shape/gain	Transmitter - omnidirectional. Receiver - directional or omnidirectional.	
Examples of typical Modulation schemes	QPSK FM	Modulation schemes currently used by wireless professional microphones systems
Dynamic range	Above 100 dB	
Typical channel bandwidth	Below 1 GHz: 200 kHz, Above 1 GHz: up to 600 kHz	Below 1 GHz, 200 kHz has been retained for compatibility with existing equipment Above 1 GHz, more than 200 kHz is required: • *To improve dynamic range* • *Because, in digital systems, the requirements of lip-sync mean that compression can*not be used
Communication mode	Continuous carrier, 100% duty cycle	Due to the multi-channel nature of these systems, all devices are switched on prior to a performance and only switched off after the end of the performance. This is also due to the intermodulation permutations of a multi-channel system and the possibility of acoustic shock if intermodulation products are reproduced over high power audio reproduction systems.
IM (receivers)	>35 dB	
Typical minimum sensitivity, BER, noise figure, etc.	Below 1 GHz: -90 dBm	Depending on channel width and modulation technique.
NOTE: Parameter not known for frequencies above 1 GHz. To be determined.		

Table B.2: System parameters, body-worn audio links (typically up to 6 simultaneous channels)

Parameter	Value	Comments
Frequency stability	20 ppm below 1GHz, 15 ppm between 1 GHz and 2 GHz and 10 ppm above 2 GHz.	As in EN 300 422 [20] (current new draft) Derived from limit in EN 300 422 [20]
Maximum radiated power	Below 1 GHz: Up to 500 mW e.r.p. Above 1 GHz: 500 mW e.i.r.p.	Typical operating distance up to 500 m
Antenna beam shape/gain	Transmitter - omnidirectional. Receiver - directional or omnidirectional	
Examples of typical Modulation schemes	QPSK and higher FM	Modulation schemes currently used by wireless professional microphones systems
Dynamic range	Above 100 dB	
Typical channel bandwidth	Below 1 GHz: 200 kHz, Above 1 GHz: up to 600 kHz	Below 1 GHz, 200 kHz has been retained for compatibility with existing equipment Above 1 GHz, more than 200 kHz is required to enable non-compressed audio transmission without delay to guarantee lip-sync
Communication mode	Continuous carrier, 100 % duty cycle	Due to the multi-channel nature of these systems, all devices are switched on prior to a performance and only switched off after the end of the performance. This is also due to the intermodulation permutations of a multi-channel system and the possibility of acoustic shock if intermodulation products are reproduced over high power audio reproduction systems
IM (receivers)	>35 dB	
Typical minimum sensitivity, BER, noise figure, etc.	Below 1 GHz: -85 dBm	Depending on channel width and modulations technique.
NOTE: Parameter not known for frequencies above 1 GHz. To be determined.		

Table B.3: System parameters, IEM

Parameter	Value	Comments
Frequency stability	20 ppm below 1GHz, 15 ppm between 1 GHz and 2 GHz and 10 ppm above 2 GHz.	As in EN 300 422 [20] (current new draft) Derived from limit in EN 300 422 [20]
Maximum radiated power	Below 1 GHz: Up to 500 mW e.r.p. Above 1 GHz: Up to 500 mW e.i.r.p.	Typical operating distance up to 200 m
Antenna beam shape/gain	Transmitter - omnidirectional. Receiver - directional or omnidirectional	
Examples of typical Modulation schemes	QPSK FM	Modulation schemes currently used by wireless professional microphones systems.
Dynamic range	Above 100 dB	
Typical channel bandwidth	Below 1 GHz: 200 kHz, Above 1 GHz: up to 600 kHz	Below 1 GHz, 200 kHz has been retained for compatibility with existing equipment Above 1 GHz, more than 200 kHz is required to enable non-compressed audio transmission without delay to guarantee lip-sync .
Communication mode	Continuous carrier, 100% duty cycle	Due to the multi-channel nature of these systems, all devices are switched on prior to a performance and only switched off after the end of the performance. This is also due to the intermodulation permutations of a multi-channel system and the possibility of acoustic shock if intermodulation products are reproduced over high power audio reproduction systems.
IM (receivers)	>35 dB	
Typical minimum sensitivity, BER, noise figure, etc.	Below 1 GHz: -85 dBm	Depending on channel width and modulations technique.
NOTE: Parameter not known for frequencies above 1 GHz. To be determined.		

Table B.4: System parameters, Audio Links

Parameter	Value	Comments
Frequency stability	20 ppm below 1GHz, 15 ppm between 1 GHz and 2 GHz and 10 ppm above 2 GHz.	As in EN 300 422 [20] (current new draft) Derived from limit in EN 300 422 [20]
Maximum radiated power	Below 1 GHz: 500 mW e.r.p. Above 1 GHz: 500 mW e.i.r.p.	Typical operating distance up to 200 m
Antenna beam shape/gain	Transmitter - omnidirectional. Receiver - directional or omnidirectional	
Examples of typical Modulation schemes	QPSK FM	Modulation schemes currently used by wireless professional microphones systems.
Dynamic range	Above 100 dB	
Typical channel bandwidth	Below 1 GHz: 200 kHz, Above 1 GHz: up to 600 kHz	Below 1 GHz, 200 kHz has been retained for compatibility with existing equipment Above 1 GHz, more than 200 kHz is required to enable non-compressed audio transmission without delay to guarantee lip-sync .
Communication mode	Continuous carrier, 100% duty cycle	Due to the multi-channel nature of these systems, all devices are switched on prior to a performance and only switched off after the end of the performance. This is also due to the intermodulation permutations of a multi-channel system and the possibility of acoustic shock if intermodulation products are reproduced over high power audio reproduction systems.
IM (receivers)	>35 dB	
Typical minimum sensitivity, BER, noise figure etc.	Below 1 GHz: -90 dBm	Depending on channel width and modulations technique.
NOTE: Parameter not known for frequencies above 1 GHz. To be determined.		

B.2 Production chain

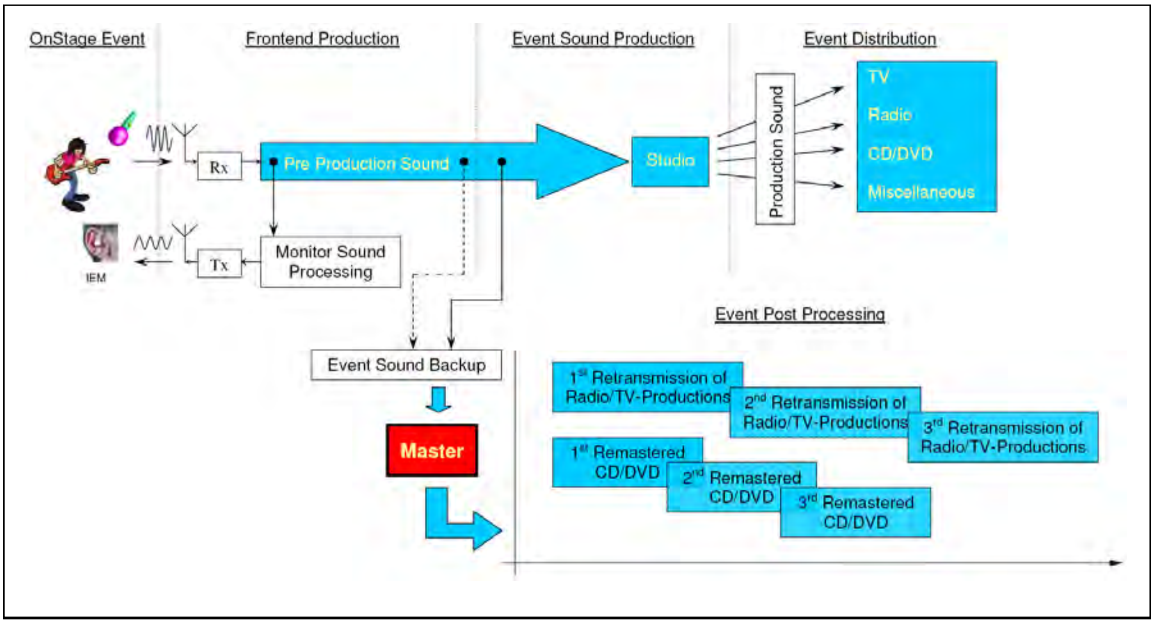


Figure B.1: Typical production chain

Figure B.1 shows the idealized operational sequence of a sound production. The actual event happens only a single time. Subsequent sound production and reproduction will repeat the performance many times. It is important to understand that whatever happens at the front-end will have effects over many years. One can assume the larger part of the creation of value will occur after the event. This must be taken into account with each regulatory decision!

B.3 Limits for RF parameters

The requested radiated power limit (e.r.p. and e.i.r.p.) is shown in table B.5.

Table B.5: Maximum e.i.r.p. values

Maximum e.r.p./ e.i.r.p. values	
Radiated power (e.r.p./e.i.r.p.)	50 mW (mean)
Mean power density	n/a n/a

NOTE: Radiated power levels for multi carrier modulation systems above 1 GHz are still to be determined.

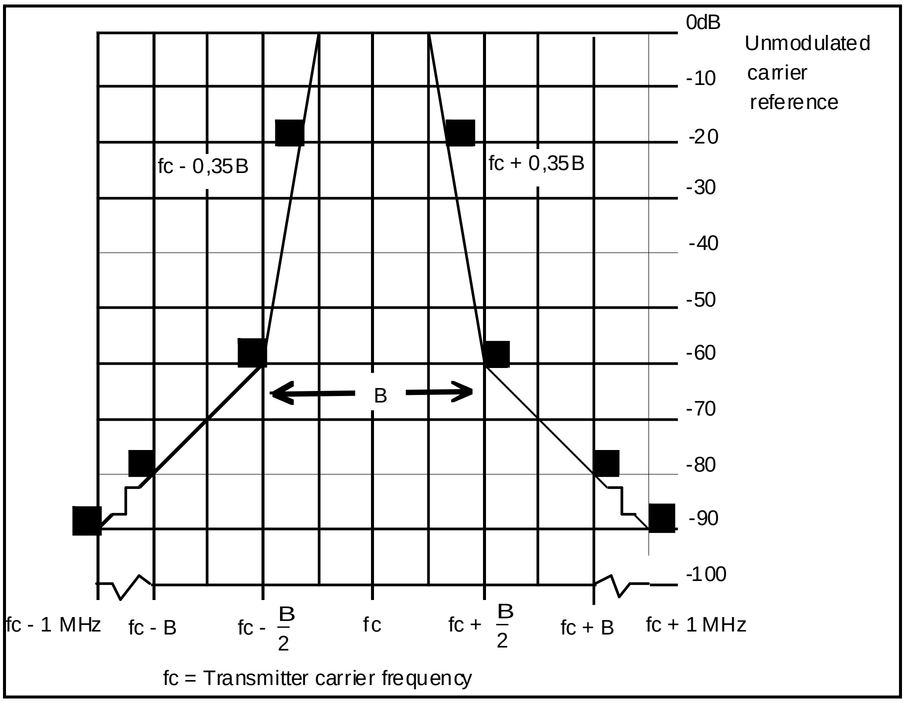
B.3.1 Out-of-Band emission masks

Table B.6 and Figure B.2 provide the details of the spectrum mask for analogue systems.

Table B.6: Break points of spectrum limit mask for analogue systems in all bands

Frequency relative to the centre of the channel	Relative level (dBc)
-1 MHz	-90
-B	-80
-0,5B	-60
-0,35B	-20
-0,25B	0
0,25B	0
0,35B	-20
0,5B	-60
B	-80
1 MHz	-90

Where B = the Necessary Bandwidth.



NOTE:1: The test modulation and test conditions for these masks are as defined in EN 300 422 [20].
NOTE 2: The analogue mask is already defined in EN 300 422 [20] and will not be changed.
NOTE 3: A broader spectrum mask is suggested for above 1 GHz because of the higher frequency tolerances involved.
NOTE 4: VCO phase and wideband noise above 1 GHz increases by approximately 6 dB.

