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System Reference document (SRdoc);
Short Range Devices (SRD) using
Nuclear Magnetic Resonance (NMR);
Technical characteristics for SRD equipment using
Nuclear Magnetic Resonance (NMR) technology
in the frequency range 0,1 kHz to 130 MHz

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Foreword

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

The present document contains 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).

Modal verbs terminology

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Executive summary

The present document provides information about applications and technical background of Nuclear Magnetic Resonance (NMR) systems. The current frequency regulation is shown. A request for clarification for allocation and regulation of NMR devices is placed.

Introduction

Nuclear Magnetic Resonance (NMR) systems are applicable for a huge spectrum of applications. For NMR systems in focus of the present document, neither the frequency regulation is clear, nor are frequency allocations available for a wide range of NMR applications.

1 Scope

The present document provides information on NMR systems operating in the frequency range below 130 MHz.

It deals only with NMR systems using earth magnetic field strength of rare earth magnets and electromagnets and not with superconducting magnets. This limits the maximum static magnetic field strength to less than 3 Tesla. As a direct result, the maximum proton nuclear magnetic resonance is limited to less than 130 MHz. The minimum nuclear resonances of nuclei in scope are below 1 kHz in earth magnetic field.

There are two types of NMR devices:

1) "enclosed NMR sensor": Material under Test is put inside the device;

2) "open NMR sensor":

   - material under Test is placed on the device;
   - opened to one side for measurement of building materials like a GPR or WPR generating wanted field emission at the sensor boundaries;
   - opened 360°, e.g. like a pole inside a Material under Test generating wanted field emission at the sensor boundaries;
   - there is no enclosure around the sensor, called "open NMR sensor".

Only "enclosed NMR" sensors" are in the scope of the present document.

Nuclear Magnetic Resonance Imaging (MRI) and Magnetic Resonance Tomography (MRT) systems are out of scope.

It reviews the present regulations for NMR systems (if any), the related markets and the evolution of the technology and it identifies limits for NMR systems operating below 130 MHz.

The present document contains the necessary information to support the possible co-existence and compatibility studies to be conducted by the CEPT/ECC, including:

- market information;
- technical information;
- regulatory issues.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] EC Decision 2013/752/EU: "Decision on harmonisation of the radio spectrum for use by short-range devices".

[i.2] CEPT/ERC Recommendation 70-03 (5 October 2018): "Relating to the use of Short Range Devices (SRD)".

[i.3] https://en.wikipedia.org/wiki/Nuclear_magnetic_resonance (04-12-2018).

[i.4] https://www.bruker.com/de/products/mr/nmr.html.

[i.5] ETSI EN 300 330 (V2.1.1) (2017-02): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz". .

[i.6] https://en.wikipedia.org/wiki/Gyromagnetic_ratio latest version of 28-11-2018.

[i.7] CISPR 11 (2017-03): "Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement".

[i.8] DS Simulia CST version 2017 3D Electromagnetic field simulation software help on "power view".

[i.9] Directive 2014/53/EU on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment.

[i.10] ITU Radio Regulations Articles Edition 2016.

[i.11] ERC report 25 (October 2017): "The European table of frequency allocations and applications in the frequency range 8.3 kHz to 3000 GHz (ECA TABLE)".

[i.12] ECC Report 001 (February 2002): "Compatibility between inductive LF and HF RFID transponder and other radio communications systems in the frequency ranges 135-148.5 kHz, 4.78-8.78 MHz and 11.56-15.56 MHz".

[i.13] ECC Report 007 (February 2002): "Compatibility between inductive LF RFID systems and radio communications systems in the frequency range 135-148.5 kHz".

[i.14] ECC Report 012 (October 2002): "Ultra Low Power Active Medical Implant systems (ULP-AMI)".

[i.15] ECC Report 024 (May 2003): "PLT, DSL, CABLE communications (Including CABLE TV), LANS and their effect on radio services".

[i.16] ECC Report 064 (February 2005): "The protection requirements of radiocommunication systems below 10.6 GHz from generic UWB applications".

[i.17] ECC Report 067 (October 2005): "Compatibility study for generic limits for the emission levels of inductive SRDs below 30 MHz".

[i.18] ERC Report 069 (February 1999): "Propagation Model And Interference Range Calculation. For Inductive Systems 10 kHz - 30 MHz".

[i.19] ECC Report 073 (October 2005): "Compatibility of SRD in the FM radio broadcasting band".

[i.20] ERC Report 074 (May 1999): "Compatibility Between Radio Frequency Identification Devices (RFID) and The Radio astronomy Service At 13 MHz".

[i.21] ECC Report 081 (May 2006): "The coexistence between Ultra Low Power - Animal Implant Devices (ULP-AID) operating in the frequency band 12.5-20 MHz and existing radiocommunication systems".

[i.22] ECC Report 098 (February 2007): "Studying the compatibility issues of the UIC EUROLOOP system with other systems in the frequency band 9.5 to 17.5 MHz".

[i.23] ECC Report 135 (September 2009): "Inductive limits in the frequency range 9 kHz to 148.5 kHz".

[i.24] ECC Report 181 (September 2012): "Improving spectrum efficiency in SRD bands".

[i.25] ECC Report 208 (January 2014): "Impact of RFID devices on radio services in the band 13.56 MHz".

[i.26] ERC Report 044 (January 1997): "Sharing inductive systems and radiocommunication systems in the band 9-135 kHz".

[i.27] ERC Report 092 (June 2000): "Sharing inductive Short Range Devices and radio communication systems in 10.2-11 MHz".

[i.28] ERC Report 095 (June 2000): "The use of 3155-3400 kHz for general inductive applications".

[i.29] ERC Report 096 (June 2000): "The use of 290-300 kHz and 500-510 kHz for general inductive applications".

[i.30] ITU-R Report SM.2180-0 (2010): "Impact of industrial, scientific and medical (ISM) equipment on radio communication services".

[i.31] Recommendation ITU-R SM.2028 (09/2012): "Protection distance calculation between inductive systems and radio communication services using frequencies below 30 MHz".

[i.32] ETSI EN 300 220-1 (V3.1.1) (2017-02): "Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz; Part 1: Technical characteristics and methods of measurement".

[i.33] ETSI EN 300 220-2 (V3.1.1) (2017-02): "Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz; Part 2: Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU for non specific radio equipment".

[i.34] ETSI EN 300 422-1 (V2.1.2) (2017-01): "Wireless Microphones; Audio PMSE up to 3 GHz; Part 1: Class A Receivers; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.35] ETSI EN 300 422-4 (V2.1.1) (2017-05): "Wireless Microphones; Audio PMSE up to 3 GHz; Part 4: Assistive Listening Devices including personal sound amplifiers and inductive systems up to 3 GHz; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.36] ETSI EN 300 433 (V2.1.1) (2016-05): "Citizens' Band (CB) radio equipment; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.37] ETSI ETS 300 718 (1997-03): "Radio Equipment and Systems (RES); Avalanche beacons; Transmitter-receiver systems".

[i.38] ETSI EN 300 718-1 (V2.1.1) (2018-01): "Avalanche Beacons operating at 457 kHz; Transmitter-receiver systems; Part 1: Harmonised Standard for access to radio spectrum".

[i.39] ETSI EN 302 065-1 (V2.1.1) (2016-11): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 1: Requirements for Generic UWB applications".

[i.40] ETSI EN 302 066 (V2.1.1) (2017-01): "Short Range Devices (SRD); Ground- and Wall- Probing Radar applications (GPR/WPR) imaging systems".

[i.41] ETSI EN 302 195 (V2.1.1) (2016-06): "Short Range Devices (SRD); Ultra Low Power Active Medical Implants (ULP-AMI) and accessories (ULP-AMI-P) operating in the frequency range 9 kHz to 315 kHz".

[i.42] ETSI EN 302 510-1 (V1.1.1) (2007-07): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio equipment in the frequency range 30 MHz to 37,5 MHz for Ultra Low Power Active Medical Membrane Implants and Accessories; Part 1: Technical characteristics and test methods".

[i.43] ETSI EN 302 536 (V2.1.1) (2017-10): "Short Range Devices (SRD); Radio equipment operating in the frequency range 315 kHz to 600 kHz for Ultra Low Power Animal Implantable Devices (ULP-AID) and associated peripherals; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.44] ETSI EN 302 608 (V2.1.1) (2017-11): "Short Range Devices (SRD); Radio equipment for Eurobalise railway systems; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.45] ECC/DEC/(05)02: "The designation and availability of frequency bands for railway purposes in the 876-880 MHz and 921-925 MHz bands".

[i.46] EC Decision 2014/641/EU: "Commission Implementing Decision of 1 September 2014 on harmonised technical conditions of radio spectrum use by wireless audio programme making and special events equipment in the Union (notified under document C(2014) 6011) Text with EEA relevance".

[i.47] ECC/DEC/(06)08: "ECC Decision of 1 December 2006: The conditions for use of the radio spectrum by Ground- and Wall- probing radar (GPR/WPR) imaging systems".

[i.48] ECC/DEC(11)02: "Industrial Level Probing Radars (LPR) operating in frequency bands 6 - 8.5 GHz, 24.05 - 26.5 GHz, 57 - 64 GHz and 75 - 85 GHz".

[i.49] Recommendation 74-01E (2001): "Unwanted emissions in the spurious domain".

[i.50] Decision (11)03 (17 June 2016): "The harmonised use of frequencies for Citizens' Band (CB) radio equipment".

[i.51] ECC/DEC/(06)04 (amended 9 December 2011): "The harmonised conditions for devices using Ultra-wideband (UWB) technology in bands below 10.6 GHz".

[i.52] ECC/DEC/(07)01 (Corrected 18 November 2016): "Building Material Analysis (BMA) devices using UWB technology".

[i.53] ECC/REC/(11)09 (Amended 22 May 2015): "UWB Location Tracking Systems TYPE 2 (LT2)".

[i.54] ECC/REC/(11)10 (21 October 2011): "Location tracking application for emergency and disaster situations (LAES)".

[i.55] ERC Rec 62-01 (1997): "Use of the Band 135.7-137.8 kHz by the Amateur Service".

[i.56] ERC/DEC(01)11 (Updated 17 November 2017): "Short Range Devices for Flying Model Control in 34.995-35.225 MHz".

[i.57] ERC/DEC(01)12 (Updated 17 November 2017): "Short Range Devices for Model Control in 40.665, 40.675, 40.685 and 40.695 MHz".

[i.58] 2007/346/EC: "Granting a derogation requested by France pursuant to Decision 2006/804/EC on harmonisation of the radio spectrum for Radio Frequency Identification (RFID) devices operating in the Ultra High Frequency (UHF) band".

[i.59] 2008/432/EC: "Amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices".

[i.60] 2009/343/EC: "Amending the Decision 2007/131/EC on the harmonised use of the radio spectrum for equipment using UWB technology".

[i.61] 2009/381/EC: "Amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by SRD".

[i.62] 2010/368/EU: "Amending the Decision 2006/771/EC on harmonisation of the radio spectrum for use by SRD".

[i.63] 2011/829/EU: "Amending Decision 2006/771/EC on the harmonisation of the radio spectrum for use by SRD".

[i.64] 2014/702/EU: "Amending 2007/131/EC on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonised manner in the Community".

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[i.66] 2017/1483/EU: "Amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by SRD and repealing Decision 2006/804/EC".

[i.67] Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility.

[i.68] Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits.

[i.69] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

[i.70] IEC EN 61010-1:2010: "Safety Requirements for electrical equipment for measurement, control and laboratory use".

[i.71] IEC EN 61326-1:2013: "Electrical equipment for measurement, measurement, control and laboratory use. EMC requirements".

[i.72] BS EN 50581:2012: "Assessment of electrical and electronic products with respect to the RoHS".

[i.73] Recommendation ITU-R SM.1056-1 (1994-2007): "Limitation of radiation from industrial, scientific and medical (ISM) equipment".

[i.74] FCC Rules & Regulations for Title 47 06-12-2018.

NOTE: Available at: https://www.fcc.gov/wireless/bureau-divisions/technologies-systems-and-innovation-division/rules-regulations-title-47.

[i.75] IEC 60601-1-2: "Medical electrical equipment - Part 1-2: General requirements for basic safety and essential performance - Collateral Standard: Electromagnetic disturbances - Requirements and tests".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

coil radiation efficiency: power applied into a coil converted to a straw field strength outside of the measurement volume of the NMR sensor

Nuclear Magnetic Resonance (NMR): measurement technique using nuclear magnetic resonance excitation and response of a material under test to get material property informations

3.2 Symbols

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

^{1}H	hydrogen nucleus
^{13}C	spin active carbon nucleus
α	flip angle of nuclear spins
P	Power
f	frequency
f_{lamor}	precession frequency of nuclear spins
H	magnetic field strength
B0	static magnetic field strength for premagnetization of nuclear spins
B1, B1+	alternating magnetic field strength for excitation of nuclear spins
Gx, Gy, Gz	Gradient field in x,y,z direction
t	time
T	Tesla
T1	Relaxation Time of all spins
T2	Relaxation Time of Free Induction Decay
TE	Echo Time

TR	Repetition Time
τ	pulse duration

3.3 Abbreviations

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

CD	Committee Draft
CEPT	European Conference of Postal and Telecommunications administrations
CG	Correspondence Group
CISPR	Comité International Spécial des Perturbations Radioélectriques
CPMG	Carr-Purcell-Meiboom-Gill sequence of pulses in a NMR experiment
ECC	Electronic Communications Committee
EMC	Electro Magnetic Compatibility
ERC	European Radiocommunications Committee
ERM	EMC and Radio spectrum Matters
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission (of the USA)
FM	Frequency Modulation
FID	Free Induction Decay
GPR	Ground Penetrating Radar
IEC	International Electrotechnical Commission
IHS	Information Handling Services
IPR	Intellectual Property Rights
ISM	Industrial Scientific Medical
ISO	International Organization for Standardization
ITU	International Telecommunication Union
LS	Liaison Statement
MoU	Memorandum of Understanding
MRI	Magnetic Resonance Imaging
MRT	Magnetic Resonance Tomography

NOTE: Also known as Magnetic Resonance Imaging (https://en.wikipedia.org/wiki/Magnetic_resonance_imaging).

MUT	Material Under Test
NMR	Nuclear Magnetic Resonance
RF	Radio Frequency
REC	RECommendation
RES	RESolution
RR	Radio Regulations
RX	Receiver
SAE	Society of Automotive Engineers
SDO	Standards Development Organization
SFC	Solid Fat Content
SR	Special Report
SRD	Short Range Device
TC	Technical Committee
TCAM	Telecommunication Conformity Assessment and Market Surveillance Committee
TR	Technical Report
TX	Transmitter
UHF	Ultra High Frequency
VHF	Very High Frequency
WD	Working Draft
WP	Working Party
WPR	Wall Penetrating Radar
WRC	World Radiocommunication Conference

4 Void

5 Presentation of the system or technology

5.1 Nuclear Magnetic Resonance Technology

Intention here is to inform about the NMR phenomenon.

Source of this clause: [i.3]

"Nuclear Magnetic Resonance (NMR) is a physical phenomenon in which nuclei in a magnetic field absorb and re-emit electromagnetic radiation. This energy is at a specific resonance frequency which depends on the strength of the magnetic field and the magnetic properties of the isotope of the atoms; in practical applications, the frequency is similar to VHF and UHF television broadcasts (60–1 000 MHz). NMR allows the observation of specific quantum mechanical magnetic properties of the atomic nucleus. Many scientific techniques exploit NMR phenomena to study molecular physics, crystals, and non-crystalline materials through nuclear magnetic resonance spectroscopy. NMR is also routinely used in advanced medical imaging techniques, such as in magnetic resonance imaging (MRI).

All isotopes that contain an odd number of protons and/or neutrons (see Isotope) have an intrinsic magnetic moment and angular momentum, in other words a nonzero spin, while all nuclides with even numbers of both have a total spin of zero. The most commonly studied nuclei are ^{1}H and ^{13}C, although nuclei from isotopes of many other elements (e.g. ^{2}H, ^{6}Li, ^{10}B, ^{11}B, ^{14}N, ^{15}N, ^{17}O, ^{19}F, ^{23}Na, ^{29}Si, ^{31}P, ^{35}Cl, ^{113}Cd, ^{129}Xe, ^{195}Pt) have been studied by high-field NMR spectroscopy as well.

A key feature of NMR is that the resonance frequency of a particular substance is directly proportional to the strength of the applied magnetic field. It is this feature exploited in imaging techniques; if a sample is placed in a non-uniform magnetic field then the resonance frequencies of the sample's nuclei depend on where in the field they are located. Since the resolution of the imaging technique depends on the magnitude of magnetic field gradient, many efforts are made to develop increased field strength.

The principle of NMR usually involves three sequential steps:

- *The alignment (polarization) of the magnetic nuclear spins in an applied, constant magnetic field B0.*
- *The perturbation of this alignment of the nuclear spins by a weak oscillating magnetic field, usually referred to as a radio-frequency (RF) pulse. The oscillation frequency required for significant perturbation is dependent upon the static magnetic field (B0) and the nuclei of observation.*
- *The detection of the NMR signal during or after the RF pulse, due to the voltage induced in a detection coil by precession of the nuclear spins around B0. After an RF pulse, precession usually occurs with the nuclei's intrinsic Larmor frequency and, in itself, does not involve transitions between spin states or energy levels.*

"

NMR utilizes 3 different magnetic fields:

- First the main magnetic field, denoted as B0.
- Second the RF field denoted as B1.
- And third, optionally, gradient fields superimposed on the B0 field, denoted as Gx, Gy, Gz for the x,y and z directions, which are commonly switched on and off in the kHz range. If gradients are used or not depends on the application and the chosen pulse sequence.