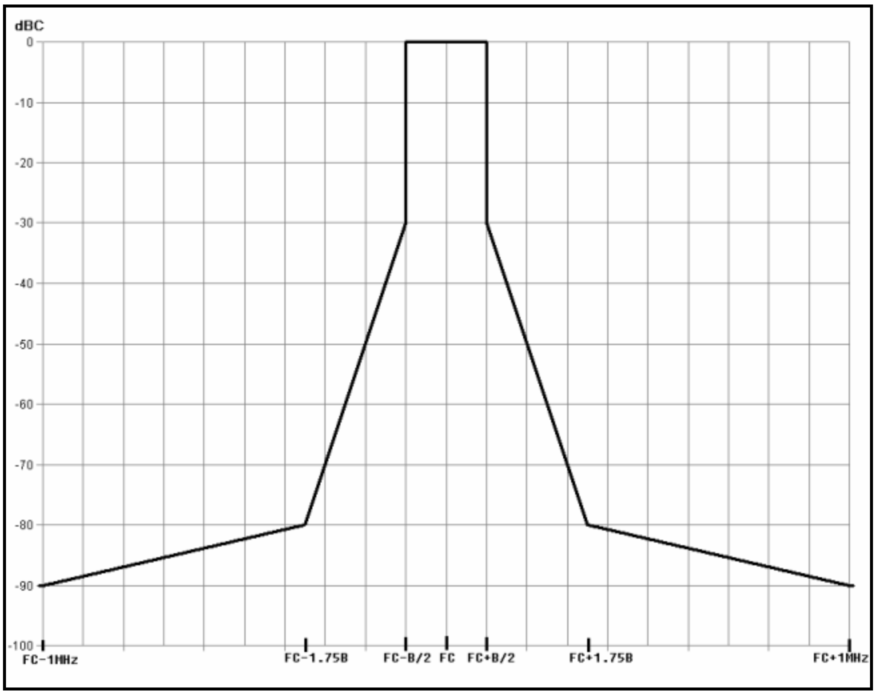
Figure B.2: Spectrum masks for analogue systems in all bands

Table B.7 and Figure B.3 provide the details of the spectrum masks for digital systems below 1 GHz.

Table B.7: Break points of spectrum limit mask for digital systems below 1 GHz

Frequency relative to the centre of the channel	Relative level (dBc)
-1 MHz	-90
-1,75 B	-80
-0,5 B	-30
-0,5 B	0
0,5 B	0
0,5 B	-30
1,75 B	-80
1 MHz	-90

Where B = the Necessary Bandwidth



NOTE 1: The test conditions and limits for this mask will be defined in EN 300 422 [20].

NOTE 2: The mask for below 1 GHz is proposed, based on commonly manufactured products.

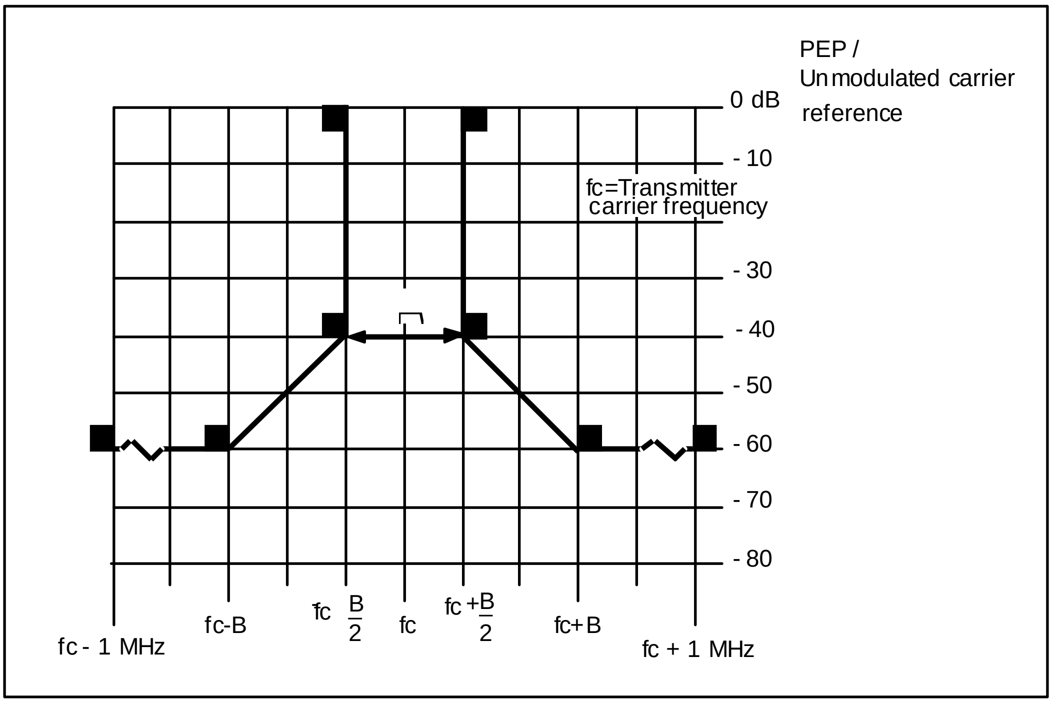
Figure B.3: Spectrum mask for digital systems below 1 GHz

Table B.8 and Figure B.4 provide the details of the spectrum masks for digital systems above 1 GHz.

Table B.8: Break points of spectrum limit mask for digital systems above 1 GHz

Frequency relative to the centre of the channel	Relative level (dBc)
-1 MHz	-60
-B	-60
-0,5 B	-40
-0,5 B	0
0,5 B	0
0,5 B	-40
B	-60
1 MHz	-60

Where B = the Necessary Bandwidth.



NOTE: The mask for above 1 GHz is already described in EN 301 840 (shown for a 400 kHz channel bandwidth).

Figure B.4: Spectrum mask for digital systems above 1 GHz

B.4 Technical justification

B.4.1 Receiver sensitivity

B.4.1.1 Test arrangement

The following test method arrangement can be used to measure the receiver sensitivity.

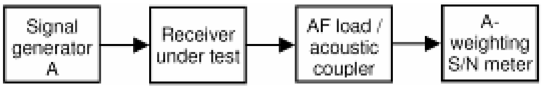


Figure B.5: Test configuration for receiver sensitivity measurement

B.4.1.2 Procedure

- Set signal generator A on receiver frequency (f_C).
- Set signal generator A RF output level to -120 dBm.
- Set signal generator A to Modulation FM, Deviation +/- 24 kHz, AF 1 000 Hz.
- Modify signal generator A RF output level until receiver S+N/N (Noise and Signal level divided by Noise level) degrades to 80 dB(A). If the used audio compander technique required alternative can be measured on a limit of 30 dB SINAD.

B.4.1.3 Limit

The typical receiver sensitivity must be below -90 dBm.

For miniaturized receiver and body worn receiver a sensitivity of -85 dBm is applicable.

NOTE 1: Further information is contained in "Attachment 2, Receiver Parameters Below 1GHz (04092006)".

NOTE 2: Suitable receiver sensitivity levels for systems above 1 GHz are yet to be determined.

B.4.2 Path loss calculation

B.4.2.1 Worst case PWMS path loss scenario

Typical components of microphone transmission path are described as:

- Microphone output power:..50 mW e.r.p.

PL_{FS} - Free space path loss: $$32.44 + 20\log_{10}\left(\frac{d}{1000}\right) + 20\log_{10}(f)$$

- PL_B - Loss effected while carrying antenna on human body:............................ up to 25 dB
- PL_N - Additional loss in the transmission path notches:.................................. up to 30 dB
- PG_{DV} - Gain by using antenna diversity techniques ....~ 7 dB
- PG_A - Gain through receiver antenna.. typically 10 dB

The worst case in a typical installation when using diversity receiver antennas is described as:

$$TotalLossWorstCaseD(dB) = 32{,}44 + 20\log_{10}\left(\frac{d}{1000}\right) + 20\log_{10}(f) + 25 + 30 - 7 - 10$$

The worst case in a typical installation not using diversity receiver technique is described as:

$$TotalLossWorstCaseND(dB) = 32{,}44 + 20\log_{10}\left(\frac{d}{1000}\right) + 20\log_{10}(f) + 25 + 30 - 10$$

B.4.2.2 Simulation

Simulation results are shown in Figure B.6.

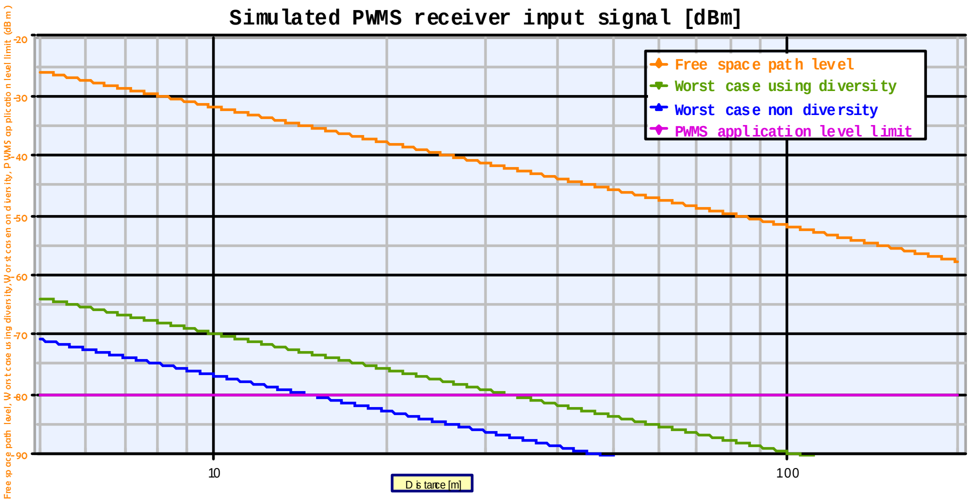


Figure B.6: Simulated PWMS receiver input signal

B.4.2.3 Results

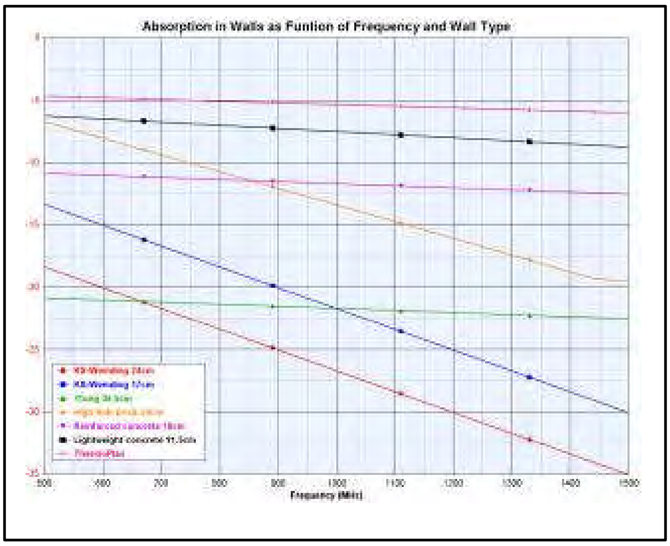
For the worst case, in a non-diversity system a distance of about 15meters, and in diversity systems a distance of about 32meters, can be achieved. A larger distance would be possible by increasing the radiated output power.

NOTE 1: Further information is contained in "Attachment 1, PWMS path loss model" for applications below 1 GHz.

NOTE 2: Suitable path loss parameters for systems above 1 GHz are yet to be determined.

B.4.3 Absorption in walls

Measurement results with regard to wall absorption are shown in Figure B.7.



Wall type / material	Absorption @650MHz	Absorption @1450MHz
Lime sandstone 24cm	21 dB	34 dB
Lime sandstone 17cm	16 dB	29 dB
Ytong 36.5cm	21 dB	23 dB
High hole brick 24cm	9 dB	19 dB
Reinforced concrete 16cm	11 dB	13 dB
Lightweight concrete 11.5cm	7 dB	9 dB
ThermoPlane	5 dB	6 dB

NOTE 1: Horizontally arranged walls typically have a smaller absorption.
Vertically arranged walls have substantially larger absorption.

NOTE 2: Some application ask for increased e.r.p. to penetrate walls.

EXAMPLE: An output power increase by 13 dB to 1W e.r.p. would permit penetration of up to 3 walls.

Figure B.7: Absorption in walls

Annex C:
Expected compatibility issues

C.1 Coexistence issues

The sharing situation of PWMS with T-DAB in the band 1 452 MHz to 1 492 MHz (and the other frequency bands) needs to be investigated, both for the effect of T-DAB transmissions on PWMS receivers as well as the effect of PWMS transmissions on T-DAB receptions. The protection ratio values for T-DAB are given in the "Technical Bases for T-DAB Planning" from the EBU [15].

The effect of PWMS indoor transmissions on the receptions of the "outdoor" primary radio services in the new candidate bands 1 492 MHz to 1 530 MHz and 1 533 MHz to 1 559 MHz needs to be investigated.

C.1.1 Existing studies

The following studies were carried out in the past:

- Investigation into digital Radiomicrophone techniques, by the Radiocommunications Agency [32].
- ECC Report 2 on the spectrum use and future requirements for SAB/SAP [2].
- ERC Report 7 on compatibility between mobile services [6].
- ERC Report 63 on wireless microphones in the 1,8 GHz band [11].
- ERC Report 88 on the compatibility between DVB-T and radio microphones in bands IV and V [12].
- ECC Final Report in response to the Second EC Mandate to develop a strategy to for Short Range Devices (SRDs) [19].

C.1.2 Current allocations in the proposed new frequency band

The following radio services are allocated in the frequency band proposed for studying for operation of PWMS application equipment:

Table C.1: European Common Allocations and Applications in the proposed frequency bands for study

RR Region 1 Allocation	European Common Allocation	Utilization	Note
UHF			
470 MHz to 608 MHz BROADCASTING 5.149 5.291A 5.296 5.302 5.306	BROADCASTING Mobile 5.291A 5.296	Radio microphone	On a tuning range basis
		SAP/SAB	Mobile applications restricted to SAB/SAP including radio microphones
		Stockholm Agreement 1961 complemented by the Chester 1997 Agreement	The band 470 MHz to862 MHz be reviewed for possible future applications after the introduction of DVB-T
608 MHz to 614 MHz BROADCASTING 5.149 5.291A 5.296 5.306	BROADCASTING Mobile Radio Astronomy 5.149 5.296 5.306	Radio astronomy applications	Continuum measurements and VLBI
		Radio microphones	On a tuning range basis
		SAP/SAB	Mobile applications restricted to SAB including radio microphones
		Stockholm Agreement 1961 complemented by the Chester 1997 Agreement	The band 470 MHz to862 MHz be reviewed for possible future applications after the introduction of DVB-T

RR Region 1 Allocation	European Common Allocation	Utilization	Note
614 MHz to 790 MHz BROADCASTING 5.149 5.291A 5.296 5.311 5.312	BROADCASTING Mobile 5.296 EU13 5.312	Radio microphone	On a tuning range basis
		SAP/SAB	Mobile applications restricted to SAB including radio microphones
		Stockholm Agreement 1961 complemented by the Chester 1997 Agreement	The band 470 MHz to862 MHz be reviewed for possible future applications after the introduction of DVB-T
790 MHz to 838 MHz BROADCASTING FIXED 5.312 5.314 5.315 5.316 5.319	BROADCASTING Mobile 5.312 EU2 5.316 EU13	Defence systems	Mobile applications restricted to tactical links and SAB/SAP including radio microphones
		Radio microphone	On a tuning range basis
		SAP/SAB	Mobile applications restricted to tactical links and SAB/SAP including radio microphones
		Stockholm Agreement 1961 complemented by the Chester 1997 Agreement	The band 470 MHz to862 MHz be reviewed for possible future applications after the introduction of DVB-T
838 MHz to 862 MHz BROADCASTING FIXED 5.312 5.314 5.316 5.319 5.321	BROADCASTING MOBILE 5.312 EU2 5.316 EU13	Defence systems	Mobile applications restricted to tactical links and SAB/SAP including radio microphones
		Radio microphone	On a tuning range basis
		SAP/SAB	Mobile applications restricted to tactical links and SAB/SAP including radio microphones
		Stockholm Agreement 1961 complemented by the Chester 1997 Agreement	The band 470 MHz to862 MHz be reviewed for possible future applications after the introduction of DVB-T
L Band			
1 452 MHz to 1 530 MHz BROADCASTING BROADCASTING-SATELLITE 5.345 5.347 FIXED MOBILE except Aeronautical Mobile 5.341 5.342 5.347A	BROADCASTING BROADCASTING-SATELLITE Fixed Mobile except aeronautical mobile 5.341 EU15	S-DAB	1 479.5 MHz to 1 492 MHz
		T-DAB Maastricht 2002 special agreement	1 452 MHz to 1 479.5 MHz
1 492 MHz to 1 518 MHz FIXED MOBILE except Aeronautical Mobile 5.341 5.342	FIXED MOBILE except aeronautical mobile 5.341 EU2 EU15	Defence systems	
		Low capacity fixed links	
1 518 MHz to 1525 MHz FIXED MOBILE except aeronautical mobile MOBILE-SATELLITE (S-E) 5.348 5.348A 5.348B 5.348C 5.341 5.342	FIXED MOBILE except aeronautical mobile MOBILE-SATELLITE (S-E) 5.348 5.348A 5.348B 5.348C 5.341 EU2 EU15	Defence systems	
		Unidirectional fixed links	
1 525 MHz to 1 530 MHz FIXED	FIXED MOBILE-	Mobile satellite applications	
		Unidirectional fixed links	

RR Region 1 Allocation	European Common Allocation	Utilization	Note
MOBILE-SATELLITE (S-E) 5.351A SPACE OPERATION (S-E) Earth Exploration-Satellite Mobile except Aeronautical Mobile 5.349 5.341 5.342 5.347A 5.350 5.351 5.352A 5.354	SATELLITE (S-E) 5.351A SPACE OPERATION (S-E) 5.341 EU15 5.351 5.354		
1,8 GHz			
1 785 MHz to 1 800 MHz FIXED MOBILE 5.384A 5.387	FIXED MOBILE EU2 EU15	Mobile applications Radio microphones	 Within the band 1 785.7 MHz to 1 799.4 MHz

The following table shows the national arrangements in UHF TV bands IV and V for PWMS applications within Europe.

Table C.2: National arrangements in UHF TV bands IV and V for PWMS applications

Country	Radio microphones						IEM	Comment	Reference
Austria	470 MHz to 606 MHz	614 MHz to 790 MHz	790 MHz to 862 MHz				518 MHz to 526 MHz		Interface Radio B10
Belgium	518 MHz to 526 MHz	534 MHz to 542 MHz		854 MHz to 862 MHz				License free	
Bulgaria									
Cyprus									
Czech Rep.									
Germany	470 MHz to 606 MHz	614 MHz to 790 MHz	790 MHz to 814 MHz	838 MHz to 862 MHz				User groups license free	Vfg. 91/2005
Denmark				800,1 MHz to 819,9 MHz					Dri 00 025
Spain									
Estonia	470 to 862 MHz								Confirmed by Estonian National Communications
Finland	470 MHz to 582 MHz		790 MHz to 822 MHz	854 MHz to 862 MHz					Confirmed by FICORA, 30 Sept 2006
France	470 MHz to 790 MHz			790 MHz to 830 MHz					Confirmed by ANFR, 5 Oct 2006
Hungary									
Ireland									
Iceland									
Italy									
Lichtenstein	470 to 790 MHz		790 to 862 MHz					License required	RIR0203-01 (low band),
Lithuania									
Luxembourg									
Malta									
Netherlands	470 to 557 MHz	630 to 637 MHz	638 to 701 MHz	702 to 790 MHz	806 to 814 MHz	814 to 816 MHz		License free	www.at-ez.nl

Country	Radio microphones						IEM	Comment	Reference
Norway			800 MHz to 820 MHz					License free	
Poland									
Portugal									
Sweden	470 MHz to 790 MHz		800 MHz to 820 MHz					Temporary use, individual license	Confirmed by PTS, Nov 2006
Slovakia									
Slovenia									
Switzerland									
UK	470 MHz to 598 MHz	606 MHz to 790 MHz	606 MHz to 854 MHz	854 MHz to 862 MHz				User group license	UK Allocation tables, 2004. 1 785 MHz to 1 800 MHz for digital radiomics only

NOTE 1: This table is for information only and does not constitute a statement of policy on behalf of any Administration.
This table is incomplete and should be updated by the various national administrations to provide a picture of the provision of spectrum for PWMS across Europe.

NOTE 2: Usage in accordance with CEPT/ERC Recommendation 70-03 [4], annex 10.

NOTE 3: Type of usage: Licence based sharing with broadcast stations and/or special licence for PWMS.

C.1.3 Implication on radio services outside the proposed frequency band

The PWMS channel is always at least at a distance of channel spacing/2 from the respective band edge.

Out-of-Band and Spurious Emission performance will conform to the requirements of EN 300 422 [20], EN 300 454 21 or EN 301 357 [22], as appropriate.

The EMC performance will conform to EN 301 489-9 [23].

C.1.4 Duty Cycle

No duty cycle restriction is proposed since typical usage includes applications that run continuous transmissions, e.g. audio applications.

C.1.5 Withdrawal of Band III channels in the UK

Frequencies between 211 – 217 MHz will cease to be available after 31 December 2007 for Programme Making use in the UK. This move will make way for more Digital Audio Broadcasting (DAB) in the UK.

Replacement VHF spectrum has been identified and the new frequencies will become available with immediate effect. The weblink http://www.jfmg.co.uk/jfmgecom/Docs/BeforeandAfter.pdf provides full details of the new allocations.

The amount of spectrum available for VHF wireless microphones remains the same, although the new set of channels is adjacent to an existing set.

Licensees have been contacted separately by letter with full details of how the migration to these new frequencies will work.

C.1.6 Co-ordinated award of 1785 - 1805 MHz in the UK and Ireland

Ofcom (UK) and ComReg (Ireland) have agreed to auction the band 1785 – 1805 MHz, jointly, in Northern Irelenad and Ireland. Please see http://www.ofcom.org.uk/consult/condocs/award1785.

C.2 Current ITU-R allocations

Professional wireless microphone systems communications are considered as an land mobile application operated under article 4.4 of the Radio Regulations.

C.3 Sharing issues

Sharing is required with all radio services allocated within the proposed frequencies of which some may be identified by the ECC.

The following technical aspects need to be taken into account as these will decrease the probability of interference with the existing radio services:

- Sharing with satellite radio receivers is facilitated through the professional usage in confined usage areas, i.e. usage normally does not take place at the same locations and is predominantly indoors.
- The co-channel use of PWMS and T-DAB would cause interference to T-DAB reception and PWMS receivers in many cases. However, it is assumed that the adjacent channel operation may be possible in many cases with significant improvement to the compatibility in both directions. The proposed sharing studies should show the exact conditions for the future compatibility situation.
- The PWMS may suffer interference if used in the adjacent channel in close proximity to a T-DAB transmitter. The proposed sharing studies should investigate the minimal separation distances required.

History

Document history		
V0.0.1	April 3rd, 2006	First draft , BnetzA
V0.0.2	May 18th, 2006	First comments, German-speaking Microphone Manufacturers' Group
V0.0.3	June 19th , 2006	Drafting a proposal - ad-hoc group
V 0.0.4	June 22nd 2006	Edited by WI Rapporteur
V 0.0.5	June 28th 2006	Edited by WI Rapporteur
V 0.0.6	July 6th 2006	Edited by WI Rapporteur
V 0.0.7	July 13th 2006	Edited by TG17 WP3
V 0.0.8	July 20th 2006	Completion of Rapporteur actions from WG17 WP3#7
V 0.0.9	July 21st 2006	Amendments to draft by Rapporteur
V 0.0.10	July 24th 2006	Errors in draft corrected by Rapporteur.
V 0.0.11	August 6th 2006	Incorporation of member comments by Rapporteur.
V 0.0.12	August 29th 2006	Incorporation of member comments by Rapporteur.
V 0.0.13	September 1st 2006	Incorporation of member comments by Rapporteur.
V 0.0.14	September 6th 2006	Incorporation of member comments by Rapporteur.
V 0.0.15	September 13th 2006	Incorporation of member comments by Rapporteur.
V 0.0.16	September 14th 2006	Circulated to TG17 WP3 email exploder
V 0.0.17		Incorporated comments from TG17 WP3 members: • Sennheiser
V 0.0.18	September 21st 2006	Incorporation of TG17 WP3 member comments
V 0.0.19	October 1st 2006	Incorporation of TG17 WP3 member comments and new information
V 0.0.20	October 7th 2006	Incorporation of TG17 WP3 member comments and new information
V 0.0.21	October 11th 2006	Incorporation of TG17 WP3 member comments and new information
V 0.0.22	October 16th 2006	Incorporation of TG17 WP3 member comments and new information
V 1.1.1_0.0.23	October 17th 2006	Draft submited to ERM-RM (and sent out for consultation)
V 1.1.1_0.0.24	November 2006	Previous version after pre-processing by EditHelp
V 1.1.1_1.0.2	December 2006	Incorporation of member comments from RM Consultation (based on version V 1.1.1_0.0.23) .
V 1.1.1_1.0.3	December 2006	Incorporation of member comments from 2nd RM Consultation (based on version V 1.1.1_1.0.2) .
V 1.1.1_2.0.1	January 2007	Editorial correction.
V 1.1.1_2.0.2	January 2007	Editorial correction

Discussion and simulation results of an applicable transmission path loss model for Professional Wireless Microphone Systems (PWMS)

Introduction

PWMS are intended for use in the entertainment and installed sound industry by professional users involved in stage productions, public events, TV programme production, public and private broadcaster's installation in conference centres / rooms, city halls, musical and theatres, sport / event centres or other professional activities / installation.