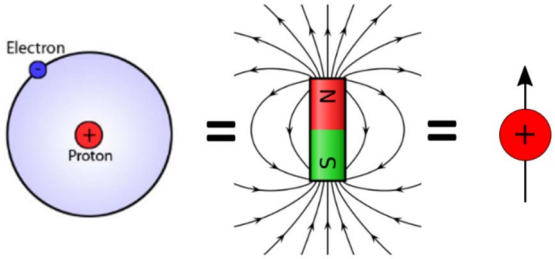


Figure 1: Nuclear magnetic spin of a hydrogen atom

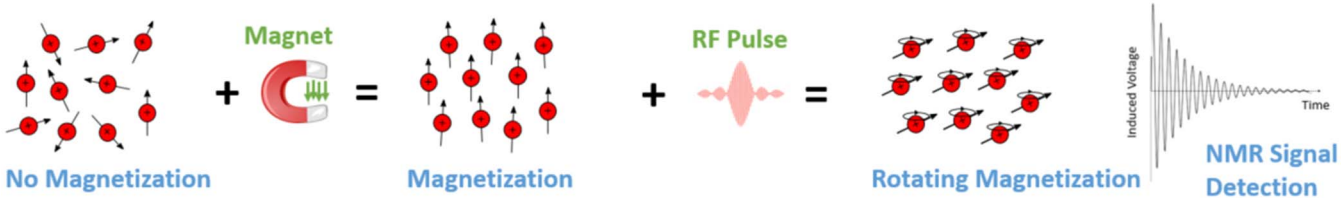


Figure 2: Static magnetization, high frequency excitation and decay of spins

The B0 field is either made by a permanent magnet or an electromagnet and are static or slowly changing over time (aging effects) and temperature.

The two fields are usually chosen to be perpendicular to each other as this maximizes the NMR signal strength. The resulting response by the total magnetization (M) of the nuclear spins is the phenomenon that is exploited in NMR spectroscopy and magnetic resonance imaging. Both use intense applied magnetic fields (B0) in order to achieve dispersion and very high stability to deliver spectral resolution, the details of which are described by chemical shifts, the Zeeman effect, and Knight shifts (in metals).

NMR phenomena are also utilized in low-field NMR, NMR spectroscopy and MRI in the Earth's magnetic field (referred to as Earth's field NMR), and in several types of magnetometers.

5.2 Examples of existing applications

5.2.1 Medical nuclear magnetic resonance imaging / tomography

Some companies offer stand-alone devices for medical diagnostics like nuclear magnetic resonance imaging (MRI) or tomography MRT. Weight > 1 ton beyond 10 tons and > 10 kVA to 110 kVA electrical power demand. These devices are placed into a shielded room. RF amplifier have some 32 kW peak power.

NOTE: Wikipedia license CC BY-SA 3.0, source: https://commons.wikimedia.org/w/index.php?curid=680466 https://de.wikipedia.org/wiki/Magnetresonanztomographie#/media/File:Modern_3T_MRI.JPG.

Figure 3: Magnetic Resonance Tomograph MRT, copyright by KasugaHuang

These applications are not in the scope of the present document.

5.2.2 Study the structure of molecules

TD-NMR Applications (Time-Domain NMR, [i.4]) are Benchtop Systems which span all kinds of industries from food, like Solid Fat Content (SFC), and oil seed analysis, via chemical and polymer industry and finally to medical and pharmaceutical industry (obesity research and MRI contrast agents).

NMR are used in process control inline with stop-flow valves for investigating a test sample. NMR can be used to measure the rheological properties of matter.

A recent research activity shows that with only a mobile phone, a thin needle and a small molecular magnetic resonance apparatus it is possible to detect cancerous tumours.

5.2.3 Geophysical applications

Based on earth magnetic field as static field source, there are applications for environmental investigations e.g. groundwater detection and well logging available. Frequency range is below 9 kHz due to low earth magnetic field strength and ^{1}H hydrogen nucleus and ^{13}C carbon nucleus. There are devices with static magnetic field for moisture detection around 450 kHz available for ^{1}H hydrogen nucleus.

5.3 Future NMR Applications

5.3.1 General

In future NMR technology can be used for a wide range of determination applications. This is based on technology improvement of static magnets, electronics and related cost, size and weight reduction.

Field of applications are:

- Food determination (quality, quantity/packaging and composition)
- Pharmacy determination (quality, quantity/packaging and composition)
- Building materials determination (humidity, hidden objects and composition)
- Vital monitoring
- Fluid determination (fuel quality and composition, engine oil quality, hydraulic oil)

Above mentioned applications are to be met with use case specific NMR sensor devices. Possible sensors include benchtop devices for stationary use, mobile devices to be carried by the user to the point of interest and sensor devices to be embedded in existing products, i.e. cars, home appliances or industrial machinery.

5.3.2 NMR mobile devices

The improvement in technology enables future NMR devices, which are to be used mobile. This implies a light-weight, small sized magnet with small sensitive volume, what further leads to low power RF application. Furthermore, in case of a car the car itself presents an additional RF shielding.

Examples (under investigation): Fuel data for optimized internal combustion engines mapping are measured at every refuelling event for some seconds.

Building materials quality assessments are done for some minutes per day.

Emergency vital parameter measurements are done for some seconds at emergency cases, if the specific information about the vital parameter is needed.

5.3.3 NMR fixed appliances

NMR devices for fixed appliances bear a small risk of disturbing other relevant services, as RF damping by walls is present and considerable distances to the outside receivers is ensured. A fixed placement allows considerable shielding of the NMR device.

Possible applications could be a U-shaped sensor placed at a conveyor band for fluid mass determination.

5.3.4 The societal benefits

NMR devices bear great potential to serve society in a variety of use cases. Environmental benefits are expected by improved employment of fuels and other resource in all kinds of vehicles and processes. Professionals and consumers may benefit in daily life issues in household, construction and maintenance. Mobile NMR devices for medical purposes in emergency cases improve ad-hoc availability of vital parameters. Fixed installed devices improve the timely availability of sophisticated laboratory methods in rural areas and developing countries for medical as well as for food quality parameter.

6 Market information

In general, there are the following categories of NMR device in market or are to be placed into market in future:

1) Fixed installed NMR devices for industrial research laboratories in low density of one to ten devices per city.

2) Benchtop NMR devices in industrial research laboratories one to hundred devices per city.

3) Quasi fixed NMR devices e.g. for hydrologic uses cases on site or applications can in geophysical applications with some devices per country.

4) Mobile NMR devices on-road and off-road vehicle, aircrafts and marine applications are not available on the market as far as known. Future take rates are under investigation.

5) Fixed installed NMR devices for industrial applications in packaging machines in low density of far less than one device per city.

7 Technical information

7.1 Detailed technical description

7.1.1 Dependencies of magnetic resonance frequency

The resonance frequency of MUT depends on the B0 static magnetic field strength and the type of nucleus. The required B1 magnetic field frequency is given by the field strength of the B0 magnetic field and a constant γ (gyromagnetic ratio) given by the nuclei under test, see formula (1). Table 1 summarizes values for NMR active nuclei. Most prominently for protons $\gamma/2\pi$ is 42,5 MHz/Tesla. The formula describes the dependency of a resonant frequency from MUT and B0 static magnetic field strength.

$$f_{\mathrm{Larmor}} = \frac{\gamma}{2\pi} \cdot B \tag{1}$$

Other nuclei are at lower frequencies with a factor γ. The sign of the gyromagnetic ratio, γ, determines the sense of precession. Nuclei such as ^{1}H and ^{13}C are said to have clockwise precession, whereas ^{15}N has counter-clockwise precession, which is expressed by a negative sign (source: [i.6]).

Table 1: Lamor frequency of different nuclei

Type of Nucleus	Gyromagnetic ratio [MHz/T]
^{1}H	42,578
^{2}H	6,536
^{3}He	32,434
^{7}Li	16,546
^{13}C	10,705
^{14}N	3,077
^{15}N	4,316
^{17}O	5,772
^{19}F	40,052
^{23}Na	11,262
^{27}Al	11,103
^{29}Si	8,465
^{31}P	17,235
^{57}Fe	1,382
^{63}Cu	11,319
^{67}Zn	2,669
^{129}Xe	11,777

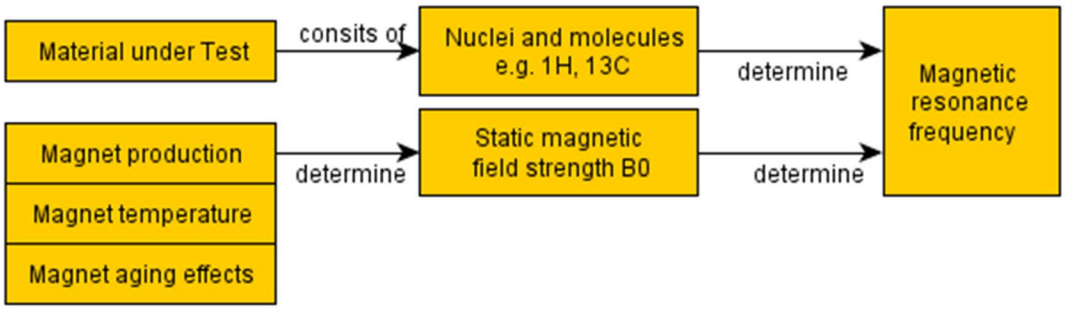


Figure 4: Cause and effect on resonance frequency

7.1.2 Range of magnetic resonance frequency

Lower limit for future applications are given by B0 static magnetic field strengths which is the earth magnetic field strength.

EXAMPLE 1: Together with B1 field resonance frequencies of nuclei under investigation, e.g. ^{13}C with 10,6 MHz/T at earth magetic field of 20 µT, a resonance frequency of:

f_{13C} = 10,6 MHz/T × 20 µT = 201,2 Hz

Upper frequency limit for the future NMR is under investigation. If super conducting magnets are not considered, upper limit around B0 = 3 T is assumed to be feasible with existing materials and magnet configurations.

EXAMPLE 2: 1H nuclei have a gyromagnetic ratio of 42,6 MHz/T, with leads to:

f_{1H} = 42,6 MHz/T × 3 T = 127,8 MHz

Therefore the frequency range of interest is from below 1 kHz to 130 MHz for the future use cases.

7.1.3 Variance of magnetic resonance frequency

Frequency dependency of B1 is a direct result of the dependency on the static magnetic field strength B0, which causes implications on required frequency bandwidth for magnetic resonance excitation:

1) B0 static magnetic field strength is varying from device to device's **magnet production** and over time by **aging effects**. The magnetic field strength B0 variance is under investigation and is assumed to be within **some 100 ppm** for future applications.

EXAMPLE 1: Resonance frequency of a proton varies by
42,57 MHz/T × 100 ppm / K = **4,257 kHz / T**

2) **Temperature drift** of the static magnetic field strength B0 of rare earth magnets inside a NMR device in service are in the range of **1 000 ppm / K** over an ambient **temperature range from -40 °C to 125 °C** for automotive applications and -40 °C to +85 °C for industrial applications.

EXAMPLE 2: Resonance frequency of a proton varies by
42,57 MHz/T × 1 000 ppm / K = 42,57 kHz / (T × K).
Over full automotive range of -40 °C to 125 °C = 165 K,
42,57 kHz / (T ×K) × 165 K **= 7,02405 MHz / T**

3) **Earth magnetic field** is in the 20 to 60 µT range and is added by superposition to B0 static magnetic field strength.

EXAMPLE 3: Resonance frequency of a proton varies by
42,57 MHz/T × 40 µT = 42,57 kHz / K = **1,7208 kHz**

An evaluation of the magnetic resonance frequency variances is provided in table 2 for some ISM frequencies and their bandwidths for 1H protons.

Maximum production variance of static magnetic field strength B0 in ppm is directly given by ISM bandwidth assuming 0 K temperature drift of the magnet.

Table 2: ISM Bands and Bandwidths and required B0 field strength and variance

Centre frequency [kHz]	Bandwidth [kHz]	Static magnetic field strength B0 for 1H resonance [T]	Maximum production variance of B0 field strength [ppm]	Enabled temperature range by frequency correction in band [K]	Current regulated bandwidth
6 780	30	0,16	30, not feasible	no temperature shift	not sufficient
13 560	14	0,32	14, not feasible	no temperature shift	not sufficient
27 120	326	0,64	326	no temperature shift	not sufficient
40 680	40	0,96	40, not feasible	no temperature shift	not sufficient

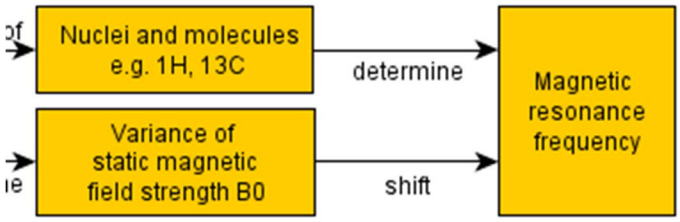


Figure 5: Variance of B0 causes shift of magnetic resonance frequency

Conclusion: Variance of static magnetic field strength B0 of NMR devices is shifting the magnetic resonance frequency more than defined bandwidths in ISM bands. For low cost NMR applications the ISM bands definition are too narrow to build low cost systems without temperature compensation and active magnetic field strength compensation.

7.1.4 Time signals and resulting spectrum

There are many different pulse patterns used in NMR measurements forming the spectral emissions and occupying bandwidth.

In the most simple excitation mode a NMR device excites nuclear spins in MUT to a 90° flip angle and then switches to receive mode to measure so called "Free Induction Decay" FID of the relaxing spins. Therefore, B1 magnetic field excitation duration and field strength are adjusted to achieve a desired flip angle α of the magnetic spin of the nuclei in the material under test.

$$\alpha = 42.6 \frac{MHz}{T} \cdot (2\pi) \cdot \tau \cdot |B_1^+| \quad (2)$$

Flip angle α assumed as $\pi/2$. $|B_1^+|$ assumed as $|B_1|$ / sqrt(2).

There is a possible trade-off between B1 resonance field excitation duration and B1 resonance field strength for the same results. The measurement can be repeated for some time depending application.

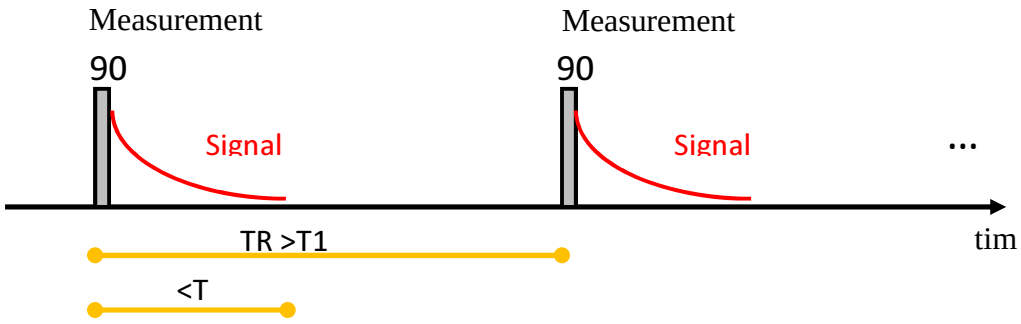


Figure 6: Simple mode of operation

An excitation time for a pulse to get a 90° flip angle is called t90.

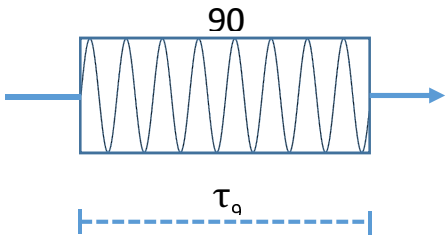


Figure 7: Detailed 90 degree pulse

An example advanced mode of operation is a spin echo sequence with multiple refocusing pulses.

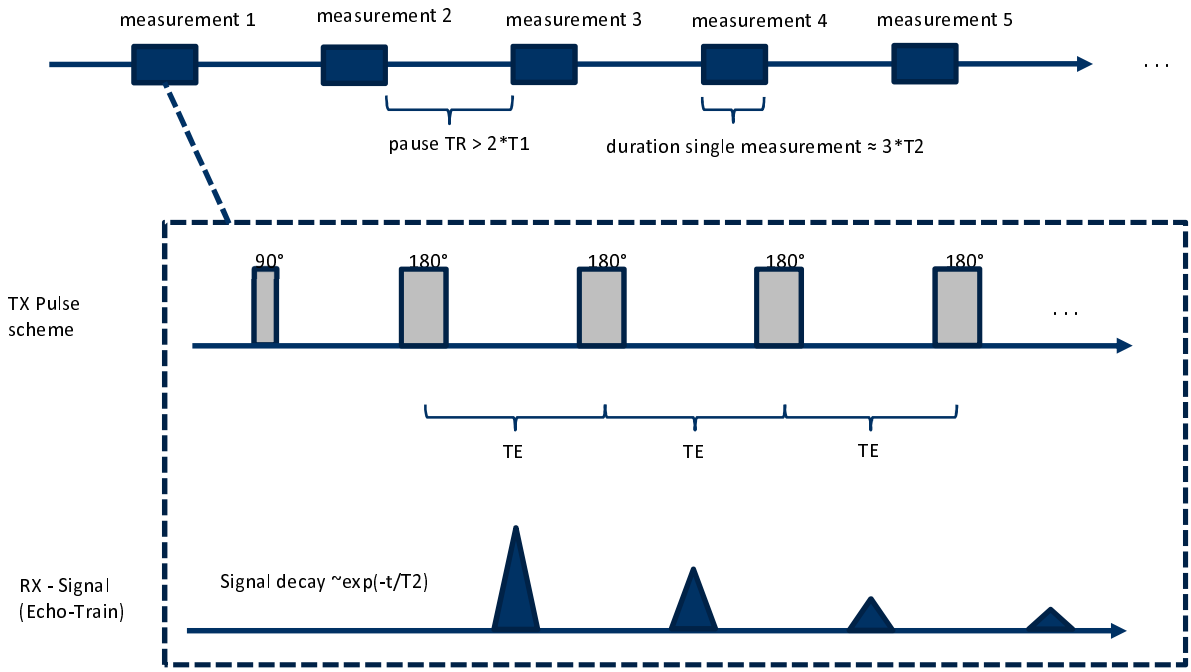


Figure 8: Example mode of operation: advanced timing

The timing of a pulse sequence in NMR is influenced by the two relaxation times T1 and T2 of the sample under test. T2 relaxation determines how long one excitation can be utilized. The T1 time determines how long the waiting time between the excitations has to be, the so called repetition time TR. TR is in the range of some milliseconds to some seconds. A basic pulse sequence for NMR is called spin echo sequence. It consists of an excitation pulse and one or more refocusing pulses. The number of refocusing pulses varies between 1 and 1 000. The time between the two refocusing pulses is called echo time TE. The refocusing pulse is twice the duration of the excitation pulse. TE is in the range of some microseconds to milliseconds. The receiver is switched on for an RX time window centred around the time point TE/2 after every refocusing pulse.