The planning of the audio transmission link is, in principle, subject to the following characteristics:

- 100 % duty cycle!
- The audio application should guarantee extremely high availability and reliability.
- An applicable maximum distance between transmitter and receiver in combination with guaranteed audio quality parameter in the minima of the RF transmission path.
- Consideration of statistically variable disturbances on the RF (radio frequency) transmission path in order to support of the audio application.

The statements listed below show well-known effects occurring in practice. To sum up, a simplified and applicable transmission path model is being discussed.

We kindly ask interested experts to participate in this work and to supply important points.

Simplified Path Loss Model for PWMS

Fundamental considerations

A generic PWMS path loss model, based on dipole antennas, can be described as

PLFS + PLB + PLT + PLN + PGDV

PL_{FS} - Basic free space path loss in the PWMS transmission path
PL_{B} - Loss effected while carrying antenna on human body
PL_{T} - Loss effected while tuning PWMS frequency away from antenna centre frequency
PL_{N} - Additional loss in the transmission path notches by multi path and polarization fading
PG_{DV} - Applicable application gain by using antenna (space) diversity techniques

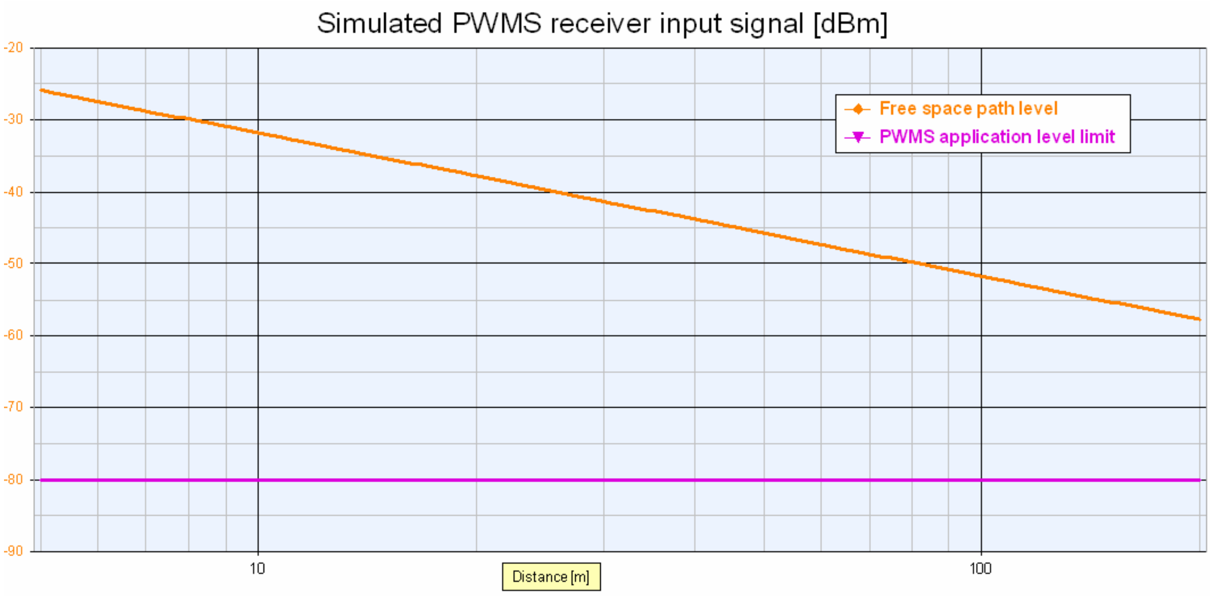
The free space path loss in the transmission path

$$PL_{FS}\,[dB] = 32.44 + 20 \log_{10} (d / 1000) + 20 \log_{10} (f)$$

d - path distance [m], f - frequency [MHz]

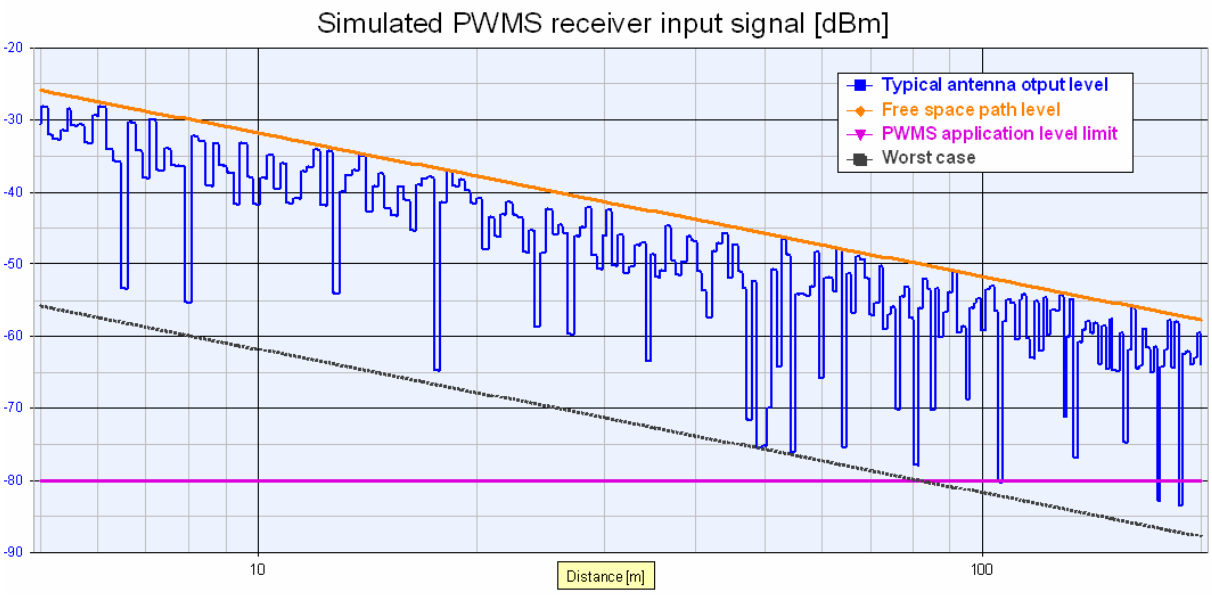
The minimal applicable PWMS receiver input signal has to be declared as being **-80 dBm**. This level will support the absolute minimum audio S/N of **80 dB(A)** in the transmission path fading notches. Example: If the transmission path notch depth is 30 dB, the receiver input signal outside the path notch has to be above -50 dBm.

Free space level depending on microphone to receiver antenna distance
(50 mW ERP @ 650 MHz)



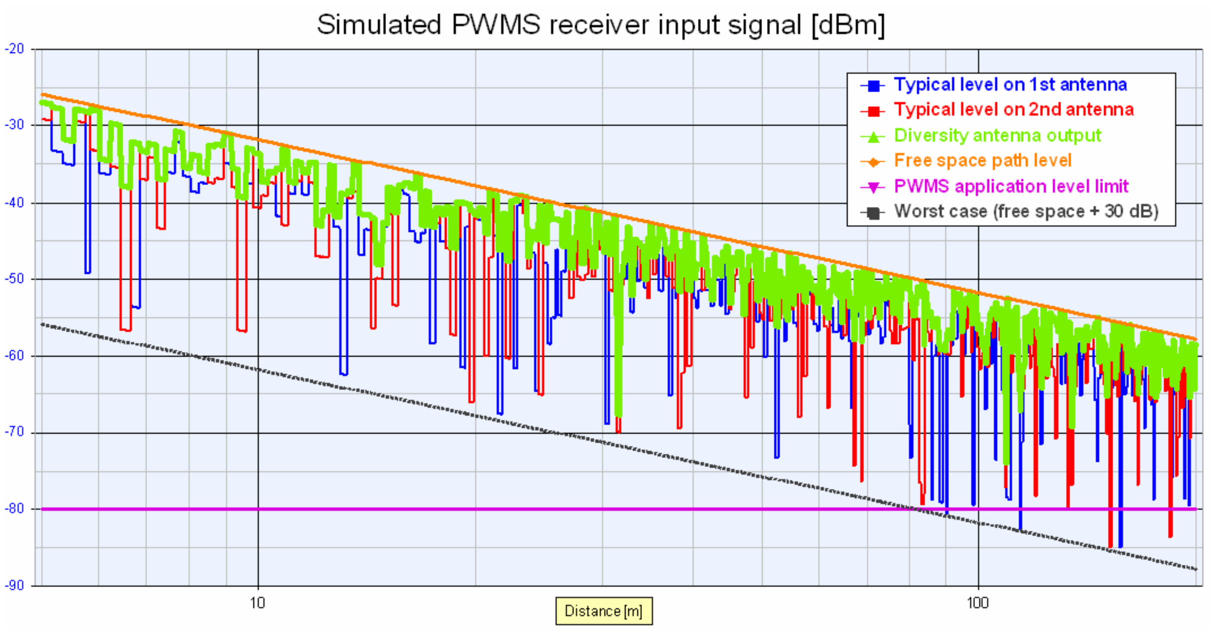
Note:
The free space simulation shows a very optimistic scenario.
A system plan on this basis would not be successful.

Typical receiver input level considering statistical distribution on transmission path
(50 mW ERP @ 650 MHz)



Note:
This simulation shows a typical signal strength distribution e.g. in theatres or sport halls

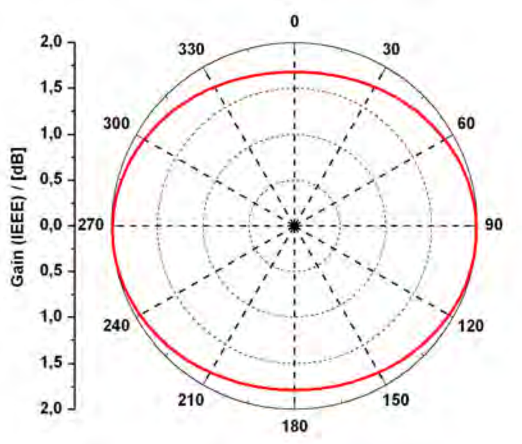
Typical receiver input level by using space diversity antennas
(50 mW ERP @ 650 MHz)



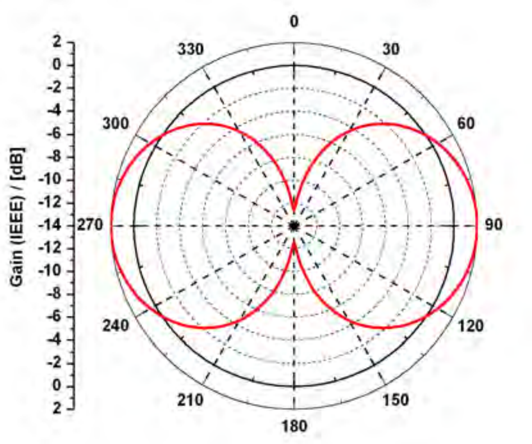
Note:
The space diversity technique will provide a typical application gain of 6-8 dB.
Space diversity does not remove all fading notches on transmission path.