The RX time window is determined by the chosen RX bandwidth and the Nyquist criterion to avoid aliasing. The occupied bandwidth is in the kHz range and a band pass filter is commonly used before down conversion. Commonly during non RX time, but especially during TX, the receiver is disconnected from the B1 coil to avoid saturation. The number of measurements is not limited and can be 24/7 for some applications.

Example time signal and power spectrum density:

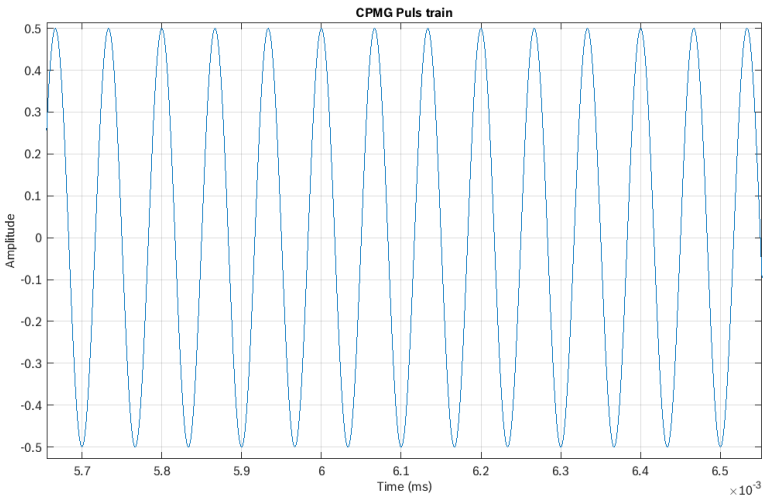


Figure 9: Zoom in a CPMG pulse train, cosine signal, frequency = 15 MHz

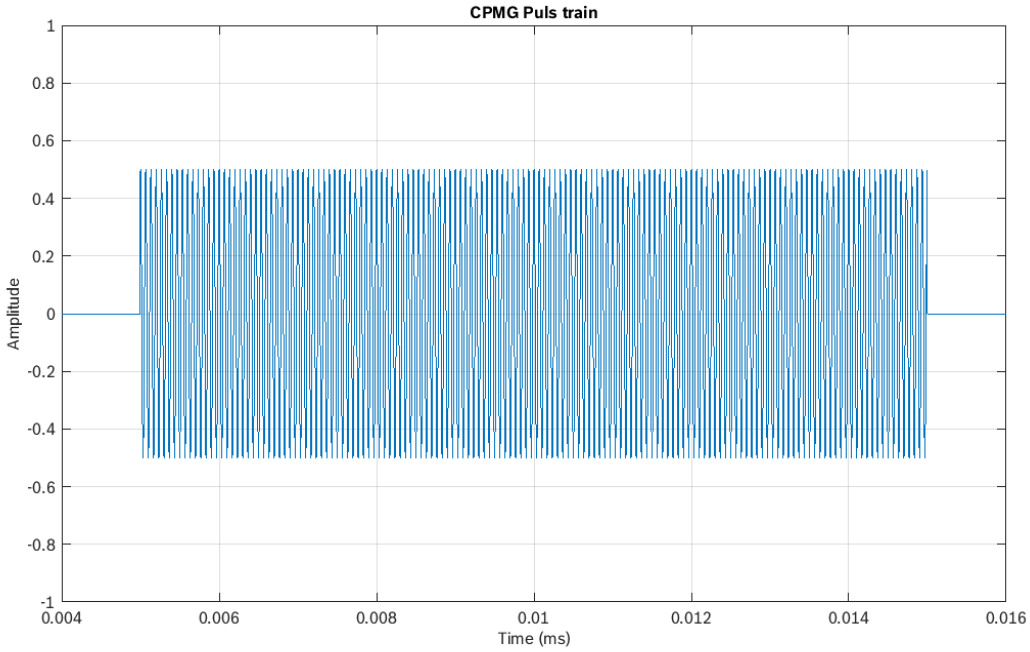


Figure 10: Zoomed out, complete pulse for a 90° flip angle excitation

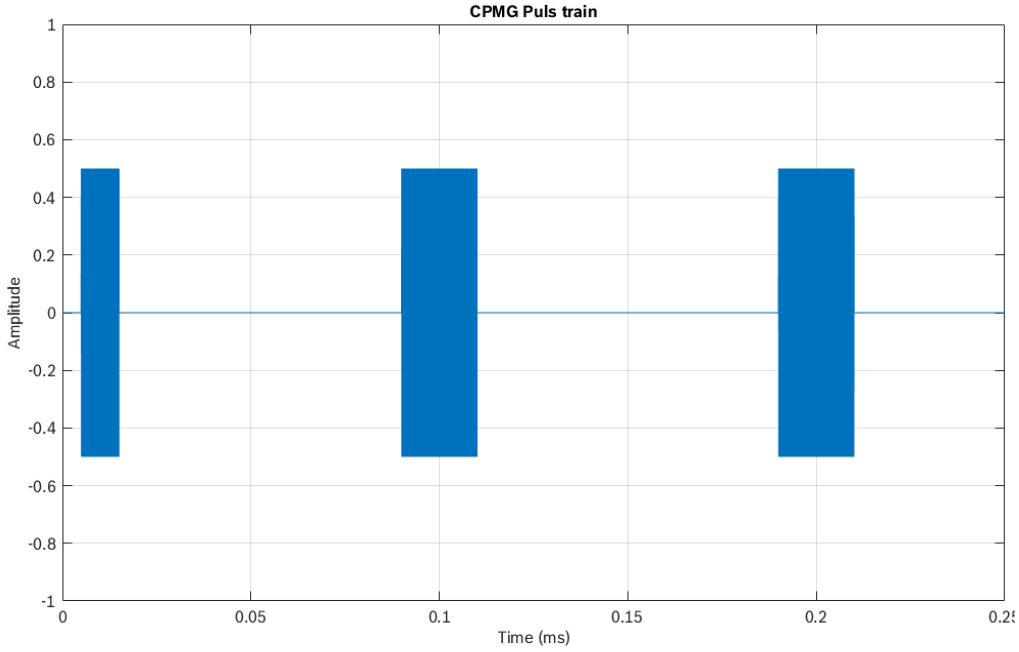


Figure 11: Zoomed out again, a first pulse for 90° flip angle and 2 pulses for 180° flip angle

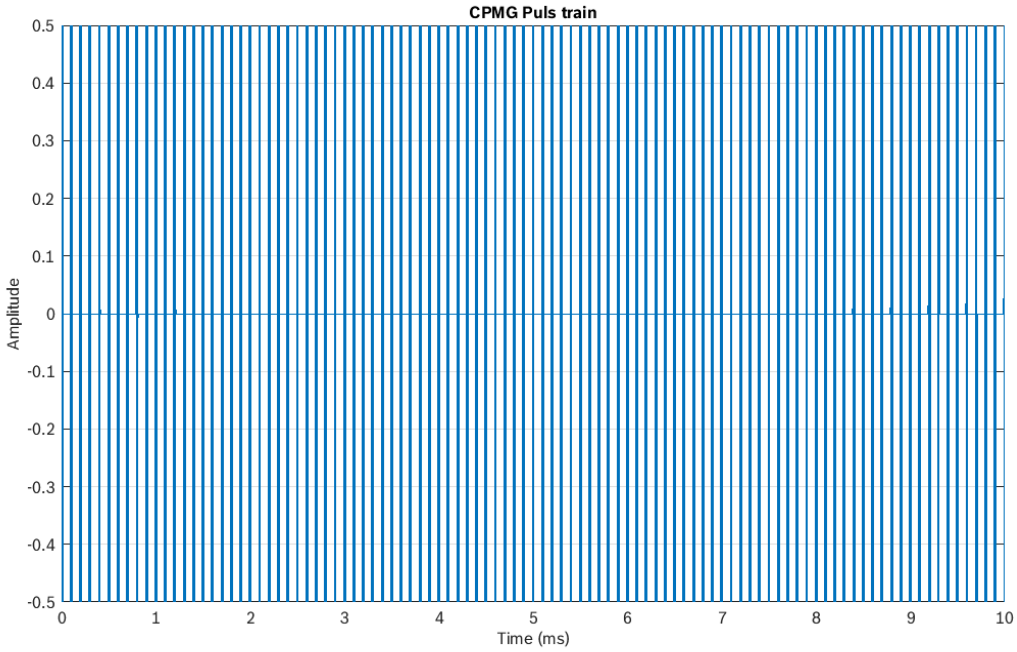


Figure 12: Complete CPMG pulse train with 100 pulses

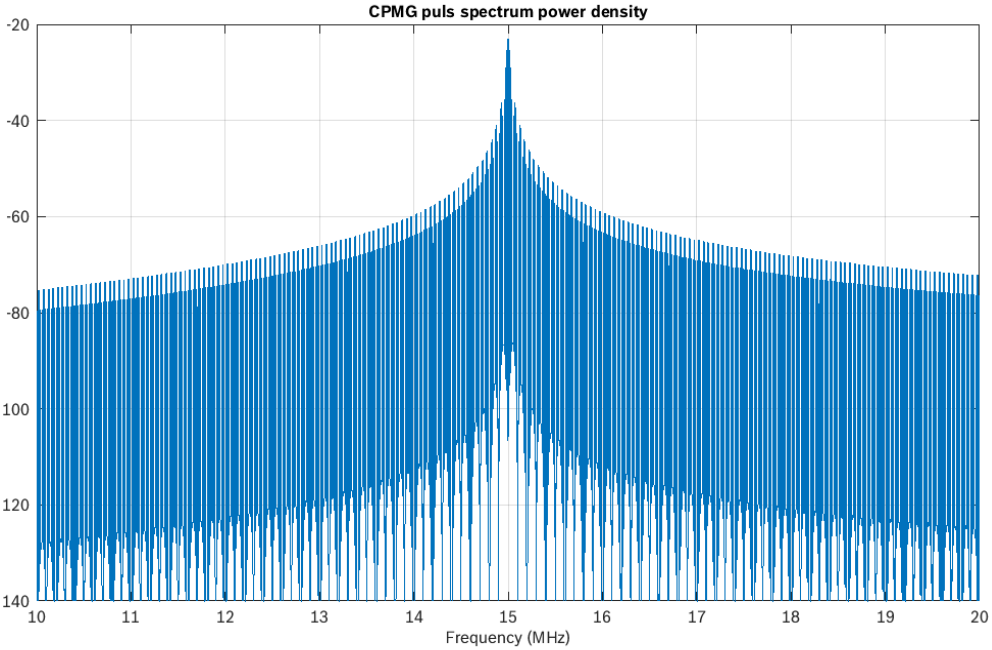


Figure 13: Pulse train power density of complete CPMG pulse train

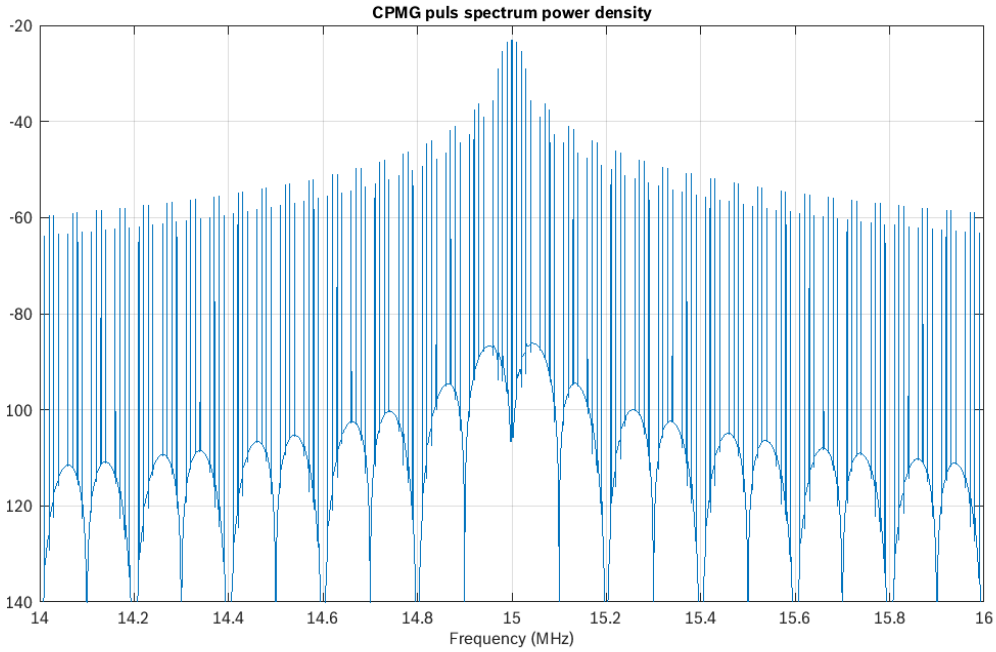


Figure 14: Power spectrum density showing pulse train timing

Occupied bandwidth is defined as 99 % of all power, calculated by total power and power density integrated over frequency. The CPMG pulse train used in this example has an **occupied bandwidth of 1,02 MHz.**

Matlab script used for this example to calculated occupied bandwidth can be found in annex C.

7.1.5 B1 Coil types

To give more precise information on possible NMR coil types, please see following generic examples.

Cylindrical air coil for enclosed sensor types

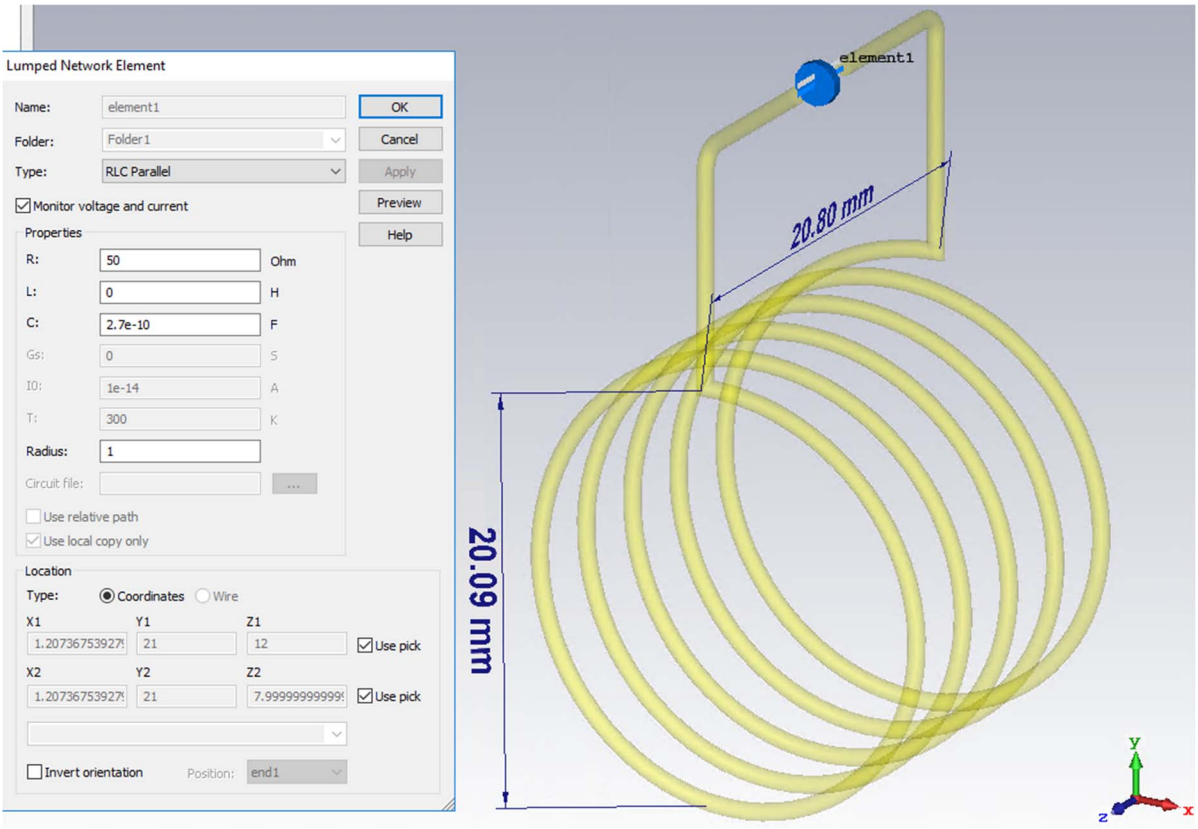


Figure 15: Simple air coil, length and diameter 20 mm, 5 turns, 0,4 mm wire diameter, material copper, background vacuum

U-shaped coil for enclosed sensors

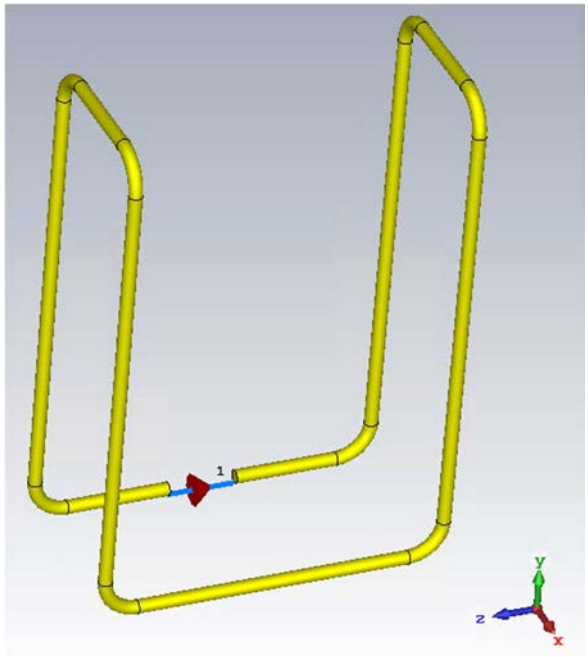


Figure 16: U-shaped coil

Planar coil for single-sided and pole type sensors

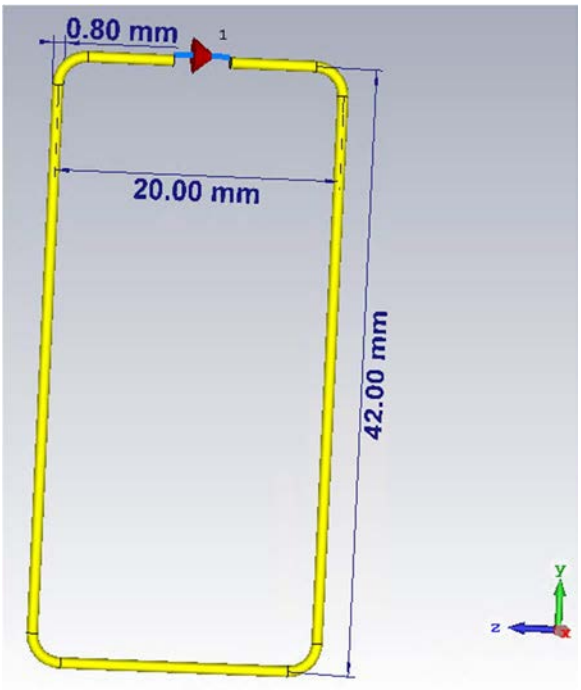


Figure 17: Simple planar coil

7.1.6 B1 Coil straw field

The spins in MUT are excited by B1 resonance magnetic field and the relaxation of the excited spins are received by coils. The 3D geometry design goal of the coils is to optimize to maximum efficiency of coupling into MUT and to minimize stray field to reduce interferer signals. An interferer can disturb the NMR receiver signal. Excitation and reception is done on the same frequency. There are applications using the same coil for excitation and reception.