Modification of path loss depending on antenna distance to human body

Body pack antenna diagram simulation in free space (650 MHz)



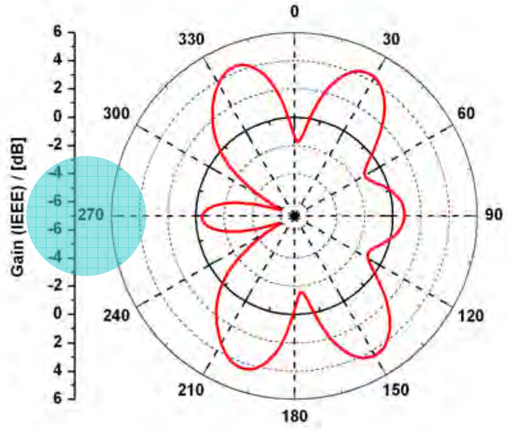
Horizontal polarization diagram



Vertical polarization diagram

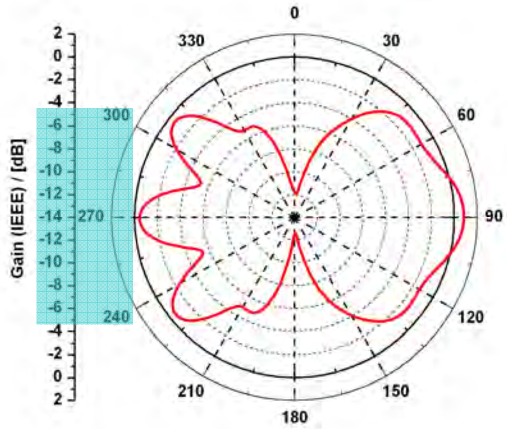
Note:
The antenna simulations data's and plots were created with CST Microwave Studio 2006

Antenna diagram simulation with antenna at a distance of 500 mm from human body model



Horizontal polarization diagram

Body pack transmitter carried away from body

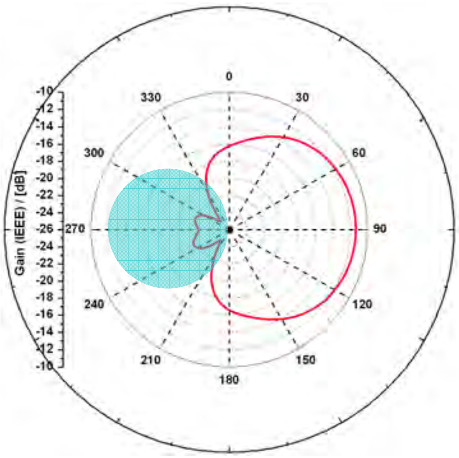


Vertical polarization diagram

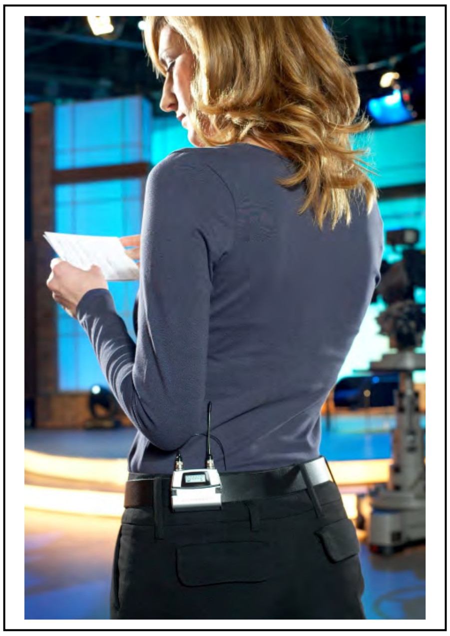
Note: The worst case additional path loss is about 6 dB.

Typical examples of shielding by carrying a wireless microphone close to human body

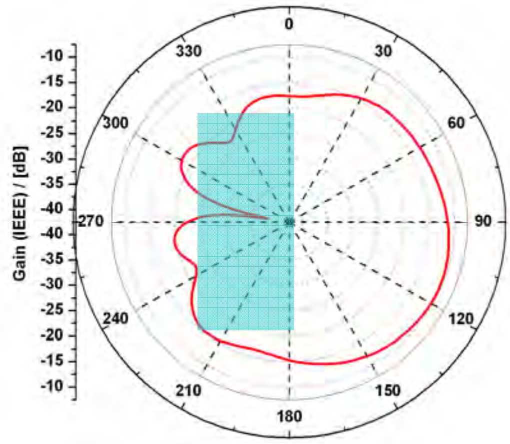
Body pack antenna diagram simulation with antenna worn on human body model



Horizontal polarization diagram



Body pack transmitter carried at body

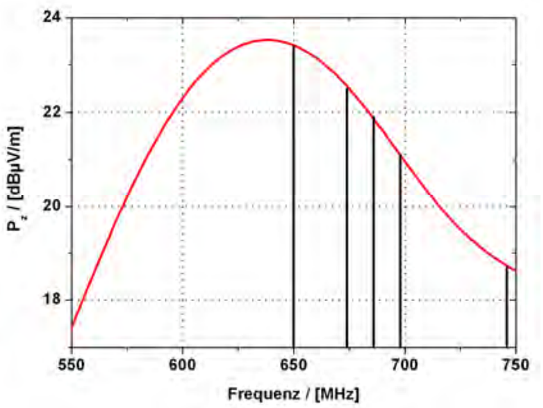


Vertical polarization diagram

Note:
The additional path loss on the main axis is typically 15 dB and in worst case above 25 dB.
An effective frequency plan will always use the worst case loss.

Changes to path loss caused by antenna bandwidth whilst varying the centre frequency

Change of field strength as a function of
PWMS frequency variation
at a distance of 100 m.



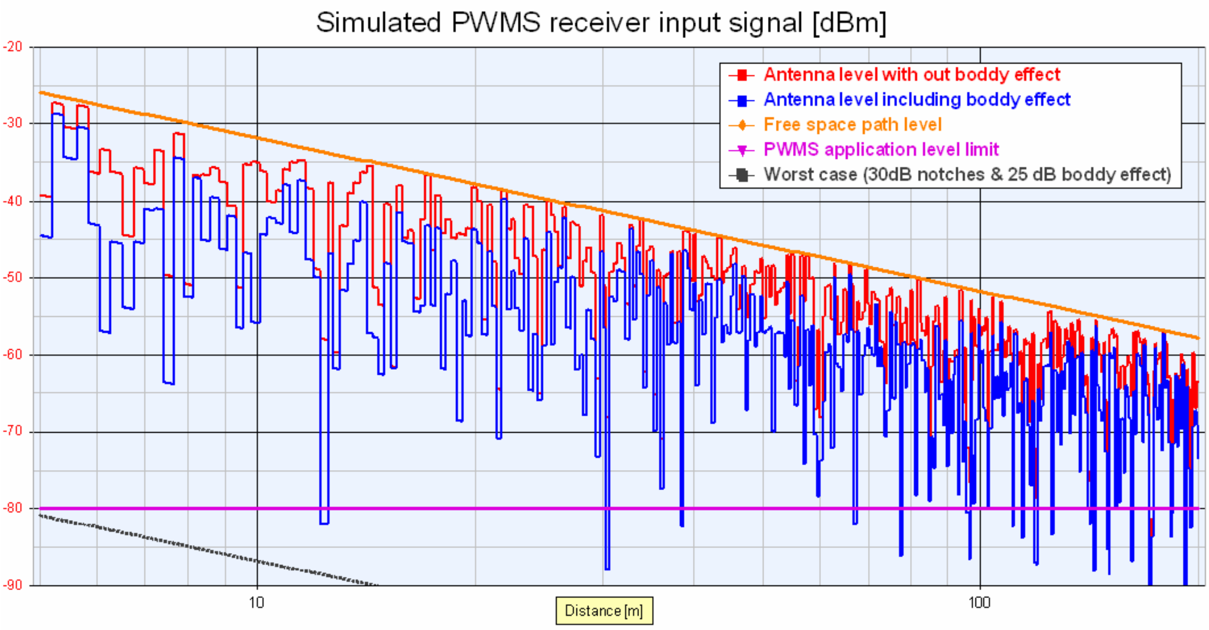
Change of field strength as a function of
PWMS frequency variation
at distances of 1, 10 and 100 m.

Distance [m]	1	10	100
Frequency [MHz]	Field strange [dBµV/m]		
650	63,41	43,41	23,41
674	62,55	42,55	22,55
686	61,91	41,91	21,91
698	61,11	41,11	21,11
746	58,75	38,75	18,75

Note: A frequency variation within 200 MHz will cause an additional loss of up to 6 dB.
PWMS concepts with extended frequency agility will increase the path loss.

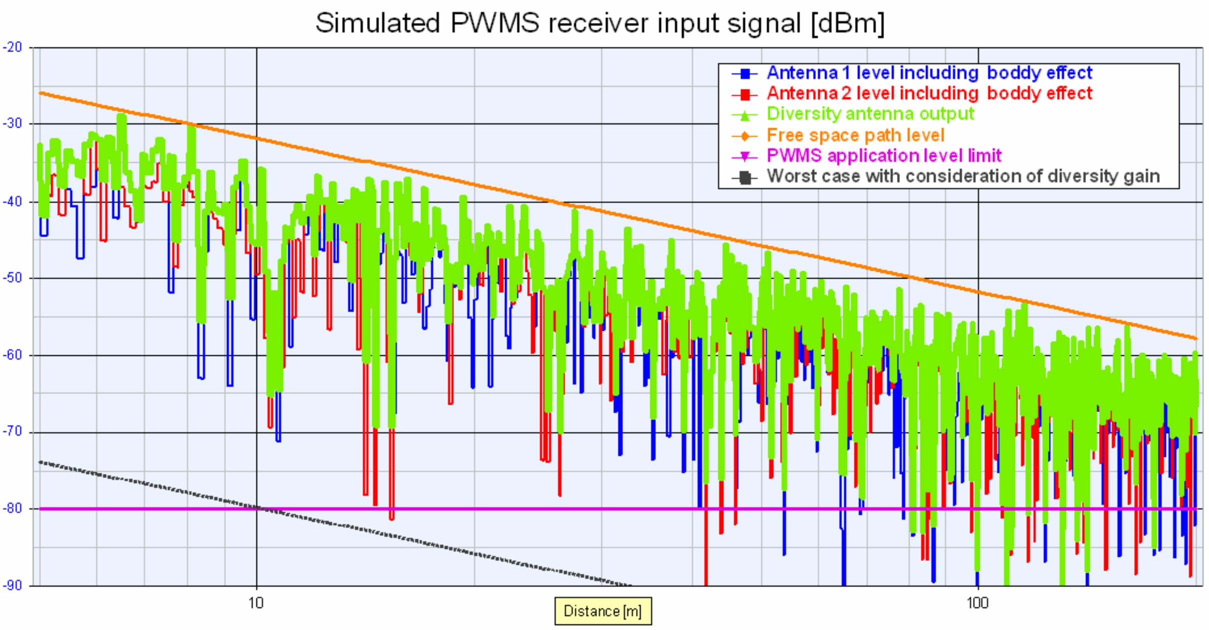
Typical PWMS receiver input level with estimated path loss on body
(50 mW ERP @ 650 MHz)

The effect of the human body on PWMS signal strength without using space diversity



Note:
In a PWMS without using antenna diversity techniques the body effect will decrease the system performance dramatically.

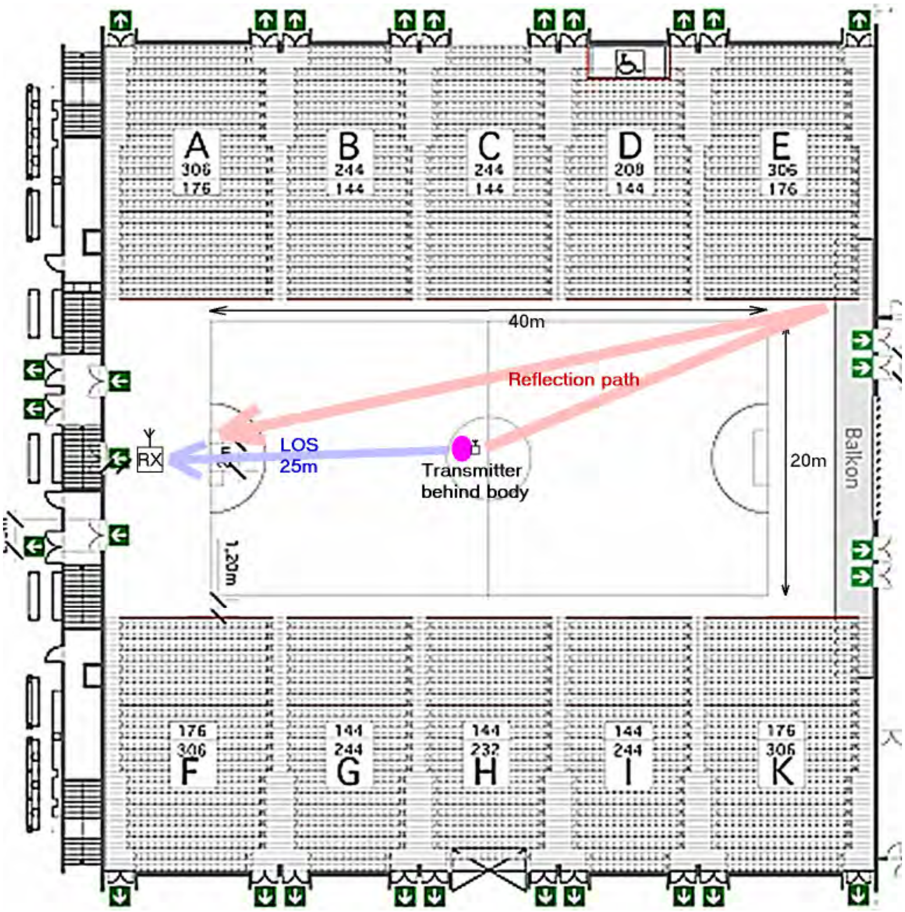
The effect of the human body on PWMS signal strength when using space diversity antennas

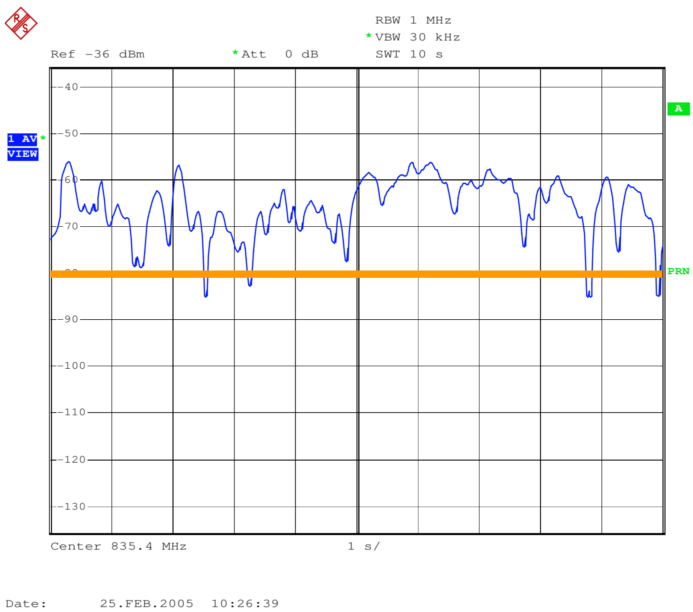


Note: Usage of antenna space diversity techniques will stabilize PWMS operation.