Table 3: Example pulse parameters for a 1H measurement and a simple air coil

System parameter	Example B1 simple air coil
Coil type	Air coil, - 20 mm diameter - 20 mm length - 5 turns - 0,4 mm wire diameter
Peak power	500 mW
Frequency for 1H nucleus @ static magnetic field strength B0 = 375 786 mT	16 MHz
Coil current	384 mA
Magnetic field strength in 10 m distance	-12 dBµA/m

Due to intrinsically low Signal to Noise ratio in NMR receiver, a NMR sensor design strives for a high coupling factor of the B1 coil with the MUT. B1 coil is designed to couple inductively into MUT as good as possible to get the best Signal to Noise ratio. Therefore, a design goal is to design B1 coil as compact and electrically small as possible. Straw fields are minimized by this design goal, since they are considered as a loss mechanism and are causing unwanted spin excitation in inhomogeneous parts of static magnetic fields.

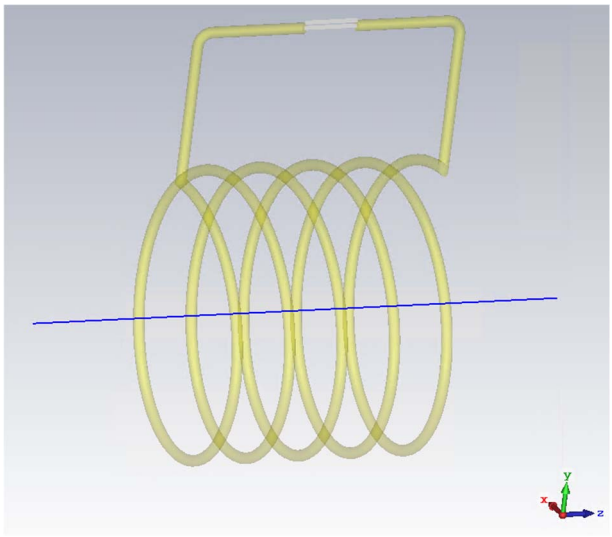


Figure 18: Centre axis of coil

Magnetic field strength in 3 m distance is calculated to show the coil radiation efficiency (figure 19).

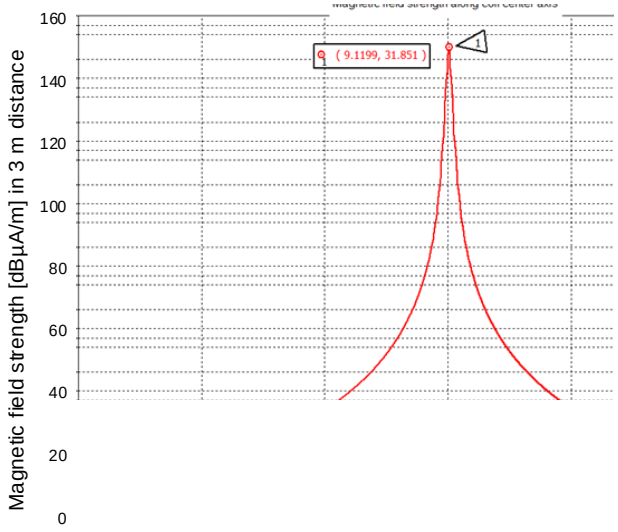


Figure 19: Magnetic field strength in dBµA/m along centre axis of coil up to 3 m distance

The Magnetic field strength at 16 MHz is 8 dBµA/m in 3 m distance with 500 mW accepted power.

To calculate the magnetic field strength in 10 m distance a -18 dB conversion factor is added to the magnetic field strength in 3 m distance see ETSI EN 300 330 [i.5], clause H.2, resulting in a magnetic field strength of -12 dBµA/m in 10 m distance.

7.1.7 Coil radiation efficiency

The coil radiation efficiency explains the difference between the radiated power and the input power of the NMR. The coil radiation efficiency is calculated below for the example in clause 7.1.6 in 3 m distance.

$$Coil\ radiation\ efficiency = 10 \cdot log_{10}\left(\frac{(H\ (r))^2 \cdot Z_0 \cdot 4\pi \cdot r^2}{accepted\ power}\right) = 10 \cdot log_{10}\left(\frac{\left(2 \cdot 10^{-6}\frac{A}{m}\right)^2 \cdot 120\ \Omega \cdot \pi \cdot 4\pi \cdot (3m)^2}{500\ mW}\right) = -54\ dB$$

With Magnetic field strength $H\ (r)$ in r [m] distance , Free space impedance Z_0

These effects are further explained below.

The Power that is stimulated at one or more ports will be divided into the power which is accepted by the structure and the power which is again leaving the structure via the ports (outgoing power).

Furthermore, the accepted power is converted either into losses (losses in dielectrics, metals or lumped elements) and/or is radiated.

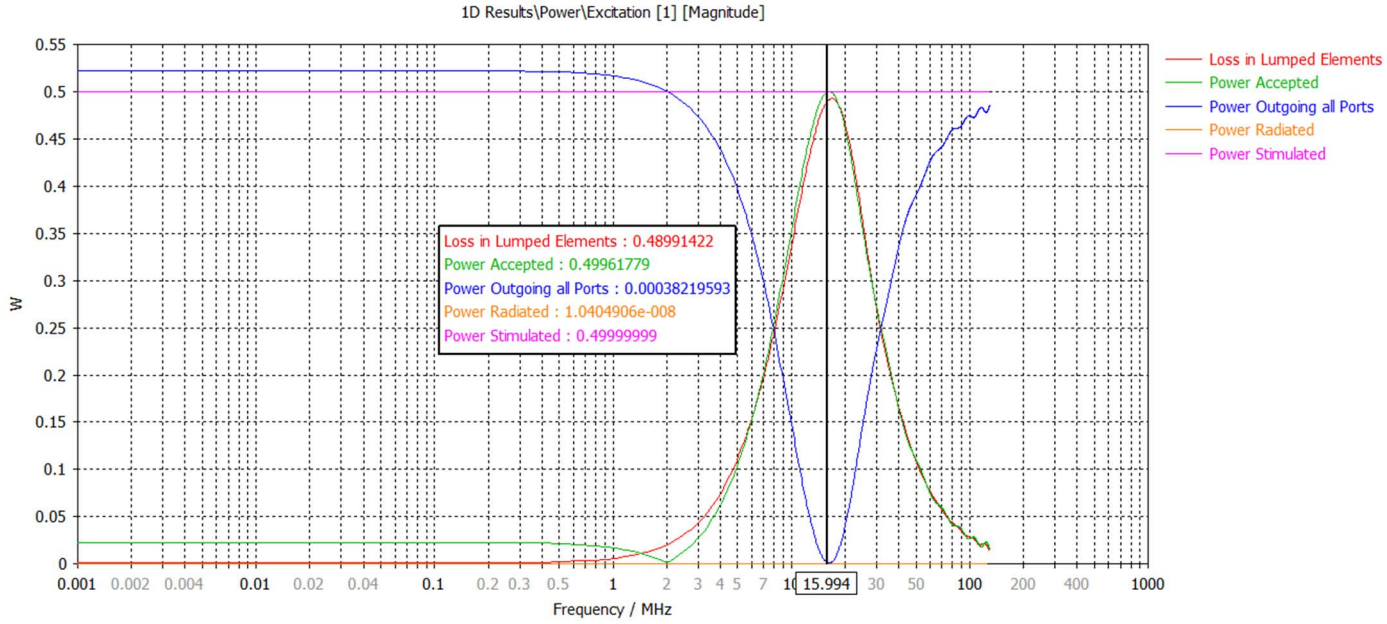
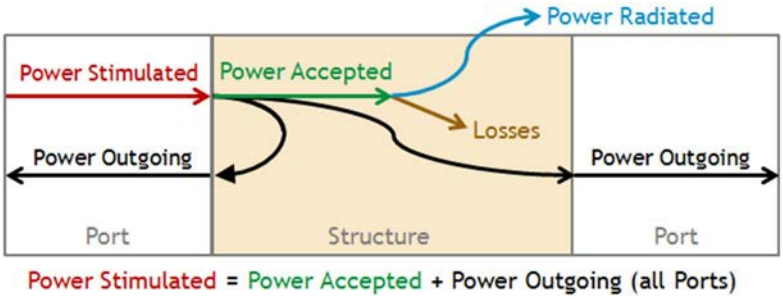


Figure 20: Power into port and coil over frequency



NOTE: From [i.8] CST help "power view".

Figure 21: Power definition

7.1.8 Example of an Enclosed NMR sensor

The corresponding magnet geometries for enclosed NMR sensors are shown in this clause to give an impression of shielding capability of B1 straw field and an additional improvement of receiver immunity of the NMR sensor. The considerably high field strength from interferer should not couple inside NMR B1 coil to ensure that the NMR sensor will perform as intended. To ensure this, a shielding of the excitation and receiver coil inside the NMR device is highly welcome to decouple B1 coil from external interferer. The external coupling factor of the B1 coil is minimized to get the best receiver immunity against interferer. This is a design goal of a NMR sensor.

Additional measures for RF shielding, e.g. housing and external port design depend on the magnet geometry. Bore magnets and C-shaped magnets can be effectively shielded in a housing of the NMR device. For example, openings for MUT sample in/output are in the range of 1 cm and thus do not impair the shielding in the future frequency range.

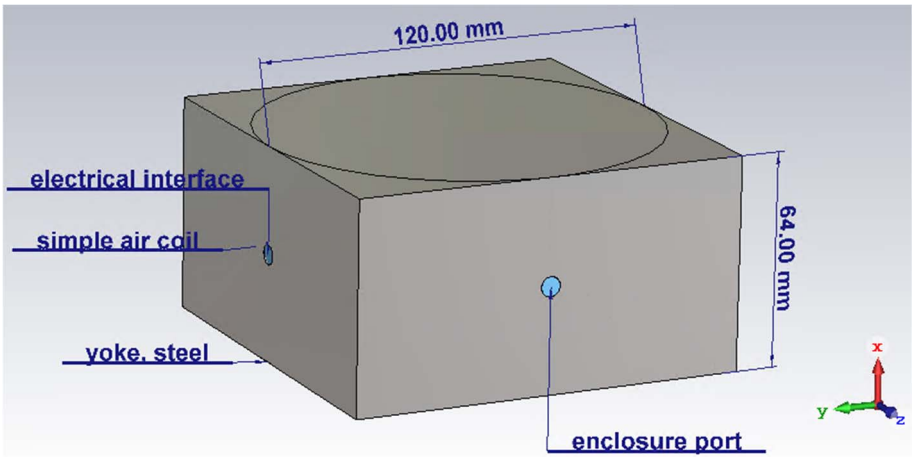


Figure 22: Example of an enclosed NMR sensor

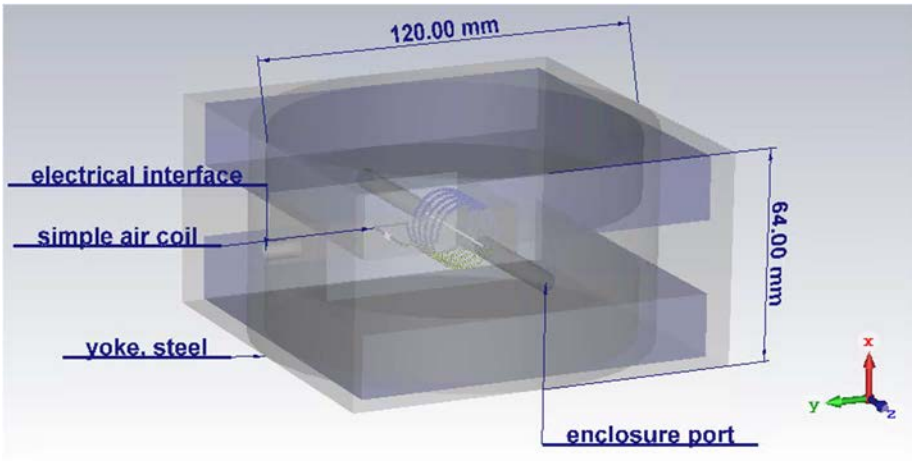


Figure 23: Enclosed NMR sensor B1 coil and sensor interfaces and ports

7.2 Technical parameters and implications on spectrum

7.2.1 Status of technical parameters

7.2.1.1 Current ITU and European Common Allocations

See annex A and ERC Report 25 [i.11].

7.2.1.2 Sharing and compatibility studies (if any) already available

Below is a list of relevant deliverables from CEPT and ITU-R.

Table 4: Relevant deliverables from CEPT and ITU-R

Recommendation/Report/Study	Title	relevance to NMR frequency range
ECC Report 001 February 2002 [i.12]	Compatibility between inductive LF and HF RFID transponder and other radio communications systems in the frequency ranges 135-148,5 kHz, 4,78-8,78 MHz and 11,56-15,56 MHz	135-148,5 kHz, 4,78-8,78 MHz and 11,56-15,56 MHz
ECC Report 007 February 2002 [i.13]	Compatibility between inductive LF RFID systems and radio communications systems in the frequency range 135-148,5 kHz	135-148,5 kHz
ECC Report 012 October 2002 [i.14]	Ultra Low Power Active Medical Implant systems (ULP-AMI)	9 kHz to 315 kHz
ECC Report 024 May 2003 [i.15]	PLT, DSL, CABLE communications (Including CABLE TV), LANS and their effect on radio services	DC to 3 GHz
ECC Report 064 February 2005 [i.16]	The protection requirements of radiocommunication systems below 10,6 GHz from generic UWB applications	0,255 - 137 MHz
ECC Report 067 October 2005 [i.17]	Compatibility study for generic limits for the emission levels of inductive SRDs below 30 MHz	< 30 MHz
ERC Report 069 February 1999 [i.18]	Propagation Model And Interference Range Calculation. For Inductive Systems 10 kHz - 30 MHz	< 30 MHz
ECC Report 073 October 2005 [i.19]	Compatibility of SRD in the FM radio broadcasting band	88 – 108 MHz
ERC Report 074 May 1999 [i.20]	Compatibility Between Radio Frequency Identification Devices (RFID) and The Radio astronomy Service At 13 MHz	13,553-13,567 MHz 13,36-13,41 MHz
ECC Report 081 May 2006 [i.21]	The coexistence between Ultra Low Power - Animal Implant Devices (ULP-AID) operating in the frequency band 12,5-20 MHz and existing radiocommunication systems	12,5 - 20 MHz
ECC Report 098 February 2007 [i.22]	Studying the compatibility issues of the UIC EUROLOOP system with other systems in the frequency band 9,5 to 17,5 MHz	4,5 MHz to 13,5 MHz 9,5 - 17,5 MHz
ECC Report 135 September 2009 [i.23]	Inductive limits in the frequency range 9 kHz to 148,5 kHz	9 - 148,5 kHz
ECC Report 181 September 2012 [i.24]	Improving spectrum efficiency in SRD bands	all
ECC Report 208 January 2014 [i.25]	Impact of RFID devices on radio services in the band 13,56 MHz	13,56 MHz
ERC Report 044 January 1997 [i.26]	Sharing inductive systems and radiocommunication systems in the band 9-135 kHz	9 - 135 kHz
ERC Report 092 June 2000 [i.27]	Sharing inductive Short Range Devices and radio communication systems in 10,2-11 MHz	10,2 - 11 MHz
ERC Report 095 June 2000 [i.28]	The use of 3 155-3 400 kHz for general inductive applications	3 155 - 3 400 kHz
ERC Report 096 June 2000 [i.29]	The use of 290-300 kHz and 500-510 kHz for general inductive applications	290-300 kHz and 500-510 kHz
ITU-R Report SM.2180 [i.30]	Impact of industrial, scientific and medical (ISM) equipment on radio communication services	
Recommendation ITU-R SM.2028 (09/2012) [i.31]	Protection distance calculation between inductive systems and radio communication services using frequencies below 30 MHz	Below 30 MHz

7.2.1.3 Sharing and compatibility issues still to be considered

CEPT needs to decide if new studies are needed, since the proposal is to apply the limits of inductive SRDs below 30 MHz the spurious emissions limits above 30 MHz.

7.2.2 Transmitter parameters

See clause 7.1.1.

7.3 Information on relevant standard(s)

Table 5

ETSI EN 300 220-1 V3.1.1 (2017-02) [i.32]	Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz; Part 1: Technical characteristics and methods of measurement	25 MHz to 1 000 MHz
ETSI EN 300 220-2 V3.1.1 (2017-02) [i.33]	Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz; Part 2: Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU [i.9] for non specific radio equipment	25 MHz to 1 000 MHz **26,957 MHz - 27,283 MHz, 40,660 MHz - 40,700 MHz** 10 mW e.r.p. No requirement The whole band **26,995 MHz, 27,045 MHz, 27,095 MHz, 27,145 MHz, 27,195 MHz:** 100 mW e.r.p. ≤ 0,1 % duty cycle 10 kHz
ETSI EN 300 330 V2.1.1 (2017-02) [i.5]	Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz	Clause 4.3.4.3 Limits H-Field limits in 10 m **9 kHz to 30 MHz**
ETSI EN 300 422-1 V2.1.2 (2017-01) [i.34]	Wireless Microphones; Audio PMSE up to 3 GHz; Part 1: Class A Receivers; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU	Clause 8.4.3 Limits, Table 3: Limits for spurious emissions 47 MHz to 74 MHz and 87,5 MHz to 137 MHz: 4 nW in operation mode, 2 nW in standby mode Table 5: Limits for receiver spurious emissions -57 dBm 9 kHz ≤ f ≤ 1 GHz
ETSI EN 300 422-4 V2.1.1 (2017-05) [i.35]	Wireless Microphones; Audio PMSE up to 3 GHz; Part 4: Assistive Listening Devices including personal sound amplifiers and inductive systems up to 3 GHz (see note 2)	See above and below
ETSI EN 300 433 [i.36]	Electromagnetic compatibility and Radio spectrum Matters (ERM); Citizens' Band (CB) radio equipment	11 m Band um 27 MHz 4 Watt
ETSI ETS 300 718 March 1997 [i.37]	Electromagnetic compatibility and Radio spectrum matters (ERM); Avalanche Beacons; Transmitter-receiver systems	Table 5 H-field at 10 m 9 kHz < f < 4,78 MHz; 24,5 to -2,8 dBmA/m 4,78 MHz < f < 30 MHz: -2,8 dBmA/m
ETSI EN 300 718-1 V2.1.1 (2018-01) [i.38]	Avalanche Beacons operating at 457 kHz; Transmitter-receiver systems; Part 1: Harmonised Standard for access to radio spectrum	Clause 4.2.3.3.2 Maximum transmitted field 457 kHz shall not exceed 7 dBµA/m (2,23 µA/m) at a distance of 10 m
ETSI EN 302 065-1 V2.1.1 (2016-11) [i.39]	Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 1: Requirements for Generic UWB applications	Table 1: Permitted ranges of operation Transmit 30 MHz to 10,6 GHz (see note 1) Table 2: Maximum value of mean power spectral density limit (e.i.r.p.) Frequency range [GHz] without mitigation techniques with mitigation techniques **f ≤ 1,6 GHz w/ or w/o mitigation -90 dBm/MHz**
ETSI EN 302 066: not listed in OJ [i.40]	Short Range Devices (SRD); Ground- and Wall- Probing Radar applications (GPR/WPR) imaging systems	

ETSI EN 302 195 V2.1.1 (2016-06) [i.41]	Short Range Devices (SRD); Ultra Low Power Active Medical Implants (ULP-AMI) and accessories (ULP-AMI-P) operating in the frequency range 9 kHz to 315 kHz	Table 1 H-field limits at 10 m: 0,009 ≤ f ≤ 0,315 MHz 30 dBµA/m H-field strength limit (Hf) at 10 m Additional information is available in CEPT/ERC Recommendation 70-03 [i.2]
ETSI EN 302 510-1 V1.1.1 (2007-07) [i.42]	Radio equipment in the frequency range 30 MHz to 37,5 MHz for Ultra Low Power Active Medical Membrane Implants and Accessories; Part 1: Technical characteristics and test methods	Clause 7.2.4 Limits maximum average power of an emission within the band **30 MHz to 37,5 MHz shall be 1 milliwatt e.r.p**
ETSI EN 302 536 V2.1.1 (2017-10) [i.43]	Radio equipment operating in the frequency range 315 kHz to 600 kHz for Ultra Low Power Animal Implantable Devices (ULP-AID) and associated peripherals;	315 kHz to 600 kHz shall be -5 dBµA/m at 10 m
ETSI EN 302 608 V2.1.1 (2017-11) [i.44]	Radio equipment for Eurobalise railway systems;	27,095 MHz: +42 dBµA/m in 10 m
NOTE 1: Limits in table 2 clause 4.3.2 and table 3 clause 4.3.3 3 are to be met ETSI EN 302 065-1 [i.39]. NOTE 2: Power limits for different frequency bands can be found in ECC/DEC/(05)02 [i.45]; the EC SRD Decisions; EC Decision 2014/641/EU [i.46]; or CEPT/ERC Recommendation 70-03 [i.2], annex 10 (or European or national regulations).		

8 Radio spectrum request and justification

The following request is placed for enclosed NMR sensor.

Table 6: Request overview

Frequency range	Limits outside the NMR device (see note)
0,1 kHz to 148 kHz	46 dBµA/m in 10 m distance at 100 Hz descending 10 dB/Decade
148 kHz to 5 MHz	-15 dBµA/m in 10 m distance
5 MHz to 30 MHz	-5 dBµA/m at 10 m distance
30 MHz to 130 MHz	-36 dBm e.r.p.
NOTE: The reference bandwidths of the limits are: • 200 Hz below 9 kHz • 1 kHz between 9 kHz and 148,5 kHz • 10 kHz between 148,5 kHz and 30 MHz • 100 kHz between 30 MHz and 130 MHz.	

The frequency range for this application is very much depending on type of nuclei and static magnetic field strength. Therefore, a wide frequency range ist requested.

A detailed justification for the frequency range and the limits is provided in clause 7.1.

9 Regulations

9.1 Current regulations

9.1.1 CEPT/EU regulation for Short Range Devices

Currently there is no specific regulation for the requested application available over the complete frequency range below 130 MHz:

- between 9 kHz and 30 MHz the assignment for inductive SRDs from the EC decision for SRDS [i.1] could be applied;
- in the ISM bands the assignment for SRDs from the EC decision for SRDS [i.1] could be applied;

- similar applications with assignments are existing for:
  - GPR/WPR [i.40] (30 MHz to 12,4 GHz) in ECC/DEC(06)08 [i.47];
  - TLPR/LPR (ECC/DEC(11)02 [i.48] above 6 GHz).
- The limits for spurious emissions from ERC/REC 74-01 [i.49] are not intended for wanted emissions but there are examples where there are used for the wanted emissions (e.g. GPR/WPR [i.40] systems above 1 GHz).

For more details see annex B.

9.1.2 ISM regulations

9.1.2.1 ITU-R

ISM applications are defined in Article 1.15 of the Radio Regulations 2016 [i.10]:

"1.15 industrial, scientific and medical (ISM) applications (of radio frequency energy): Operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications."

The ISM bands are defined by [i.10] (article 5) in footnotes 5.138, 5.150 and 5.280.

In addition Recommendation ITU-R SM.1056-1 on the "Limitation of radiation from industrial, scientific and medical (ISM) equipment" [i.73] provides the following recommendations to administrations:

1) that administrations may use the latest edition of CISPR Publication 11 [i.7], including amendments, as a guide for the application of limits and methods of measurements for ISM devices, in order to protect radiocommunications;

2) that continued cooperation with the CISPR should be initiated to ensure that radiocommunication needs are fully taken into consideration.

An overview of ISM applications and equipment is provided in Annex 1 of this recommendation. Currently it is not clear whether NMR applications are to be seen as SRDs or ISM.

9.1.2.2 CISPR 11

CISPR 11 [i.7] mainly applies to ISM equipment working in the ISM frequency ranges (see below).

Centre frequency MHz	**Frequency range** MHz	**Maximum radiation limit** [b]	**Number of appropriate footnote to the table of frequency allocation of the ITU Radio Regulations** [a]
6,780	6,765 – 6,795	Under consideration	5.138
13,560	13,553 – 13,567	Unrestricted	5.150
27,120	26,957 – 27,283	Unrestricted	5.150
40,680	40,66 – 40,70	Unrestricted	5.150
433,920	433,05 – 434,79	Under consideration	5.138 in Region 1, except countries mentioned in 5.280
915,000	902 – 928	Unrestricted	5.150 in Region 2 only
2 450	2 400 – 2 500	Unrestricted	5.150
5 800	5 725 – 5 875	Unrestricted	5.150
24 125	24 000 – 24 250	Unrestricted	5.150
61 250	61 000 – 61 500	Under consideration	5.138
122 500	122 000 – 123 000	Under consideration	5.138
245 000	244 000 – 246 000	Under consideration	5.138

Figure 24: An overview of ISM regulations from [i.10]

CISPR 11 [i.7] defines **Group 2 equipment as:**

- group 2 contains all ISM RF equipment in which radio-frequency energy in the frequency range 9 kHz to 400 GHz is intentionally generated and used or only used locally, in the form of electromagnetic radiation, inductive and/or capacitive coupling, for the treatment of material, **for inspection/analysis purposes**, or for transfer of electromagnetic energy.

NMR can be seen a device under group 2 as "analysis of material characteristics".

But CISPR 11 [i.7] also specifies "radiation disturbance limits" outside the ISM frequency bands (see below) and it is not clear if the non-ISM bands can also be used for intentional emissions.

Table 7: Electromagnetic radiation disturbance limits for class A group 2 equipment measured on a test site

Frequency range MHz	Limits for a measuring distance D in m					
	On a test site D = 30 m from the equipment		On a test site D = 10 m from the equipment		On a test site D = 3 m from the equipment [a]	
	Electric field	Magnetic field	Electric field	Magnetic field	Electric field	Magnetic field
	Quasi-peak	Quasi-peak	Quasi-peak	Quasi-peak	Quasi-peak	Quasi-peak
	dB(μV/m)	dB(μA/m)	dB(μV/m)	dB(μA/m)	dB(μV/m)	dB(μA/m)
0,15 – 0,49	–	33,5	–	57,5	–	82
0,49 – 1,705	–	23,5	–	47,5	–	72
1,705 – 2,194	–	28,5	–	52,5	–	77
2,194 – 3,95	–	23,5	–	43,5	–	68
3,95 – 11	–	8,5	–	18,5	–	43,5 decreasing linearly with logarithm of frequency to 28,5
11 – 20	–	8,5	–	18,5	–	28,5
20 – 30	–	-1,5	–	8,5	–	18,5
30 – 47	58	–	68	–	78	–
47 – 53,91	40	–	50	–	60	–
53,91 – 54,56	40	–	50	–	60	–
54,56 – 68	40	–	50	–	60	–
68 – 80,872	53	–	63	–	73	–
80,872 – 81,848	68	–	78	–	88	–
81,848 – 87	53	–	63	–	73	–
87 – 134,786	50	–	60	–	70	–
134,786 – 136,414	60	–	70	–	80	–
136,414 – 156	50	–	60	–	70	–
156 – 174	64	–	74	–	84	–
174 – 188,7	40	–	50	–	60	–
188,7 – 190,979	50	–	60	–	70	–
190,979 – 230	40	–	50	–	60	–
230 – 400	50	–	60	–	70	–
400 – 470	53	–	63	–	73	–
470 – 1 000	50	–	60	–	70	–

On a test site, class A equipment can be measured at a nominal distance of 3 m, 10 m or 30 m. A measuring distance less than 10 m is allowed only for equipment which complies with the definition given in 3.17.

At the transition frequency, the more stringent limit shall apply.

[a] In the frequency range 30 MHz to 1 GHz, the 3 m separation distance applies only to *small size equipment* meeting the size criterion defined in 3.17.

Table 8: Electromagnetic radiation disturbance limits for class B group 2 equipment measured on a test site in IEC 60601-1-2 [i.75]

Frequency range MHz	Limits for a measuring distance D in m				
	Electric field				Magnetic field
	D = 10 m		D = 3 m [b]		D = 3 m
	Quasi-peak	Average [a]	Quasi-peak	Average [a]	Quasi-peak
	dB(μV/m)		dB(μV/m)		dB(μA/m)
0,15 – 30	–	–	–	–	39 Decreasing linearly with the logarithm of frequency to 3
30 – 80,872	30	25	40	35	–
80,872 – 81,848	50	45	60	55	–
81,848 – 134,786	30	25	40	35	–
134,786 – 136,414	50	45	60	55	–
136,414 – 230	30	25	40	35	–
230 – 1 000	37	32	47	42	–

On a test site, class B equipment can be measured at a nominal distance of 3 m or 10 m. In the frequency range 30 MHz to 1 GHz, a measuring distance less than 10 m is allowed only for equipment which complies with the definition given in 3.17.

At the transition frequency, the more stringent limit should apply.

[a] The average limits apply to magnetron driven equipment and microwave ovens only. If magnetron driven equipment or microwave ovens exceed the quasi-peak limit at certain frequencies, then the measurement shall be repeated at these frequencies with the average detector and the average limits specified in this table apply.

[b] In the frequency range 30 MHz to 1 GHz, the 3 m separation distance applies only to *small size equipment* meeting the size criterion defined in 3.17.

CISPR 11 [i.7] is listed for the EMC Directive in the OJEU of the EC but not for the Radio Equipment directive.

9.1.2.3 Regulation of NMR Benchtop devices today

Declaration of Conformity for devices working at 45 MHz and 80 MHz relates to:

- Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility [i.67];
- Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits [i.68];
- Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment [i.69];

and cites standards:

- EN 61010-1:2010: Safety Requirements for electrical equipment for measurement, control and laboratory use [i.70];
- EN 61326-1:2013: Electrical equipment for measurement, measurement, control and laboratory use. EMC requirements [i.71]. The recommended radiated limits are linked to CISPR11;
- EN 50581:2012: Assessment of electrical and electronic products with respect to the RoHS [i.72].

9.1.3 FCC [i.75] Part 18, ISM

9.1.3.1 §18.107 Definitions

"

(a) Radio frequency (RF) energy. Electromagnetic energy at any frequency in the radio spectrum from 9 kHz to 3 THz (3,000 GHz).

(b) Harmful interference. Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with this chapter.

(c) Industrial, scientific, and medical (ISM) equipment. Equipment or appliances designed to generate and use locally RF energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunication. Typical ISM applications are the production of physical, biological, or chemical effects such as heating, ionization of gases, mechanical vibrations, hair removal and acceleration of charged particles.

(d) Industrial heating equipment. A category of ISM equipment used for or in connection with industrial heating operations utilized in a manufacturing or production process.

(e) Medical diathermy equipment. A category of ISM equipment used for therapeutic purposes, not including surgical diathermy apparatus designed for intermittent operation with low power.

(f) Ultrasonic equipment. A category of ISM equipment in which the RF energy is used to excite or drive an electromechanical transducer for the production of sonic or ultrasonic mechanical energy for industrial, scientific, medical or other noncommunication purposes.

(g) Consumer ISM equipment. A category of ISM equipment used or intended to be used by the general public in a residential environment, notwithstanding use in other areas. Examples are domestic microwave ovens, jewelry cleaners for home use, ultrasonic humidifiers.

(h) ISM frequency. A frequency assigned by this part for the use of ISM equipment. A specified tolerance is associated with each ISM frequency. See §18.301.

(i) Marketing. As used in this part, marketing shall include sale or lease, offer for sale or lease, advertising for sale or lease, the import or shipment or other distribution for the purpose of sale or lease or offer for sale or lease. See subpart I of part 2 of this chapter.

(j) Magnetic resonance equipment. A category of ISM equipment in which RF energy is used to create images and data representing spatially resolved density of transient atomic resources within an object.

NOTE: In the foregoing, sale (or lease) shall mean sale (or lease) to the user or a vendor who in turn sells (or leases) to the user. Sale shall not be construed to apply to devices sold to a second party for manufacture or fabrication into a device which is subsequently sold (or leased) to the user.

"

9.1.3.2 §18.301 Operating frequencies

"

*ISM equipment **may** be operated on any frequency above 9 kHz except as indicated in §18.303. The following frequency bands, in accordance with §2.106 of the rules, are allocated for use by ISM equipment:*

ISM frequency	Tolerance
6,78 MHz	±15,0 kHz
13,56 MHz	±7,0 kHz
27,12 MHz	±163,0 kHz
40,68 MHz	±20,0 kHz
915 MHz	±13,0 MHz
2,450 MHz	±50,0 MHz
5,800 MHz	±75,0 MHz
24,125 MHz	±125,0 MHz
61,25 GHz	±250,0 MHz
122,50 GHz	±500,0 MHz
245,00 GHz	±1,0 GHz

"

9.1.3.3 §18.303 Prohibited frequency bands

"

Operation of ISM equipment within the following safety, search and rescue frequency bands is prohibited: 490-510 kHz, 2 170-2 194 kHz, 8 354-8 374 kHz, 121,4-121,6 MHz, 156,7-156,9 MHz, and 242,8-243,2 MHz.