The Problem: Not every audio application (e.g. most IEMs) can use diversity techniques.

PWMS input receiver level monitored in a practical environment (835 MHz)





Note:
This diagram shows a PWMS receiver input level recorded in the AWD Hall Hanover. The distance between transmitter and receiver was about 25 m. Being shielded by the actor's body the direct path (LOS) signal was overlapped by the reflection path signal. The actor's body has been moved slowly. It is significant that at this distance the receiver input level falls below the PWMS minimum required value.

Worst case scenario

Components of microphone transmission path are described as:

- Microphone output power: 50 mW ERP
- PL_{FS} - Free space path loss: 32.44+20*log10(d/1000)+20*log10(f)
- PL_{B} - Loss effected while carrying antenna on human body: up to 25 dB
- PL_{N} - Additional loss in the transmission path notches: up to 30 dB
- PG_{DV} - Gain by using antenna diversity techniques ~ 7 dB
- PG_{A} - Gain through receiver antenna typical 10 dB

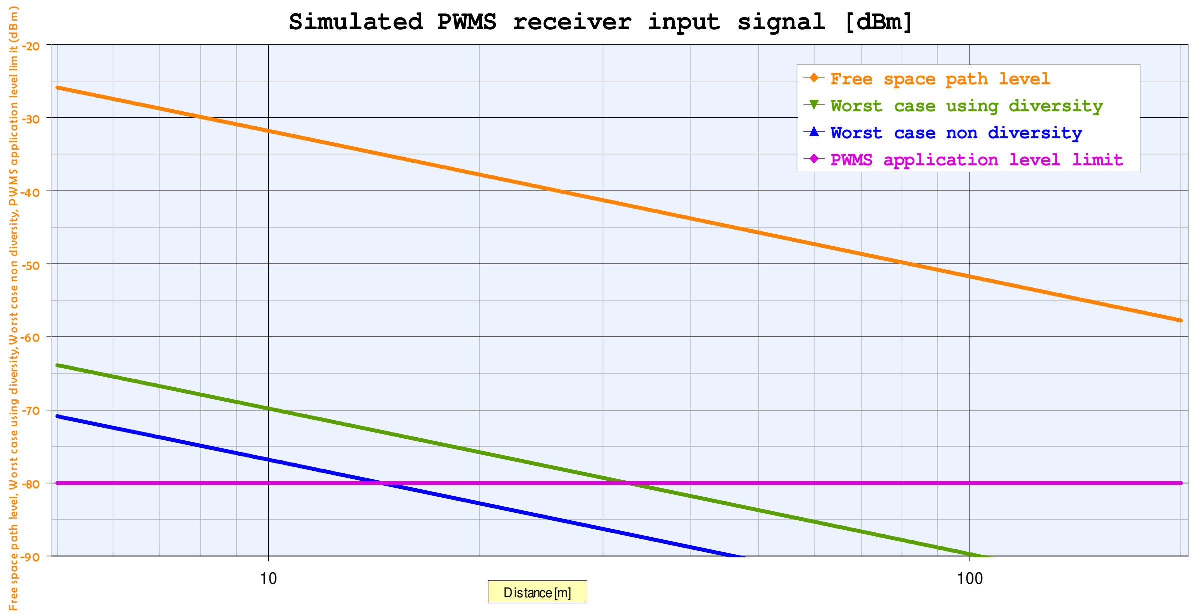
The worst case in a typical installation when using diversity receiver antennas is described as:

TotalLossWorstCaseD [dB] = $32.44 + 20*\log_{10}(d/1000) + 20*\log_{10}(f) + 25 + 30 - 7 - 10$

The worst case in a typical installation not using diversity receiver technique is described as:

TotalLossWorstCaseND [dB] = $32.44 + 20*\log_{10}(d/1000) + 20*\log_{10}(f) + 25 + 30 - 10$

Simulation:



Results:
For the worst case, in non diversity systems a distance of about 15m and in diversity systems a distance of about 32m can be guaranteed. A larger distance will be possible by increasing the radiated output power.

Conclusion

The examples shown above demonstrate the situation in the PWMS transmission channel. It is often assumed to be a simple LOS scenario, but in reality the situation is totally different.

There are even additional interference problems on a PWMS audio link which effect system performance (e.g. Interference, Man Made Noise, antennas placed in actor make-up or on stage placed installations), but they have not been covered here.

Applicable Receiver Parameter for PWMS below 1 GHz

Introduction:

PWMS must produce high-quality audio results in a difficult environment. Therefore technical minimum parameters are described, which are to be fulfilled. On basis of standardized measuring procedures good reproductibility has to be achieved.

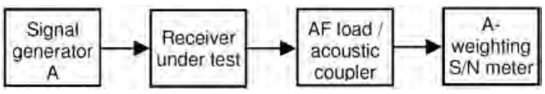
General test requirement:

- The test equipment is installed and operated under the conditions described by the manufacturer. The operating and environmental conditions are enclosed.
- On input and output only analogues audio signals are connected. Digital signals must be converted by manufacturer adapters into analogue input and / or output signals.
- With diversity receivers both receiver channels must be examined. The worst case results must be indicated.
- STEREO receiver will be measured in MONO mode

Definition:

The sensitivity of a receiver is a measure of its ability to receive weak signals and to produce an output having usable strength and acceptable quality (ITU-R-SM331).

Test set up:



Procedure:

- Set signal generator A on receiver frequency (f_C)
- Set signal generator A RF output level to -120 dBm
- Set signal generator A to Modulation FM, Deviation +/- 24 kHz, AF 1000 Hz
- Modify signal generator A RF output level until receiver S+N/N (Noise and Signal level divided by Noise level) degrades to 80 dB(A). If the used audio compander technique required alternative can be measured on a limit of 30 dB SINAD.

Limits: The typical receiver sensitivity must be below -90 dBm.
For miniaturized body worn receiver a sensitivity of -85 dBm is applicable.

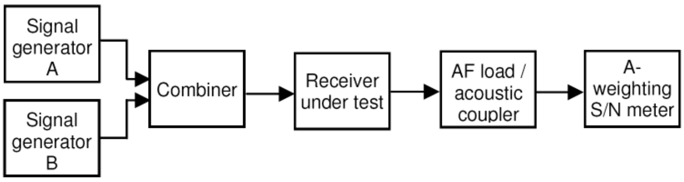
Experimental results:

No	Receiver	Receiver Sensitivity [dBm]	80 dB S+N/N	30 dB SINAD
1	Sample 1	-97	X	-
2	Sample 2	-94	X	-
3	Sample 3	-98	-	X
4	Sample 4	-97	X	-

Co-channel rejection level

Definition:

The PWMS Co-Channel rejection level will be calculated as the level of the unwanted signal to the level of the wanted signal which degrades the receiver output audio S+N/N to 80 dB(A).



Procedure:

- Set signal generator A on receiver frequency (f_C)
- Set signal generator A RF output level measured at receiver input to -80 dBm
- Set signal generator A to Modulation FM, Deviation +/- 24 kHz, AF 1000 Hz
- Set signal generator B on receiver frequency (f_C)
- Set signal generator B RF output level to -120 dBm
- Set signal generator B to Modulation FM, Deviation +/- 24 kHz, AF 400 Hz
- Modify signal generator B RF output level until receiver S+N/N degrades to 80 dB(A). If the used audio compander technique required alternative can be measured on a limit of 30 dB SINAD.

Limit: No limit required at this point.

Experimental results:

No	Receiver	Co-channel rejection level [dBm] measured at combiner output	80 dB S+N/N	30 dB SINAD
1	Sample 1	-103	X	-
2	Sample 2	-105	X	-
3	Sample 3	-98	-	X
4	Sample 4	-101	X	-

Co-channel rejection ratio

Procedure:

- Compute the difference of -80 dBm and co-channel rejection level

Limit: The applicable protection ratio suggestion is 30 dB. The results shall be below this limit.

Experimental results:

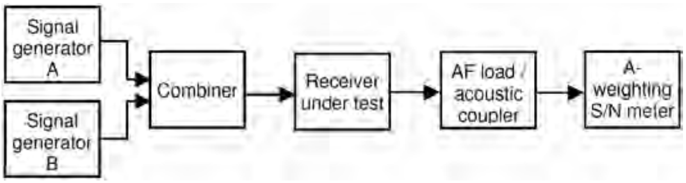
No	Receiver	Co-channel protection ratio [dB]	80 dB S+N/N	30 dB SINAD
1	Sample 1	23	X	-
2	Sample 2	25	X	-
3	Sample 3	9	-	X
4	Sample 4	21	X	-

Selectivity

Definition:

The selectivity of a receiver is a measurement of its ability to discriminate between a wanted signal to which the receiver is tuned and unwanted signals. Selectivity is specified as the ratio (in dB) of the adjacent channel signal level to the assigned channel signal level. For PWMS application the receiver selectivity will be measured in an offset of f_C +/- 0.4 MHz.

Test setup:

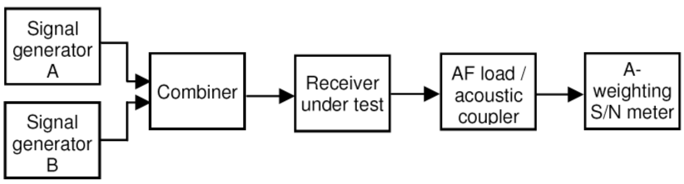


Note:
There are many receiver characteristics which are in principle measured with the same test set up. Because the measured results often overlap themselves the selectivity measurement will be summarized with the Blocking or Desensitization Level measuring method.

Blocking or Desensitization Level

Definition:

Receiver blocking or desensitization occurs when a strong off-channel signal overloads a receiver front end and thus reduces the sensitivity to weaker on-channel signals. This occurs when an undesired signal is very close to a nearby receiver's operating frequency.



Procedure:

- Set signal generator A on receiver frequency (f_C)
- Set signal generator A RF output level measured at receiver input to -80 dBm
- Set signal generator A to Modulation FM, Deviation +/- 24 kHz, AF 1000 Hz
- Set signal generator B modulation to an CW RF output signal (un-modulated)

- Set signal generator B on receiver frequency add a blocking offset of f_C-100 MHz
- Set signal generator B RF output level to -120 dBm
- Modify signal generator B RF output level until receiver S+N/N degrades to 80 dB(A). If the used audio compander technique required alternative can be measured on a limit of 30 dB SINAD.
- Repeat the last 4 measurement steps with the f_C offsets of -20 MHz, -5 MHz, -1 MHz, -0.4 MHz, 0.4 MHz, 1 MHz, 5 MHz, 20 MHz and 100 MHz.

Note: The spurious frequencies are part of receiver mask

Limits: No limits required at this point

Experimental results:

No	Receiver	Desensitization level [dBm] measured at combiner output											
	Freq. offset [MHz]	-100	-20	-5	-1	-0.4	0.4	1	5	20	100	**80 dB S+N/N**	**30 dB SINAD**
1	Sample 1	3	-7	-10	-16	-17	-18	-15	-12	-9	0	X	-
2	Sample 2	5	5	0	-17	-24	-24	-17	0	-16	5	X	-
3	Sample 3	8	-7	-6	-14	-22	-22	-14	-7	-5	2	-	X
4	Sample 4	4	0	-2	-8	-14	-14	-8	-1	0	4	X	-

<u>Desensitization rejection ratio</u>

Procedure:

- Compute the difference of -80 dBm and desensitization level

Limits: The results must be above the limits in the table below.

Frequency offset [MHz]	Desensitization rejection ratio limits [dB]									
	-100	-20	-5	-1	-0.4	0.4	1	5	20	100
	65	65	65	60	50	50	60	65	65	65

Experimental results:

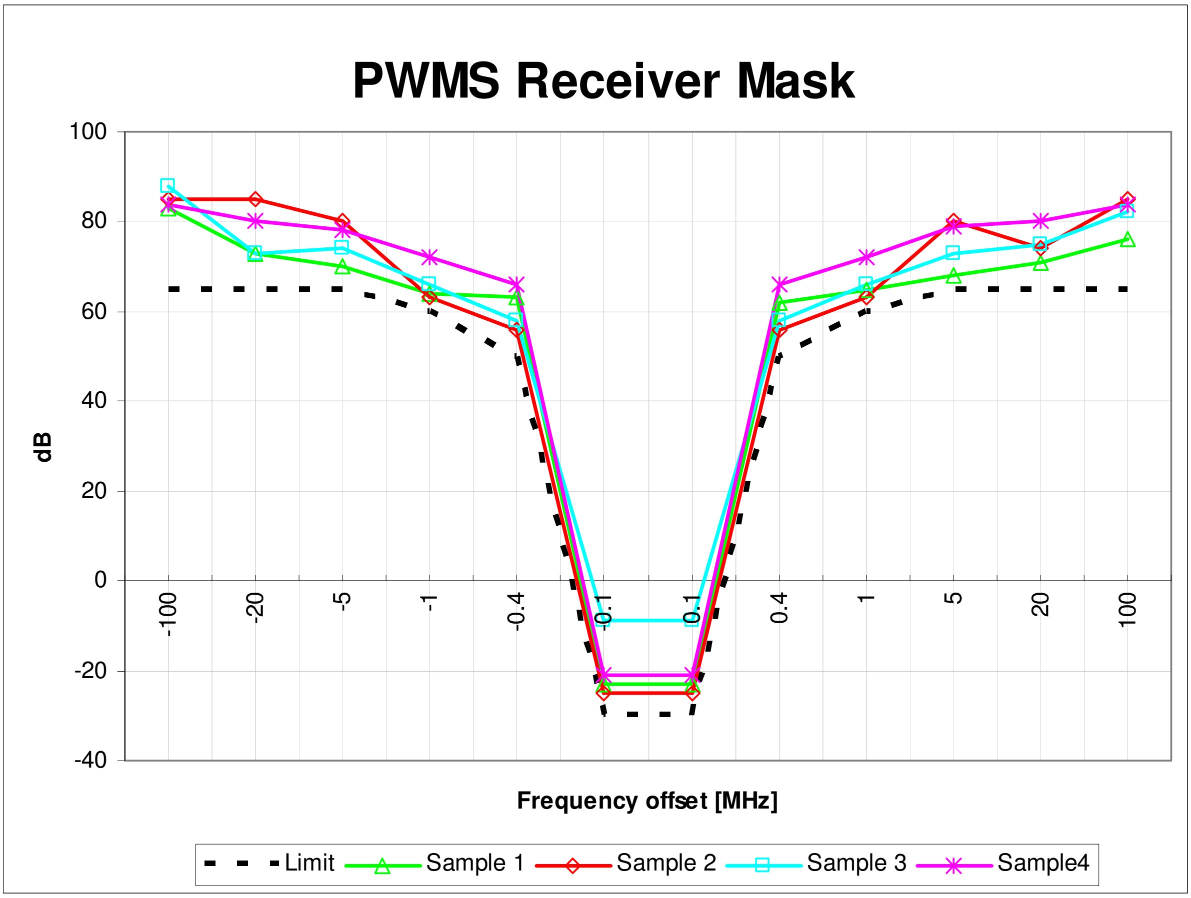
No	Receiver	Desensitization rejection ratio [dB]											
	Freq. offset [MHz]	-100	-20	-5	-1	-0.4	0.4	1	5	20	100	**80 dB S+N/N**	**30 dB SINAD**
1	Sample 1	83	73	70	64	63	62	65	68	71	76	X	-
2	Sample 2	85	85	80	63	56	56	63	80	74	85	X	-
3	Sample 3	88	73	74	66	58	58	66	73	75	82	-	X
4	Sample 4	84	80	78	72	66	66	72	79	80	84	X	-

Experimental results of PWMS receiver mask:

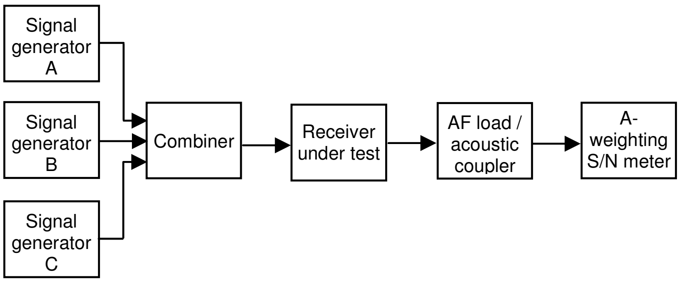
Frequency offset [MHz]	PWMS receiver mask [dB]											
	-100	-20	-5	-1	-0.4	-0.1	0.1	0.4	1	5	20	100
Limit	65	65	65	60	50	-30	-30	50	60	65	65	65
Sample 1	83	73	70	64	63	-23	-23	62	65	68	71	76
Sample 2	85	85	80	63	56	-25	-25	56	63	80	74	85
Sample 3	88	73	74	66	58	-9	-9	58	66	73	75	82
Sample 4	84	80	78	72	66	-21	-21	66	72	79	80	84

Note:
The table entry at f_C +/- 0.1 MHz will be described by negative value of co-channel protection ratio.

Receiver mask build from experimental results:



Intermodulation / Interferer level



Procedure:

- Set signal generator A on receiver frequency (f_C)
- Set signal generator A RF output level measured at receiver input to -80 dBm
- Set signal generator A to Modulation FM, Deviation +/- 24 kHz, AF 1000 Hz
- Set signal generator B modulation to an CW RF output signal (un-modulated)
- Set signal generator C modulation to FM, Deviation +/- 24 kHz, AF 400 Hz

- Set signal generator B & C RF output levels to -120 dBm
- Set signal generator B on receiver frequency f_C - 400kHz
- Set signal generator C on receiver frequency f_C - 800kHz
- Modify signal generator B&C RF output levels (B equal C) until S+N/N degrades to 80 dB(A). If the used audio compander technique required alternative can be measured on a limit of 30 dB SINAD.

- Set signal generator B & C RF output levels to -120 dBm
- Set signal generator B on receiver frequency f_C + 400kHz
- Set signal generator C on receiver frequency f_C + 800kHz
- Modify signal generator B&C RF output levels (B equal C) until S+N/N degrades to 80 dB(A). If the used audio compander technique required alternative can be measured on a limit of 30 dB SINAD.

Experimental results:

No	Receiver	Interferer level [dBm]	
-		Lower band	Upper band
1	Sample 1	-40	-40
2	Sample 2	-40	-40
3	Sample 3	-39	-39
4	Sample 4	-31	-31

Intermodulation rejection

- Compute the difference of -80 dBm and level in Results(6)

Limit: The Interferer rejection must be above (35) dB.

Experimental results:

No	Receiver	Interferer rejection [dB]	
-		Lower band	Upper band
1	Sample 1	40	40
2	Sample 2	40	40
3	Sample 3	41	41
4	Sample 4	49	49

<u>Test Procedure for **P**rofessional **W**ireless **M**icrophone **S**ystem **R**eceivers</u>

(updated 05-02-07)

Introduction:

PWMS must produce high-quality audio results in a difficult environment. Therefore minimum technical parameters are described, which are to be fulfilled. On basis of standardized measuring procedures good reproducibility has to be achieved.

General test requirement:

- The test equipment should be installed and operated under the conditions described by the manufacturer. The operating and environmental conditions are enclosed.

- On input and output only analogue audio signals are connected. Digital signals must be converted by manufacturer adapters into analogue input and / or output signals.

- With diversity receivers both receiver channels must be examined. The worst case results must be indicated.

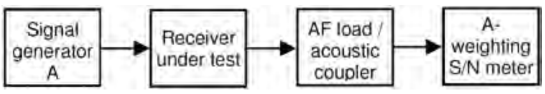
- Analogue STEREO receivers must be measured in MONO mode

Part1: Test procedure for analogue receiver

Definition:

The sensitivity of a receiver is a measure of its ability to receive weak signals and to produce an output having usable strength and acceptable quality (ITU-R-SM331).

Test set up:



Procedure:
- Set signal generator A to receiver frequency (f_C)
- Set signal generator A RF output level to -120 dBm
- Set signal generator A to FM modulation, deviation +/- 24 kHz, AF 1000 Hz
- Modify signal generator A RF output level until receiver S+N/N (Noise and Signal level divided by Noise level) degrades to 80 dB(A). If required, depending on the analogue audio compander technology used, the sensitivity can alternatively be measured on a limit of 30 dB SINAD.
- Record the RF level indicated by signal generator and the measurement result method in the table below.

Results(1):

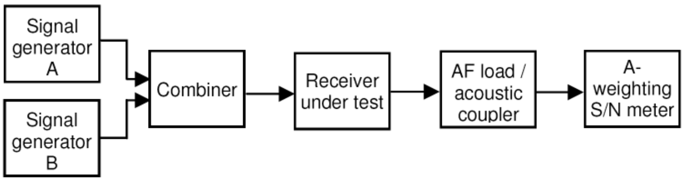
No	Receiver	Receiver Sensitivity [dBm]	80 dB S+N/N	30 dB SINAD
1	Sample 1			
2	Sample 2			

Limits:
The typical receiver sensitivity must be below -90 dBm below 1 GHz and -93 dBm above 1 GHz.
For miniaturized body worn receivers a sensitivity of -85 dBm below 1 GHz and -88 dBm above 1 GHz is applicable.

Co-channel rejection level

Definition:

The PWMS Co-Channel rejection level will be calculated as the level of the unwanted signal to the level of the wanted signal which degrades the receiver output audio S+N/N to 80 dB(A).



Procedure:

- Set signal generator A to receiver frequency (f_C)
- Set signal generator A RF output level measured at receiver input to -80 dBm
- Set signal generator A to FM modulation FM, deviation +/- 24 kHz, AF 1000 Hz
- Set signal generator B to receiver frequency (f_C)
- Set signal generator B RF output level to -120 dBm
- Set signal generator B to FM modulation, deviation +/- 24 kHz, AF 400 Hz
- Modify signal generator B RF output level until receiver S+N/N degrades to 80 dB(A). If required, depending on the analogue audio compander technology used, the co-channel rejection can alternatively be measured on a limit of 30 dB SINAD.
- Record the generator B RF level measured at receiver input and the measurement result method into the table below

Results(2):

No	Receiver	Co-channel rejection level [dBm] measured at combiner output	80 dB S+N/N	30 dB SINAD
1	Sample 1			
2	Sample 2			

Limit: No limit required at this point.

Co-channel rejection ratio

Procedure:

- Calculate the difference between -80 dBm and co-channel rejection level recorded in Results(2)
- Record the result and the measurement result method in the table below

Results(3):

No	Receiver	Co-channel protection ratio [dB]	80 dB S+N/N	30 dB SINAD
1	Sample 1			
2	Sample 2			

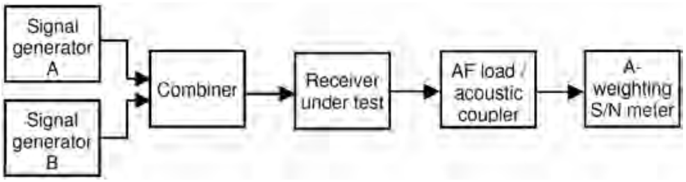
Limit: The applicable protection ratio suggested is 30 dB. The results shall be below this limit.

Selectivity

Definition:

The selectivity of a receiver is a measurement of its ability to discriminate between a wanted signal to which the receiver is tuned and unwanted signals. Selectivity is specified as the ratio (in dB) of the adjacent channel signal level to the wanted channel signal level. For PWMS applications the receiver selectivity will be measured at an offset of f_C +/- 0.4 MHz below 1GHz and f_C +/- 0.5 MHz above 1GHz.