"

9.1.3.4 §18.305 Field strength limits

"

(a) ISM equipment operating on a frequency specified in §18.301 is permitted unlimited radiated energy in the band specified for that frequency.

(b) The field strength levels of emissions which lie outside the bands specified in §18.301, unless otherwise indicated, shall not exceed the following:

Equipment	Operating frequency	RF Power generated by equipment (watts)	Field strength limit (µV/m)	Distance (meters)
Any type unless otherwise specified (miscellaneous)	Any ISM frequency	Below 500 500 or more	25 25 × SQRT(power/500)	300 [1]300
	Any non-ISM frequency	Below 500 500 or more	15 15 × SQRT(power/500)	300 [1]300
Industrial heaters and RF stabilized arc welders	On or below 5,725 MHz Above 5,725 MHz	Any Any	10 ([2])	1,600 ([2])
Medical diathermy	Any ISM frequency Any non-ISM frequency	Any Any	25 15	300 300
Ultrasonic	Below 490 kHz	Below 500 500 or more	2,400/F(kHz) 2,400/F(kHz) × SQRT(power/500)	300 [3]300
	490 to 1,600 kHz Above 1,600 kHz	Any Any	24,000/F(kHz) 15	30 30
Induction cooking ranges	Below 90 kHz On or above 90 kHz	Any Any	1,500 300	[4]30 [4]30

[1]Field strength may not exceed 10 μV/m at 1 600 meters. Consumer equipment operating below 1 000 MHz is not permitted the increase in field strength otherwise permitted here for power over 500 watts.

[2]Reduced to the greatest extent possible.

[3]Field strength may not exceed 10 μV/m at 1 600 meters. Consumer equipment is not permitted the increase in field strength otherwise permitted here for over 500 watts.

[4]Induction cooking ranges manufactured prior to February 1, 1980, shall be subject to the field strength limits for miscellaneous ISM equipment.

(c) The field strength limits for RF lighting devices shall be the following:

Frequency (MHz)	***Field strength limit at 30 meters (μV/m)***
Non-consumer equipment:	
30-88	*30*
88-216	*50*
216-1000	*70*
Consumer equipment:	
30-88	*10*
88-216	*15*
216-1000	*20*

Notes

1. The tighter limit shall apply at the boundary between two frequency ranges.

2. Testing for compliance with these limits may be made at closer distances, provided a sufficient number of measurements are taken to plot the radiation pattern, to determine the major lobes of radiation, and to determine the expected field strength level at 30, 300, or 1600 meters. Alternatively, if measurements are made at only one closer fixed distance, then the permissible field strength limits shall be adjusted using 1/d as an attenuation factor.

"

9.2 Proposed regulation

First of all it should be clarified if a NMR application working within a shielded enclosure could be seen as ISM equipment.

The following limits are proposed for enclosed NMR sensor.

Table 9: Proposal overview

Frequency range	Limits outside the NMR device (see note)
0,1 kHz to 148 kHz	46 dBμA/m in 10 m distance at 100 Hz descending 10 dB/Decade
148 kHz to 5 MHz	-15 dBμA/m in 10 m distance
5 MHz to 30 MHz	-5 dBμA/m at 10 m distance
30 MHz to 130 MHz	-36 dBm e.r.p.
NOTE: The reference bandwidths of the limits are: • 200 Hz below 9 kHz • 1 kHz between 9 kHz and 148,5 kHz • 10 kHz between 148,5 kHz and 30 MHz • 100 kHz between 30 MHz and 130 MHz.	

One option would be include new entries to Annex 9 of CEPT/ERC Rcommendation 70-03 [i.2].

Annex A:
ITU allocations

1 8,3-110 kHz

Allocation to services		
Region 1	***Region 2***	***Region 3***
Below 8.3	*(Not allocated)* *5.53 5.54*	
8.3-9	*METEOROLOGICAL AIDS 5.54A 5.54B 5.54C*	
9-11.3	*METEOROLOGICAL AIDS 5.54A* *RADIONAVIGATION*	
11.3-14	*RADIONAVIGATION*	
14-19.95	*FIXED* *MARITIME MOBILE 5.57* *5.55 5.56*	
19.95-20.05	*STANDARD FREQUENCY AND TIME SIGNAL (20 kHz)*	
20.05-70	*FIXED* *MARITIME MOBILE 5.57* *5.56 5.58*	
70-72 *RADIONAVIGATION 5.60*	***70-90*** *FIXED* *MARITIME MOBILE 5.57* *MARITIME RADIO-NAVIGATION 5.60* *Radiolocation*	***70-72*** *RADIONAVIGATION 5.60* *Fixed* *Maritime mobile 5.57* *5.59*
72-84 *FIXED* *MARITIME MOBILE 5.57* *RADIONAVIGATION 5.60* *5.56*		***72-84*** *FIXED* *MARITIME MOBILE 5.57* *RADIONAVIGATION 5.60*
84-86 *RADIONAVIGATION 5.60*		***84-86*** *RADIONAVIGATION 5.60* *Fixed* *Maritime mobile 5.57* *5.59*
86-90 *FIXED* *MARITIME MOBILE 5.57* *RADIONAVIGATION* *5.56*	*5.61*	***86-90*** *FIXED* *MARITIME MOBILE 5.57* *RADIONAVIGATION 5.60*
90-110	*RADIONAVIGATION 5.62* *Fixed* *5.64*	

5.53 *Administrations authorizing the use of frequencies below 8.3 kHz shall ensure that no harmful interference is caused to services to which the bands above 8.3 kHz are allocated.* *(WRC-12)*

5.54 *Administrations conducting scientific research using frequencies below 8.3 kHz are urged to advise other administrations that may be concerned in order that such research may be afforded all practicable protection from harmful interference.* *(WRC-12)*

5.54A *Use of the 8.3-11.3 kHz frequency band by stations in the meteorological aids service is limited to passive use only. In the band 9-11.3 kHz, meteorological aids stations shall not claim protection from stations of the radio navigation service submitted for notification to the Bureau prior to 1 January 2013. For sharing between stations of the meteorological aids service and stations in the radio navigation service submitted for notification after this date, the most recent version of Recommendation ITU-R RS.1881 should be applied.* *(WRC-12)*

5.54B *Additional allocation: in Algeria, Saudi Arabia, Bahrain, Egypt, the United Arab Emirates, the Russian Federation, Iran (Islamic Republic of), Iraq, Kuwait, Lebanon, Morocco, Qatar, the Syrian Arab Republic, Sudan and Tunisia, the frequency band 8.3-9 kHz is also allocated to the radio navigation, fixed and mobile services on a primary basis.* *(WRC-15)*

5.54C *Additional allocation: in China, the frequency band 8.3-9 kHz is also allocated to the maritime radio navigation and maritime mobile services on a primary basis.* *(WRC-12)*

5.55 *Additional allocation: in Armenia, the Russian Federation, Georgia, Kyrgyzstan, Tajikistan and Turkmenistan, the frequency band 14-17 kHz is also allocated to the radio navigation service on a primary basis.* *(WRC-15)*

5.56 *The stations of services to which the bands 14-19.95 kHz and 20.05-70 kHz and in Region 1 also the bands 72-84 kHz and 86-90 kHz are allocated may transmit standard frequency and time signals. Such stations shall be afforded protection from harmful interference. In Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan, the frequencies 25 kHz and 50 kHz will be used for this purpose under the same conditions.* *(WRC-12)*

5.57 *The use of the bands 14-19.95 kHz, 20.05-70 kHz and 70-90 kHz (72-84 kHz and 86-90 kHz in Region 1) by the maritime mobile service is limited to coast radiotelegraph stations (A1A and F1B only). Exceptionally, the use of class J2B or J7B emissions is authorized subject to the necessary bandwidth not exceeding that normally used for class A1A or F1B emissions in the band concerned.*

5.58 *Additional allocation: in Armenia, Azerbaijan, the Russian Federation, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan, the band 67-70 kHz is also allocated to the radio navigation service on a primary basis.* *(WRC-2000)*

5.59 *Different category of service: in Bangladesh and Pakistan, the allocation of the bands 70-72 kHz and 84-86 kHz to the fixed and maritime mobile services is on a primary basis (see No. **5.33**).* *(WRC-2000)*

5.60 *In the bands 70-90 kHz (70-86 kHz in Region 1) and 110-130 kHz (112-130 kHz in Region 1), pulsed radio navigation systems may be used on condition that they do not cause harmful interference to other services to which these bands are allocated.*

5.61 *In Region 2, the establishment and operation of stations in the maritime radio navigation service in the bands 70-90 kHz and 110-130 kHz shall be subject to agreement obtained under No. **9.21** with administrations whose services, operating in accordance with the Table, may be affected. However, stations of the fixed, maritime mobile and radiolocation services shall not cause harmful interference to stations in the maritime radio navigation service established under such agreements.*

5.62 *Administrations which operate stations in the radio navigation service in the band 90-110 kHz are urged to coordinate technical and operating characteristics in such a way as to avoid harmful interference to the services provided by these stations.*

5.63 *(SUP - WRC-97)*

5.64 *Only classes A1A or F1B, A2C, A3C, F1C or F3C emissions are authorized for stations of the fixed service in the bands allocated to this service between 90 kHz and 160 kHz (148.5 kHz in Region 1) and for stations of the maritime mobile service in the bands allocated to this service between 110 kHz and 160 kHz (148.5 kHz in Region 1). Exceptionally, class J2B or J7B emissions are also authorized in the bands between 110 kHz and 160 kHz (148.5 kHz in Region 1) for stations of the maritime mobile service.*

110-255 kHz

Allocation to services		
Region 1	***Region 2***	***Region 3***
110-112 *FIXED* *MARITIME MOBILE* *RADIONAVIGATION* *5.64*	***110-130*** *FIXED* *MARITIME MOBILE* *MARITIME RADIO-NAVIGATION 5.60* *Radiolocation*	***110-112*** *FIXED* *MARITIME MOBILE* *RADIONAVIGATION 5.60* *5.64*
112-115 *RADIONAVIGATION 5.60*		***112-117.6*** *RADIONAVIGATION 5.60*
115-117.6 *RADIONAVIGATION 5.60* *Fixed* *Maritime mobile* *5.64 5.66*		*Fixed* *Maritime mobile* *5.64 5.65*
117.6-126 *FIXED* *MARITIME MOBILE* *RADIONAVIGATION 5.60* *5.64*		***117.6-126*** *FIXED* *MARITIME MOBILE* *RADIONAVIGATION 5.60* *5.64*
126-129 *RADIONAVIGATION 5.60*		***126-129*** *RADIONAVIGATION 5.60* *Fixed* *Maritime mobile* *5.64 5.65*
129-130 *FIXED* *MARITIME MOBILE* *RADIONAVIGATION 5.60* *5.64*	*5.61 5.64*	***129-130*** *FIXED* *MARITIME MOBILE* *RADIONAVIGATION 5.60* *5.64*
130-135.7 *FIXED* *MARITIME MOBILE* *5.64 5.67*	***130-135.7*** *FIXED* *MARITIME MOBILE* *5.64*	***130-135.7*** *FIXED* *MARITIME MOBILE* *RADIONAVIGATION* *5.64*
135.7-137.8 *FIXED* *MARITIME MOBILE* *Amateur 5.67A* *5.64 5.67 5.67B*	***135.7-137.8*** *FIXED* *MARITIME MOBILE* *Amateur 5.67A* *5.64*	***135.7-137.8*** *FIXED* *MARITIME MOBILE* *RADIONAVIGATION* *Amateur 5.67A* *5.64 5.67B*
137.8-148.5 *FIXED* *MARITIME MOBILE* *5.64 5.67*	***137.8-160*** *FIXED* *MARITIME MOBILE* *5.64*	***137.8-160*** *FIXED* *MARITIME MOBILE* *RADIONAVIGATION* *5.64*
148.5-255 *BROADCASTING* *5.68 5.69 5.70*	***160-190*** *FIXED*	***160-190*** *FIXED* *Aeronautical radio navigation*
	190-200 *AERONAUTICAL RADIONAVIGATION*	

5.65 *Different category of service: in Bangladesh, the allocation of the bands 112-117.6 kHz and 126-129 kHz to the fixed and maritime mobile services is on a primary basis (see No. **5.33**).* *(WRC-2000)*

5.66 *Different category of service: in Germany, the allocation of the band 115-117.6 kHz to the fixed and maritime mobile services is on a primary basis (see No. **5.33**) and to the radio navigation service on a secondary basis (see No. **5.32**).*

5.67 *Additional allocation: in Mongolia, Kyrgyzstan and Turkmenistan, the band 130-148.5 kHz is also allocated to the radio navigation service on a secondary basis. Within and between these countries this service shall have an equal right to operate.* *(WRC-07)*

5.67A *Stations in the amateur service using frequencies in the band 135.7-137.8 kHz shall not exceed a maximum radiated power of 1 W (e.i.r.p.) and shall not cause harmful interference to stations of the radio navigation service operating in countries listed in No. **5.67**.* *(WRC-07)*

5.67B *The use of the band 135.7-137.8 kHz in Algeria, Egypt, Iran (Islamic Republic of), Iraq, Lebanon, Syrian Arab Republic, Sudan, South Sudan and Tunisia is limited to the fixed and maritime mobile services. The amateur service shall not be used in the above-mentioned countries in the band 135.7-137.8 kHz, and this should be taken into account by the countries authorizing such use.* *(WRC-12)*

5.68 *Alternative allocation: in Congo (Rep. of the), the Dem. Rep. of the Congo and South Africa, the frequency band 160-200 kHz is allocated to the fixed service on a primary basis.* *(WRC-15)*

5.69 *Additional allocation: in Somalia, the band 200-255 kHz is also allocated to the aeronautical radio navigation service on a primary basis.*

5.70 *Alternative allocation: in Angola, Botswana, Burundi, the Central African Rep., Congo (Rep. of the), Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Nigeria, Oman, the Dem. Rep. of the Congo, South Africa, Swaziland, Tanzania, Chad, Zambia and Zimbabwe, the band 200-283.5 kHz is allocated to the aeronautical radio navigation service on a primary basis.* *(WRC-12)*

200-415 kHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td></td><td>200-275
AERONAUTICAL RADIONAVIGATION
Aeronautical mobile</td><td rowspan="2">200-285
AERONAUTICAL RADIONAVIGATION
Aeronautical mobile</td></tr>
<tr><td rowspan="2">255-283.5
BROADCASTING
AERONAUTICAL RADIONAVIGATION
5.70 5.71</td><td>275-285
AERONAUTICAL RADIONAVIGATION
Aeronautical mobile
Maritime radio navigation (radiobeacons)</td></tr>
<tr><td>283.5-315
AERONAUTICAL RADIONAVIGATION
MARITIME RADIONAVIGATION (radiobeacons) 5.73
5.74</td><td colspan="2">285-315
AERONAUTICAL RADIONAVIGATION
MARITIME RADIONAVIGATION (radiobeacons) 5.73</td></tr>
<tr><td>315-325
AERONAUTICAL RADIONAVIGATION
Maritime radio navigation (radiobeacons) 5.73
5.75</td><td>315-325
MARITIME RADIONAVIGATION (radiobeacons) 5.73
Aeronautical radio navigation</td><td>315-325
AERONAUTICAL RADIONAVIGATION
MARITIME RADIONAVIGATION (radiobeacons) 5.73</td></tr>
<tr><td rowspan="2">325-405
AERONAUTICAL RADIONAVIGATION</td><td>325-335
AERONAUTICAL RADIONAVIGATION
Aeronautical mobile
Maritime radio navigation (radiobeacons)</td><td rowspan="2">325-405
AERONAUTICAL RADIONAVIGATION
Aeronautical mobile</td></tr>
<tr><td>335-405
AERONAUTICAL RADIONAVIGATION
Aeronautical mobile</td></tr>
<tr><td>405-415
RADIONAVIGATION 5.76</td><td colspan="2">405-415
RADIONAVIGATION 5.76
Aeronautical mobile</td></tr>
</table>

5.71 *Alternative allocation: in Tunisia, the band 255-283.5 kHz is allocated to the broadcasting service on a primary basis.*

5.72 *(SUP - WRC-12)*

5.73 *The band 285-325 kHz (283.5-325 kHz in Region 1) in the maritime radio navigation service may be used to transmit supplementary navigational information using narrow-band techniques, on condition that no harmful interference is caused to radiobeacon stations operating in the radio navigation service. (WRC-97)*

5.74 *Additional Allocation: in Region 1, the frequency band 285.3-285.7 kHz is also allocated to the maritime radio navigation service (other than radiobeacons) on a primary basis.*

5.75 *Different category of service: in Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Moldova, Kyrgyzstan, Tajikistan, Turkmenistan, Ukraine and the Black Sea areas of Romania, the allocation of the band 315-325 kHz to the maritime radio navigation service is on a primary basis under the condition that in the Baltic Sea area, the assignment of frequencies in this band to new stations in the maritime or aeronautical radio navigation services shall be subject to prior consultation between the administrations concerned. (WRC-07)*

5.76 *The frequency 410 kHz is designated for radio direction-finding in the maritime radio navigation service. The other radio navigation services to which the band 405-415 kHz is allocated shall not cause harmful interference to radio direction-finding in the band 406.5-413.5 kHz.*

415-495 kHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>415-435
MARITIME MOBILE 5.79
AERONAUTICAL RADIONAVIGATION</td><td colspan="2" rowspan="2">415-472
MARITIME MOBILE 5.79
Aeronautical radio navigation 5.77 5.80</td></tr>
<tr><td>435-472
MARITIME MOBILE 5.79
Aeronautical radio navigation 5.77
5.82</td></tr>
<tr><td colspan="3">472-479
MARITIME MOBILE 5.79
Amateur 5.80A
Aeronautical radio navigation 5.77 5.80
5.80B 5.82</td></tr>
<tr><td>479-495
MARITIME MOBILE 5.79 5.79A
Aeronautical radionavigation 5.77
5.82</td><td colspan="2">479-495
MARITIME MOBILE 5.79 5.79A
Aeronautical radionavigation 5.77 5.80
5.82</td></tr>
</table>

5.77 *Different category of service: in Australia, China, the French overseas communities of Region 3, Korea (Rep. of), India, Iran (Islamic Republic of), Japan, Pakistan, Papua New Guinea and Sri Lanka, the allocation of the frequency band 415-495 kHz to the aeronautical radionavigation service is on a primary basis. In Armenia, Azerbaijan, Belarus, the Russian Federation, Kazakhstan, Latvia, Uzbekistan and Kyrgyzstan, the allocation of the frequency band 435-495 kHz to the aeronautical radionavigation service is on a primary basis. Administrations in all the aforementioned countries shall take all practical steps necessary to ensure that aeronautical radionavigation stations in the frequency band 435-495 kHz do not cause interference to reception by coast stations of transmissions from ship stations on frequencies designated for ship stations on a worldwide basis.* *(WRC-12)*

5.78 *Different category of service: in Cuba, the United States of America and Mexico, the allocation of the band 415-435 kHz to the aeronautical radionavigation service is on a primary basis.*

5.79 *The use of the bands 415-495 kHz and 505-526.5 kHz (505-510 kHz in Region 2) by the maritime mobile service is limited to radiotelegraphy.*

5.79A *When establishing coast stations in the NAVTEX service on the frequencies 490 kHz, 518 kHz and 4 209.5 kHz, administrations are strongly recommended to coordinate the operating characteristics in accordance with the procedures of the International Maritime Organization (IMO) (see Resolution **339 (Rev.WRC-07)**).* *(WRC-07)*

5.80 *In Region 2, the use of the band 435-495 kHz by the aeronautical radionavigation service is limited to non-directional beacons not employing voice transmission.*

5.80A *The maximum equivalent isotropically radiated power (e.i.r.p.) of stations in the amateur service using frequencies in the band 472-479 kHz shall not exceed 1 W. Administrations may increase this limit of e.i.r.p. to 5 W in portions of their territory which are at a distance of over 800 km from the borders of Algeria, Saudi Arabia, Azerbaijan, Bahrain, Belarus, China, Comoros, Djibouti, Egypt, United Arab Emirates, the Russian Federation, Iran (Islamic Republic of), Iraq, Jordan, Kazakhstan, Kuwait, Lebanon, Libya, Morocco, Mauritania, Oman, Uzbekistan, Qatar, Syrian Arab Republic, Kyrgyzstan, Somalia, Sudan, Tunisia, Ukraine and Yemen. In this frequency band, stations in the amateur service shall not cause harmful interference to, or claim protection from, stations of the aeronautical radionavigation service.* *(WRC-12)*

5.80B *The use of the frequency band 472-479 kHz in Algeria, Saudi Arabia, Azerbaijan, Bahrain, Belarus, China, Comoros, Djibouti, Egypt, United Arab Emirates, the Russian Federation, Iraq, Jordan, Kazakhstan, Kuwait, Lebanon, Libya, Mauritania, Oman, Uzbekistan, Qatar, Syrian Arab Republic, Kyrgyzstan, Somalia, Sudan, Tunisia and Yemen is limited to the maritime mobile and aeronautical radionavigation services. The amateur service shall not be used in the above-mentioned countries in this frequency band, and this should be taken into account by the countries authorizing such use.* *(WRC-12)*

5.81 *(SUP - WRC-2000)*

5.82 *In the maritime mobile service, the frequency 490 kHz is to be used exclusively for the transmission by coast stations of navigational and meteorological warnings and urgent information to ships, by means of narrow-band direct-printing telegraphy. The conditions for use of the frequency 490 kHz are prescribed in Articles **31** and **52**. In using the frequency band 415-495 kHz for the aeronautical radionavigation service, administrations are requested to ensure that no harmful interference is caused to the frequency 490 kHz. In using the frequency band 472-479 kHz for the amateur service, administrations shall ensure that no harmful interference is caused to the frequency 490 kHz.* *(WRC-12)*

495-1 800 kHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td colspan="3">495-505 MARITIME MOBILE</td></tr>
<tr><td rowspan="3">505-526.5
MARITIME MOBILE 5.79 5.79A 5.84
AERONAUTICAL RADIONAVIGATION</td><td>505-510
MARITIME MOBILE 5.79</td><td rowspan="3">505-526.5
MARITIME MOBILE 5.79 5.79A 5.84
AERONAUTICAL RADIONAVIGATION
Aeronautical mobile
Land mobile</td></tr>
<tr><td>510-525
MARITIME MOBILE 5.79A 5.84
AERONAUTICAL RADIONAVIGATION</td></tr>
<tr><td rowspan="2">525-535
BROADCASTING 5.86
AERONAUTICAL RADIONAVIGATION</td></tr>
<tr><td rowspan="3">526.5-1 606.5
BROADCASTING

5.87 5.87A</td><td>526.5-535
BROADCASTING
Mobile
5.88</td></tr>
<tr><td>535-1 605
BROADCASTING</td><td rowspan="2">535-1 606.5
BROADCASTING</td></tr>
<tr><td rowspan="2">1 605-1 625
BROADCASTING 5.89

5.90</td></tr>
<tr><td>1 606.5-1 625
FIXED
MARITIME MOBILE 5.90
LAND MOBILE

5.92</td><td rowspan="4">1 606.5-1 800
FIXED
MOBILE
RADIOLOCATION
RADIONAVIGATION

5.91</td></tr>
<tr><td>1 625-1 635
RADIOLOCATION

5.93</td><td rowspan="2">1 625-1 705
FIXED
MOBILE
BROADCASTING 5.89
Radiolocation
5.90</td></tr>
<tr><td rowspan="2">1 635-1 800
FIXED
MARITIME MOBILE 5.90
LAND MOBILE

5.92 5.96</td></tr>
<tr><td>1 705-1 800
FIXED
MOBILE
RADIOLOCATION
AERONAUTICAL RADIONAVIGATION</td></tr>
</table>

5.82A *(SUP - WRC-12)*

5.82B *(SUP - WRC-12)*

5.83 *(SUP - WRC-07)*

5.84 *The conditions for the use of the frequency 518 kHz by the maritime mobile service are prescribed in Articles **31** and **52**. (WRC-07)*

5.85 *Not used.*

5.86 *In Region 2, in the band 525-535 kHz the carrier power of broadcasting stations shall not exceed 1 kW during the day and 250 W at night.*

5.87 *Additional allocation: in Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Niger and Swaziland, the band 526.5-535 kHz is also allocated to the mobile service on a secondary basis. (WRC-12)*

5.87A *Additional allocation: in Uzbekistan, the band 526.5-1 606.5 kHz is also allocated to the radionavigation service on a primary basis. Such use is subject to agreement obtained under No. **9.21** with administrations concerned and limited to ground-based radiobeacons in operation on 27 October 1997 until the end of their lifetime. (WRC-97)*

5.88 *Additional allocation: in China, the band 526.5-535 kHz is also allocated to the aeronautical radionavigation service on a secondary basis.*

5.89 *In Region 2, the use of the band 1 605-1 705 kHz by stations of the broadcasting service is subject to the Plan established by the Regional Administrative Radio Conference (Rio de Janeiro, 1988).*

The examination of frequency assignments to stations of the fixed and mobile services in the band 1 625-1 705 kHz shall take account of the allotments appearing in the Plan established by the Regional Administrative Radio Conference (Rio de Janeiro, 1988).

5.90 *In the band 1 605-1 705 kHz, in cases where a broadcasting station of Region 2 is concerned, the service area of the maritime mobile stations in Region 1 shall be limited to that provided by ground-wave propagation.*

5.91 *Additional allocation: in the Philippines and Sri Lanka, the band 1 606.5-1 705 kHz is also allocated to the broadcasting service on a secondary basis. (WRC-97)*

5.92 *Some countries of Region 1 use radiodetermination systems in the bands 1 606.5-1 625 kHz, 1 635-1 800 kHz, 1 850-2 160 kHz, 2 194-2 300 kHz, 2 502-2 850 kHz and 3 500-3 800 kHz, subject to agreement obtained under No. **9.21**. The radiated mean power of these stations shall not exceed 50 W.*

5.93 *Additional allocation: in Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Hungary, Kazakhstan, Latvia, Lithuania, Mongolia, Nigeria, Uzbekistan, Poland, Kyrgyzstan, Slovakia, Tajikistan, Chad, Turkmenistan and Ukraine, the frequency bands 1 625-1 635 kHz, 1 800-1 810 kHz and 2 160-2 170 kHz are also allocated to the fixed and land mobile services on a primary basis, subject to agreement obtained under No. **9.21**. (WRC-15)*

5.94 and 5.95 *Not used.*

5.96 *In Germany, Armenia, Austria, Azerbaijan, Belarus, Croatia, Denmark, Estonia, the Russian Federation, Finland, Georgia, Hungary, Ireland, Iceland, Israel, Kazakhstan, Latvia, Liechtenstein, Lithuania, Malta, Moldova, Norway, Uzbekistan, Poland, Kyrgyzstan, Slovakia, the Czech Rep., the United Kingdom, Sweden, Switzerland, Tajikistan, Turkmenistan and Ukraine, administrations may allocate up to 200 kHz to their amateur service in the frequency bands 1 715-1 800 kHz and 1 850-2 000 kHz. However, when allocating the frequency bands within this range to their amateur service, administrations shall, after prior consultation with administrations of neighbouring countries, take such steps as may be necessary to prevent harmful interference from their amateur service to the fixed and mobile services of other countries. The mean power of any amateur station shall not exceed 10 W. (WRC-15)*

1 800-2 194 kHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>1 800-1 810
RADIOLOCATION
5.93</td><td rowspan="2">1 800-1 850
AMATEUR</td><td rowspan="2">1 800-2 000
AMATEUR
FIXED
MOBILE except aeronautical mobile
RADIONAVIGATION
Radiolocation</td></tr>
<tr><td>1 810-1 850
AMATEUR
5.98 5.99 5.100</td></tr>
<tr><td>1 850-2 000
FIXED
MOBILE except aeronautical mobile
5.92 5.96 5.103</td><td>1 850-2 000
AMATEUR
FIXED
MOBILE except aeronautical mobile
RADIOLOCATION
RADIONAVIGATION
5.102</td><td>5.97</td></tr>
<tr><td>2 000-2 025
FIXED
MOBILE except aeronautical mobile (R)
5.92 5.103</td><td colspan="2" rowspan="3">2 000-2 065
FIXED
MOBILE</td></tr>
<tr><td>2 025-2 045
FIXED
MOBILE except aeronautical mobile (R)
Meteorological aids 5.104
5.92 5.103</td></tr>
<tr><td rowspan="2">2 045-2 160
FIXED
MARITIME MOBILE
LAND MOBILE
5.92</td></tr>
<tr><td colspan="2">2 065-2 107
MARITIME MOBILE 5.105
5.106</td></tr>
<tr><td rowspan="2">2 160-2 170
RADIOLOCATION
5.93 5.107</td><td colspan="2">2 107-2 170
FIXED
MOBILE</td></tr>
<tr><td colspan="2">2 170-2 173.5 MARITIME MOBILE</td></tr>
<tr><td colspan="2">2 173.5-2 190.5 MOBILE (distress and calling)
5.108 5.109 5.110 5.111</td></tr>
<tr><td colspan="2">2 190.5-2 194 MARITIME MOBILE</td></tr>
</table>

5.97 *In Region 3, the Loran system operates either on 1 850 kHz or 1 950 kHz, the bands occupied being 1 825-1 875 kHz and 1 925-1 975 kHz respectively. Other services to which the band 1 800-2 000 kHz is allocated may use any frequency therein on condition that no harmful interference is caused to the Loran system operating on 1 850 kHz or 1 950 kHz.*

5.98 *Alternative allocation: in Armenia, Azerbaijan, Belarus, Belgium, Cameroon, Congo (Rep. of the), Denmark, Egypt, Eritrea, Spain, Ethiopia, the Russian Federation, Georgia, Greece, Italy, Kazakhstan, Lebanon, Lithuania, the Syrian Arab Republic, Kyrgyzstan, Somalia, Tajikistan, Tunisia, Turkmenistan and Turkey, the frequency band 1 810-1 830 kHz is allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis.* *(WRC-15)*

5.99 *Additional allocation: in Saudi Arabia, Austria, Iraq, Libya, Uzbekistan, Slovakia, Romania, Slovenia, Chad, and Togo, the band 1 810-1 830 kHz is also allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis.* *(WRC-12)*

5.100 *In Region 1, the authorization to use the band 1 810-1 830 kHz by the amateur service in countries situated totally or partially north of 40° N shall be given only after consultation with the countries mentioned in Nos.* ***5.98*** *and* ***5.99*** *to define the necessary steps to be taken to prevent harmful interference between amateur stations and stations of other services operating in accordance with Nos.* ***5.98*** *and* ***5.99****.*

5.101 *(SUP - WRC-12)*

5.102 *Alternative allocation: in Bolivia, Chile, Paraguay and Peru, the frequency band 1 850-2 000 kHz is allocated to the fixed, mobile except aeronautical mobile, radiolocation and radionavigation services on a primary basis.* *(WRC-15)*

5.103 *In Region 1, in making assignments to stations in the fixed and mobile services in the bands 1 850-2 045 kHz, 2 194-2 498 kHz, 2 502-2 625 kHz and 2 650-2 850 kHz, administrations should bear in mind the special requirements of the maritime mobile service.*

5.104 *In Region 1, the use of the band 2 025-2 045 kHz by the meteorological aids service is limited to oceanographic buoy stations.*

5.105 *In Region 2, except in Greenland, coast stations and ship stations using radiotelephony in the band 2 065-2 107 kHz shall be limited to class J3E emissions and to a peak envelope power not exceeding 1 kW. Preferably, the following carrier frequencies should be used: 2 065.0 kHz, 2 079.0 kHz, 2 082.5 kHz, 2 086.0 kHz, 2 093.0 kHz, 2 096.5 kHz, 2 100.0 kHz and 2 103.5 kHz. In Argentina and Uruguay, the carrier frequencies 2 068.5 kHz and 2 075.5 kHz are also used for this purpose, while the frequencies within the band 2 072-2 075.5 kHz are used as provided in No.* ***52.165****.*

5.106 *In Regions 2 and 3, provided no harmful interference is caused to the maritime mobile service, the frequencies between 2 065 kHz and 2 107 kHz may be used by stations of the fixed service communicating only within national borders and whose mean power does not exceed 50 W. In notifying the frequencies, the attention of the Bureau should be drawn to these provisions.*

5.107 *Additional allocation: in Saudi Arabia, Eritrea, Ethiopia, Iraq, Libya, Somalia and Swaziland, the band 2 160-2 170 kHz is also allocated to the fixed and mobile, except aeronautical mobile (R), services on a primary basis. The mean power of stations in these services shall not exceed 50 W.* *(WRC-12)*

5.108 *The carrier frequency 2 182 kHz is an international distress and calling frequency for radiotelephony. The conditions for the use of the band 2 173.5-2 190.5 kHz are prescribed in Articles* ***31*** *and* ***52****.* *(WRC-07)*

5.109 *The frequencies 2 187.5 kHz, 4 207.5 kHz, 6 312 kHz, 8 414.5 kHz, 12 577 kHz and 16 804.5 kHz are international distress frequencies for digital selective calling. The conditions for the use of these frequencies are prescribed in Article* ***31****.*

5.110 *The frequencies 2 174.5 kHz, 4 177.5 kHz, 6 268 kHz, 8 376.5 kHz, 12 520 kHz and 16 695 kHz are international distress frequencies for narrow-band direct-printing telegraphy. The conditions for the use of these frequencies are prescribed in Article* ***31****.*

5.111 *The carrier frequencies 2 182 kHz, 3 023 kHz, 5 680 kHz, 8 364 kHz and the frequencies 121.5 MHz, 156.525 MHz, 156.8 MHz and 243 MHz may also be used, in accordance with the procedures in force for terrestrial radiocommunication services, for search and rescue operations concerning manned space vehicles. The conditions for the use of the frequencies are prescribed in Article* ***31****.*

The same applies to the frequencies 10 003 kHz, 14 993 kHz and 19 993 kHz, but in each of these cases emissions must be confined in a band of ±3 kHz about the frequency. *(WRC-07)*

2 194-3 230 kHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>2 194-2 300
FIXED
MOBILE except aeronautical mobile (R)
5.92 5.103 5.112</td><td colspan="2">2 194-2 300
FIXED
MOBILE
5.112</td></tr>
<tr><td rowspan="2">2 300-2 498
FIXED
MOBILE except aeronautical mobile (R)
BROADCASTING 5.113
5.103</td><td colspan="2">2 300-2 495
FIXED
MOBILE
BROADCASTING 5.113</td></tr>
<tr><td rowspan="2">2 495-2 501
STANDARD FREQUENCY AND TIME SIGNAL (2 500 kHz)</td></tr>
<tr><td>2 498-2 501
STANDARD FREQUENCY AND TIME SIGNAL (2 500 kHz)</td></tr>
<tr><td>2 501-2 502</td><td colspan="2">STANDARD FREQUENCY AND TIME SIGNAL
Space Research</td></tr>
<tr><td rowspan="2">2 502-2 625
FIXED
MOBILE except aeronautical mobile (R)
5.92 5.103 5.114</td><td colspan="2">2 502-2 505
STANDARD FREQUENCY AND TIME SIGNAL</td></tr>
<tr><td rowspan="3">2 505-2 850
FIXED
MOBILE</td></tr>
<tr><td>2 625-2 650
MARITIME MOBILE
MARITIME RADIONAVIGATION
5.92</td></tr>
<tr><td>2 650-2 850
FIXED
MOBILE except aeronautical mobile (R)
5.92 5.103</td></tr>
<tr><td>2 850-3 025</td><td colspan="2">AERONAUTICAL MOBILE (R)
5.111 5.115</td></tr>
<tr><td>3 025-3 155</td><td colspan="2">AERONAUTICAL MOBILE (OR)</td></tr>
<tr><td>3 155-3 200</td><td colspan="2">FIXED
MOBILE except aeronautical mobile (R)
5.116 5.117</td></tr>
<tr><td>3 200-3 230</td><td colspan="2">FIXED
MOBILE except aeronautical mobile (R)
BROADCASTING 5.113
5.116</td></tr>
</table>

5.112 *Alternative allocation: in Denmark and Sri Lanka, the band 2 194-2 300 kHz is allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis. (WRC-12)*

5.113 *For the conditions for the use of the bands 2 300-2 495 kHz (2 498 kHz in Region 1), 3 200-3 400 kHz, 4 750-4 995 kHz and 5 005-5 060 kHz by the broadcasting service, see Nos.* ***5.16*** *to* ***5.20****,* ***5.21*** *and* ***23.3*** *to* ***23.10****.*

5.114 *Alternative allocation: in Denmark and Iraq, the band 2 502-2 625 kHz is allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis. (WRC-12)*

5.115 *The carrier (reference) frequencies 3 023 kHz and 5 680 kHz may also be used, in accordance with Article* ***31****, by stations of the maritime mobile service engaged in coordinated search and rescue operations. (WRC-07)*

5.116 *Administrations are urged to authorize the use of the band 3 155-3 195 kHz to provide a common worldwide channel for low power wireless hearing aids. Additional channels for these devices may be assigned by administrations in the bands between 3 155 kHz and 3 400 kHz to suit local needs.*

It should be noted that frequencies in the range 3 000 kHz to 4 000 kHz are suitable for hearing aid devices which are designed to operate over short distances within the induction field.