Test setup:

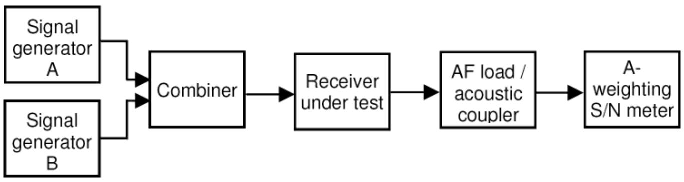


Note:
There are many receiver characteristics which are in principle measured with the same test set up. Because the measured results often overlap themselves the selectivity measurement will be summarized with the Blocking or Desensitization Level measuring method.

Blocking or Desensitization Level

Definition:

Receiver blocking or desensitization occurs when a strong off-channel signal overloads a receiver front end and thus reduces the sensitivity to weaker on-channel signals. This occurs when an undesired signal is very close to a nearby receiver's operating frequency.



Procedure:
- Set signal generator A to receiver frequency (f_C)
- Set signal generator A RF output level measured at receiver input to -80 dBm
- Set signal generator A to FM modulation, deviation +/- 24 kHz, AF 1000 Hz
- Set signal generator B modulation to a CW RF output signal (un-modulated)

- Set signal generator B to receiver frequency add a blocking offset of f_C-100 MHz
- Set signal generator B RF output level to -120 dBm
- Modify signal generator B RF output level until receiver S+N/N degrades to 80 dB(A). If required, depending on the analogue audio compander technology used, the desensitization level can alternatively be measured on a limit of 30 dB SINAD.
- Record the generator B RF level measured at receiver input and the measurement result method in the table below

Repeat the last 4 measurement steps with the f_C offsets of

below 1 GHz: -20MHz, -5MHz, -1MHz, -0.4MHz, 0.4MHz, 1MHz, 5MHz, 20MHz and 100MHz
above 1 GHz: -20MHz, -5MHz, -1MHz, -0.5MHz, 0.5MHz, 1MHz, 5MHz, 20MHz and 100MHz.

Record the measurement results in the table below.

Note: Any spurious response frequencies are to be considered part of the mask and should be avoided by at least twice the IF bandwidth.

Results(4):

No	Receiver	Desensitization level [dBm] measured at combiner output											
	Freq. offset [MHz]	-100	-20	-5	-1	-0.4[1] or -0.5[2]	0.4[1] or -0.5[2]	1	5	20	100	**80 dB S+N/N**	**30 dB SINAD**
1	Sample 1												
2	Sample 2												

[1)] below 1GHz
[2)] above 1GHz

Limits: No limits required at this point

Desensitization rejection ratio

Procedure:

- Calculate the difference between -80 dBm and desensitization level recorded in Results(4)
- Record the result in the table below

Results(5):

No	Receiver	Desensitization rejection ratio [dB]											
Freq. offset [MHz]		-100	-20	-5	-1	-0.4[1] or -0.5[2]	0.4[1] or -0.5[2]	1	5	20	100	**80 dB S+N/N**	**30 dB SINAD**
1	Sample 1												
2	Sample 2												

[1)] below 1GHz
[2)] above 1GHz

Limits below 1 GHz: The results must be above the limits in the table below.

Frequency offset [MHz]	Desensitization rejection ratio limit [dB]									
	-100	-20	-5	-1	-0.4	0.4	1	5	20	100
	65	65	65	60	47	47	60	65	65	65

Limits above 1 GHz: The results must be above the limits in the table below.

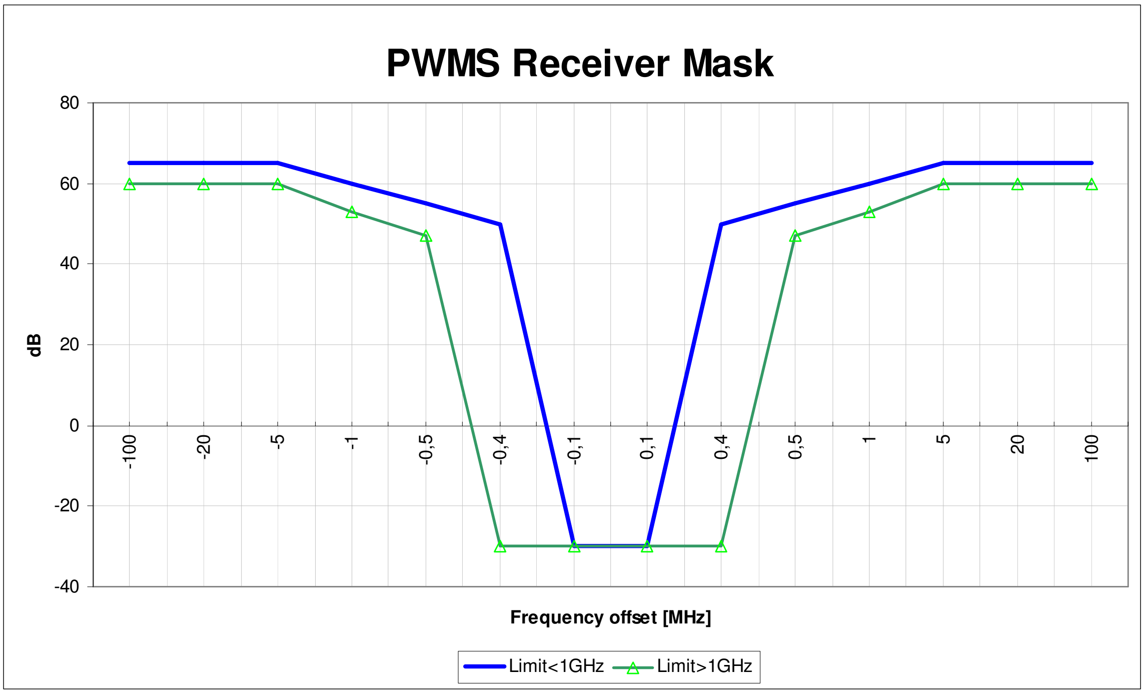
Frequency offset [MHz]	Desensitization rejection ratio limit [dB]									
	-100	-20	-5	-1	-0.5	0.5	1	5	20	100
	60	60	60	53	47	47	53	60	60	60

Note: Table has been updated (02-05-07)

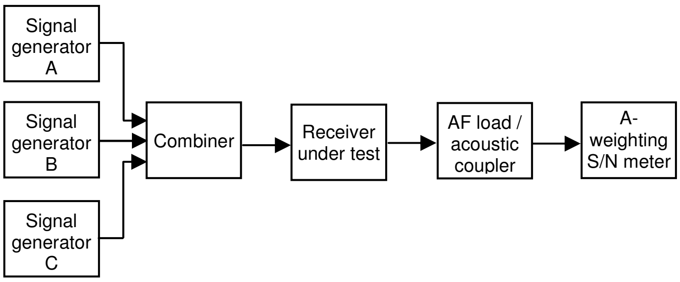
PWMS receiver mask:

Frequency offset [MHz]	PWMS receiver mask [dB]													
	-100	-20	-5	-1	-0.5	-0.4	-0.1	0.1	0.4	0.5	1	5	20	100
below 1 GHz	65	65	65	60	55	47	-30[1]	-30[1]	47	55	60	65	65	65
above 1 GHz	60	60	60	53	47	-30[2]	-30[1]	-30[1]	-30[2]	47	53	60	60	60
Sample 1														
Sample 2														

Notes:
[1)] The table entries at f_C +/- 0.1 MHz are described by negative value of co-channel protection ratio.
[2)] The table entries at f_C +/- 0.5 MHz are connected to the possible higher receiver bandwidth above 1 GHz and will also be described by negative value of co-channel protection ratio.



Intermodulation / Interferer level



Procedure:

- Set signal generator A to receiver frequency (f_C)
- Set signal generator A RF output level measured at receiver input to -80 dBm
- Set signal generator A to FM modulation, deviation +/- 24 kHz, AF 1000 Hz
- Set signal generator B modulation to a CW RF output signal (un-modulated)
- Set signal generator C to FM modulation, deviation +/- 24 kHz, AF 400 Hz

- Set signal generator B & C RF output levels to -120 dBm
- Set signal generator B to receiver frequency f_C – 0.4 MHz below 1 GHz or -0.5 MHz above 1 GHz
- Set signal generator C to receiver frequency f_C – 0.8 MHz below 1 GHz or -1.0 MHz above 1 GHz
- Modify signal generator B&C RF output levels (B equal C) until S+N/N degrades to 80 dB(A). If required, depending on the analogue audio compander technology used, the intermodulation level can alternatively be measured on a limit of 30 dB SINAD.
- Record the generator B&C RF level measured at receiver input in the table below (lower band)

- Set signal generator B & C RF output levels to -120 dBm
- Set signal generator B on receiver frequency f_C + 0.4MHz below 1 GHz or +0.5MHz above 1 GHz
- Set signal generator C on receiver frequency f_C + 0.8MHz below 1 GHz or +1.0MHz above 1 GHz
- Modify signal generator B&C RF output levels (B equal C) until S+N/N degrades to 80 dB(A). If required, depending on the analogue audio compander technology used, the measurement can alternatively be taken on a limit of 30 dB SINAD.
- Record the generator B&C RF level measured at receiver input into the table below (upper band)

Results(6):

No	Receiver	Interferer level [dBm]	
-		Lower band	Upper band
1	Sample 1		
2	Sample 2		

Intermodulation rejection

- Calculate the difference between -80 dBm and level in Results(6)
- record the result in the table below

Results(7):

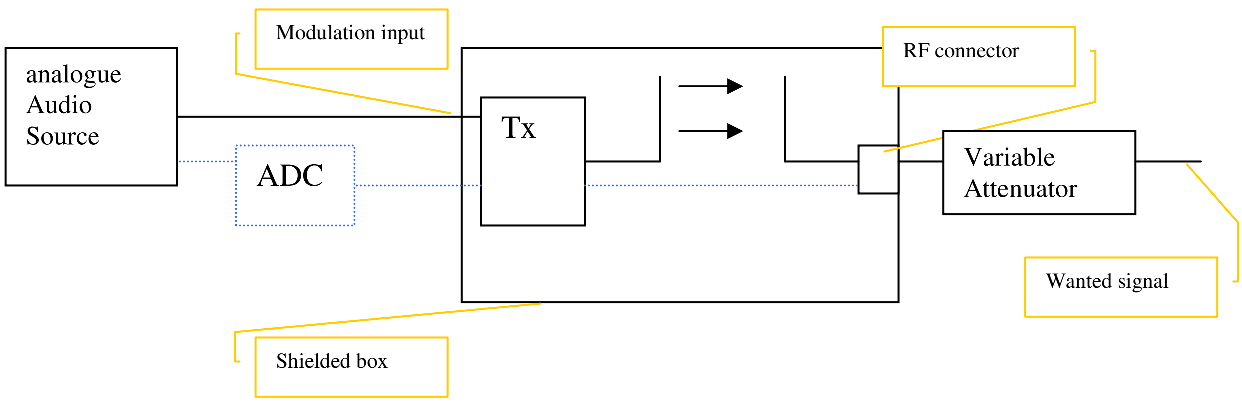
No	Receiver	Interferer rejection [dB]	
-		Lower band	Upper band
1	Sample 1		
2	Sample 2		

Limit: The Interferer rejection must be above 35 dB below 1GHz or 30 dB above 1 GHz.

Part 2: Modification of test procedure for digital receiver test

Basically the same test procedures as for analogue systems shall apply. Where appropriate, A/D or D/A converters shall be provided by the manufacturer.

1.) Signal generator A ("wanted signal") shall be replaced by the following setup:



The Transmitter (Tx) shall be provided by the manufacturer. The Tx is modulated by an analogue or digital audio signal. In the latter case an analogue-digital-converter (ADC) will be used. The output of the transmitter is fed to an RF-connector (directly or via an antenna), The level of this RF signal shall be measured by a spectrum analyser, adjusted by an attenuator according to the test procedure used as wanted signal. This setup allows the use of different digital modulation techniques used by different manufacturers.

The modulation level shall be 6dB below the level when ADC clipping occurs, AF 1000Hz

Notes:
The 'Shielded box' must shield all inputs (for example, audio signal or DC power) by better than 60 dB to all points at the connected receiver under test (DUT).
Shielded boxes can be replaced by EMC test chambers or GTEM cells.

2.) Receiver audio output :

The same performance criteria as for analogue receivers shall apply.
Digital audio output signals shall be converted to analogue signals using a DAC provided by the manufacturer; the analogue signal shall be the measure for the performance.