5.117 *Alternative allocation: in Côte d'Ivoire, Denmark, Egypt, Liberia, Sri Lanka and Togo, the band 3 155-3 200 kHz is allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis. (WRC-12)*

3 230-5 003 kHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>3 230-3 400</td><td colspan="2">FIXED
MOBILE except aeronautical mobile
BROADCASTING 5.113
5.116 5.118</td></tr>
<tr><td>3 400-3 500</td><td colspan="2">AERONAUTICAL MOBILE (R)</td></tr>
<tr><td rowspan="2">3 500-3 800
AMATEUR
FIXED
MOBILE except aeronautical mobile
5.92</td><td>3 500-3 750
AMATEUR
5.119</td><td rowspan="3">3 500-3 900
AMATEUR
FIXED
MOBILE</td></tr>
<tr><td rowspan="3">3 750-4 000
AMATEUR
FIXED
MOBILE except aeronautical mobile (R)</td></tr>
<tr><td>3 800-3 900
FIXED
AERONAUTICAL MOBILE (OR)
LAND MOBILE</td></tr>
<tr><td>3 900-3 950
AERONAUTICAL MOBILE (OR)
5.123</td><td>3 900-3 950
AERONAUTICAL MOBILE
BROADCASTING</td></tr>
<tr><td>3 950-4 000
FIXED
BROADCASTING</td><td>5.122 5.125</td><td>3 950-4 000
FIXED
BROADCASTING
5.126</td></tr>
<tr><td>4 000-4 063</td><td colspan="2">FIXED
MARITIME MOBILE 5.127
5.126</td></tr>
<tr><td>4 063-4 438</td><td colspan="2">MARITIME MOBILE 5.79A 5.109 5.110 5.130 5.131 5.132
5.128</td></tr>
<tr><td>4 438-4 488
FIXED
MOBILE except aeronautical mobile (R)
Radiolocation 5.132A
5.132B</td><td>4 438-4 488
FIXED
MOBILE except aeronautical mobile (R)
RADIOLOCATION 5.132A</td><td>4 438-4 488
FIXED
MOBILE except aeronautical mobile
Radiolocation 5.132A</td></tr>
</table>

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td colspan="2">4 488-4 650
FIXED
MOBILE except aeronautical mobile (R)</td><td>4 488-4 650
FIXED
MOBILE except aeronautical mobile</td></tr>
<tr><td>4 650-4 700</td><td colspan="2">AERONAUTICAL MOBILE (R)</td></tr>
<tr><td>4 700-4 750</td><td colspan="2">AERONAUTICAL MOBILE (OR)</td></tr>
<tr><td>4 750-4 850
FIXED
AERONAUTICAL MOBILE (OR)
LAND MOBILE
BROADCASTING 5.113</td><td>4 750-4 850
FIXED
MOBILE except aeronautical mobile (R)
BROADCASTING 5.113</td><td>4 750-4 850
FIXED
BROADCASTING 5.113
Land mobile</td></tr>
<tr><td>4 850-4 995</td><td colspan="2">FIXED
LAND MOBILE
BROADCASTING 5.113</td></tr>
<tr><td>4 995-5 003</td><td colspan="2">STANDARD FREQUENCY AND TIME SIGNAL (5 000 kHz)</td></tr>
</table>

5.118 *Additional allocation: in the United States, Mexico, Peru and Uruguay, the band 3 230-3 400 kHz is also allocated to the radiolocation service on a secondary basis.* *(WRC-03)*

5.119 *Additional allocation: in Peru, the frequency band 3 500-3 750 kHz is also allocated to the fixed and mobile services on a primary basis.* *(WRC-15)*

5.120 *(SUP - WRC-2000)*

5.121 *Not used.*

5.122 *Alternative allocation: in Bolivia, Chile, Ecuador, Paraguay and Peru, the frequency band 3 750-4 000 kHz is allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis.* *(WRC-15)*

5.123 *Additional allocation: in Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe, the band 3 900-3 950 kHz is also allocated to the broadcasting service on a primary basis, subject to agreement obtained under No.* ***9.21****.*

5.124 *(SUP - WRC-2000)*

5.125 *Additional allocation: in Greenland, the band 3 950-4 000 kHz is also allocated to the broadcasting service on a primary basis. The power of the broadcasting stations operating in this band shall not exceed that necessary for a national service and shall in no case exceed 5 kW.*

5.126 *In Region 3, the stations of those services to which the band 3 995-4 005 kHz is allocated may transmit standard frequency and time signals.*

5.127 *The use of the band 4 000-4 063 kHz by the maritime mobile service is limited to ship stations using radiotelephony (see No.* ***52.220*** *and Appendix* ***17****).*

5.128 *Frequencies in the bands 4 063-4 123 kHz and 4 130-4 438 kHz may be used exceptionally by stations in the fixed service, communicating only within the boundary of the country in which they are located, with a mean power not exceeding 50 W, on condition that harmful interference is not caused to the maritime mobile service. In addition, in Afghanistan, Argentina, Armenia, Azerbaijan, Belarus, Botswana, Burkina Faso, the Central African Rep., China, the Russian Federation, Georgia, India, Kazakhstan, Mali, Niger, Pakistan, Kyrgyzstan, Tajikistan, Chad, Turkmenistan and Ukraine, in the bands 4 063-4 123 kHz, 4 130-4 133 kHz and 4 408-4 438 kHz, stations in the fixed service, with a mean power not exceeding 1 kW, can be operated on condition that they are situated at least 600 km from the coast and that harmful interference is not caused to the maritime mobile service.* *(WRC-12)*

5.129 *(SUP - WRC-07)*

5.130 *The conditions for the use of the carrier frequencies 4 125 kHz and 6 215 kHz are prescribed in Articles* ***31*** *and* ***52****.* *(WRC-07)*

5.131 *The frequency 4 209.5 kHz is used exclusively for the transmission by coast stations of meteorological and navigational warnings and urgent information to ships by means of narrow-band direct-printing techniques.* *(WRC-97)*

5.132 *The frequencies 4 210 kHz, 6 314 kHz, 8 416.5 kHz, 12 579 kHz, 16 806.5 kHz, 19 680.5 kHz, 22 376 kHz and 26 100.5 kHz are the international frequencies for the transmission of maritime safety information (MSI) (see Appendix **17**).*

5.132A *Stations in the radiolocation service shall not cause harmful interference to, or claim protection from, stations operating in the fixed or mobile services. Applications of the radiolocation service are limited to oceanographic radars operating in accordance with Resolution **612 (Rev.WRC-12)**.* *(WRC-12)*

5.132B *Alternative allocation: in Armenia, Belarus, Moldova, Uzbekistan and Kyrgyzstan, the frequency band 4 438-4 488 kHz is allocated to the fixed and mobile, except aeronautical mobile (R), services on a primary basis.* *(WRC-15)*

5 003-7 000 kHz

Allocation to services		
Region 1	***Region 2***	***Region 3***
5 003-5 005	*STANDARD FREQUENCY AND TIME SIGNAL* *Space research*	
5 005-5 060	*FIXED* *BROADCASTING 5.113*	
5 060-5 250	*FIXED* *Mobile except aeronautical mobile* *5.133*	
5 250-5 275 *FIXED* *MOBILE except aeronautical mobile* *Radiolocation 5.132A* *5.133A*	***5 250-5 275*** *FIXED* *MOBILE except aeronautical mobile* *RADIOLOCATION 5.132A*	***5 250-5 275*** *FIXED* *MOBILE except aeronautical mobile* *Radiolocation 5.132A*
5 275-5 351.5	*FIXED* *MOBILE except aeronautical mobile*	
5 351.5-5 366.5	*FIXED* *MOBILE except aeronautical mobile* *Amateur 5.133B*	
5 366.5-5 450	*FIXED* *MOBILE except aeronautical mobile*	
5 450-5 480 *FIXED* *AERONAUTICAL MOBILE (OR)* *LAND MOBILE*	***5 450-5 480*** *AERONAUTICAL MOBILE (R)*	***5 450-5 480*** *FIXED* *AERONAUTICAL MOBILE (OR)* *LAND MOBILE*
5 480-5 680	*AERONAUTICAL MOBILE (R)* *5.111 5.115*	
5 680-5 730	*AERONAUTICAL MOBILE (OR)* *5.111 5.115*	
5 730-5 900 *FIXED* *LAND MOBILE*	***5 730-5 900*** *FIXED* *MOBILE except aeronautical mobile (R)*	***5 730-5 900*** *FIXED* *Mobile except aeronautical mobile (R)*
5 900-5 950	*BROADCASTING 5.134* *5.136*	
5 950-6 200	*BROADCASTING*	
6 200-6 525	*MARITIME MOBILE 5.109 5.110 5.130 5.132* *5.137*	
6 525-6 685	*AERONAUTICAL MOBILE (R)*	

Allocation to services		
Region 1	***Region 2***	***Region 3***
6 685-6 765	*AERONAUTICAL MOBILE (OR)*	
6 765-7 000	*FIXED* *MOBILE except aeronautical mobile (R)* *5.138*	

5.133 *Different category of service: in Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Kazakhstan, Latvia, Lithuania, Niger, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan and Ukraine, the allocation of the band 5 130-5 250 kHz to the mobile, except aeronautical mobile, service is on a primary basis (see No.* ***5.33****).* *(WRC-12)*

5.133A *Alternative allocation: in Armenia, Belarus, Moldova, Uzbekistan and Kyrgyzstan, the frequency bands 5 250-5 275 kHz and 26 200-26 350 kHz are allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis.* *(WRC-15)*

5.133B *Stations in the amateur service using the frequency band 5 351.5-5 366.5 kHz shall not exceed a maximum radiated power of 15 W (e.i.r.p.). However, in Region 2 in Mexico, stations in the amateur service using the frequency band 5 351.5-5 366.5 kHz shall not exceed a maximum radiated power of 20 W (e.i.r.p.). In the following Region 2 countries: Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Dominica, El Salvador, Ecuador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela, as well as the overseas territories of the Netherlands in Region 2, stations in the amateur service using the frequency band 5 351.5-5 366.5 kHz shall not exceed a maximum radiated power of 25 W (e.i.r.p.).* *(WRC-15)*

5.134 *The use of the bands 5 900-5 950 kHz, 7 300-7 350 kHz, 9 400-9 500 kHz, 11 600-11 650 kHz, 12 050-12 100 kHz, 13 570-13 600 kHz, 13 800-13 870 kHz, 15 600-15 800 kHz, 17 480-17 550 kHz and 18 900-19 020 kHz by the broadcasting service is subject to the application of the procedure of Article* ***12****. Administrations are encouraged to use these bands to facilitate the introduction of digitally modulated emissions in accordance with the provisions of Resolution* ***517 (Rev.WRC-07)****[*]. *(WRC-07)*

5.135 *(SUP - WRC-97)*

5.136 *Additional allocation: frequencies in the band 5 900-5 950 kHz may be used by stations in the following services, communicating only within the boundary of the country in which they are located: fixed service (in all three Regions), land mobile service (in Region 1), mobile except aeronautical mobile (R) service (in Regions 2 and 3), on condition that harmful interference is not caused to the broadcasting service. When using frequencies for these services, administrations are urged to use the minimum power required and to take account of the seasonal use of frequencies by the broadcasting service published in accordance with the Radio Regulations.* *(WRC-07)*

5.137 *On condition that harmful interference is not caused to the maritime mobile service, the bands 6 200-6 213.5 kHz and 6 220.5-6 525 kHz may be used exceptionally by stations in the fixed service, communicating only within the boundary of the country in which they are located, with a mean power not exceeding 50 W. At the time of notification of these frequencies, the attention of the Bureau will be drawn to the above conditions.*

5.138 *The following bands:*

6 765-6 795 kHz (centre frequency 6 780 kHz),

433.05-434.79 MHz (centre frequency 433.92 MHz) in Region 1 except in the countries mentioned in No. ***5.280****,*

61-61.5 GHz (centre frequency 61.25 GHz),

122-123 GHz (centre frequency 122.5 GHz), and

244-246 GHz (centre frequency 245 GHz)

are designated for industrial, scientific and medical (ISM) applications. The use of these frequency bands for ISM applications shall be subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication services might be affected. In applying this provision, administrations shall have due regard to the latest relevant Recommendation ITU-Rs.

[*] *Note by the Secretariat:* This Resolution was revised by WRC-15.

5.138A *(SUP - WRC-12)*

5.139 *(SUP - WRC-12)*

7 000-7 450 kHz

Allocation to services		
Region 1	***Region 2***	***Region 3***
7 000-7 100	*AMATEUR* *AMATEUR-SATELLITE* *5.140 5.141 5.141A*	
7 100-7 200	*AMATEUR* *5.141A 5.141B*	
7 200-7 300 *BROADCASTING*	***7 200-7 300*** *AMATEUR* *5.142*	***7 200-7 300*** *BROADCASTING*
7 300-7 400	*BROADCASTING 5.134* *5.143 5.143A 5.143B 5.143C 5.143D*	
7 400-7 450 *BROADCASTING* *5.143B 5.143C*	***7 400-7 450*** *FIXED* *MOBILE except aeronautical mobile (R)*	***7 400-7 450*** *BROADCASTING* *5.143A 5.143C*

5.140 *Additional allocation: in Angola, Iraq, Somalia and Togo, the frequency band 7 000-7 050 kHz is also allocated to the fixed service on a primary basis.* *(WRC-15)*

5.141 *Alternative allocation: in Egypt, Eritrea, Ethiopia, Guinea, Libya, Madagascar and Niger, the band 7 000-7 050 kHz is allocated to the fixed service on a primary basis.* *(WRC-12)*

5.141A *Additional allocation: in Uzbekistan and Kyrgyzstan, the bands 7 000-7 100 kHz and 7 100-7 200 kHz are also allocated to the fixed and land mobile services on a secondary basis.* *(WRC-03)*

5.141B *Additional allocation: in Algeria, Saudi Arabia, Australia, Bahrain, Botswana, Brunei Darussalam, China, Comoros, Korea (Rep. of), Diego Garcia, Djibouti, Egypt, United Arab Emirates, Eritrea, Guinea, Indonesia, Iran (Islamic Republic of), Japan, Jordan, Kuwait, Libya, Mali, Morocco, Mauritania, Niger, New Zealand, Oman, Papua New Guinea, Qatar, the Syrian Arab Republic, Singapore, Sudan, South Sudan, Tunisia, Viet Nam and Yemen, the frequency band 7 100-7 200 kHz is also allocated to the fixed and the mobile, except aeronautical mobile (R), services on a primary basis.* *(WRC-15)*

5.141C *(SUP - WRC-12)*

5.142 *The use of the band 7 200-7 300 kHz in Region 2 by the amateur service shall not impose constraints on the broadcasting service future for use within Region 1 and Region 3.* *(WRC-12)*

5.143 *Additional allocation: frequencies in the band 7 300-7 350 kHz may be used by stations in the fixed service and in the land mobile service, communicating only within the boundary of the country in which they are located, on condition that harmful interference is not caused to the broadcasting service. When using frequencies for these services, administrations are urged to use the minimum power required and to take account of the seasonal use of frequencies by the broadcasting service published in accordance with the Radio Regulations.* *(WRC-07)*

5.143A *In Region 3, frequencies in the band 7 350-7 450 kHz may be used by stations in the fixed service on a primary basis and land mobile service on a secondary basis, communicating only within the boundary of the country in which they are located, on condition that harmful interference is not caused to the broadcasting service. When using frequencies for these services, administrations are urged to use the minimum power required and to take account of the seasonal use of frequencies by the broadcasting service published in accordance with the Radio Regulations.* *(WRC-12)*

5.143B *In Region 1, frequencies in the band 7 350-7 450 kHz may be used by stations in the fixed and land mobile services communicating only within the boundary of the country in which they are located on condition that harmful interference is not caused to the broadcasting service. The total radiated power of each station shall not exceed 24 dBW.* *(WRC-12)*

5.143C *Additional allocation: in Algeria, Saudi Arabia, Bahrain, Comoros, Djibouti, Egypt, United Arab Emirates, Iran (Islamic Republic of), Jordan, Kuwait, Libya, Morocco, Mauritania, Niger, Oman, Qatar, the Syrian Arab Republic, Sudan, South Sudan, Tunisia and Yemen, the bands 7 350-7 400 kHz and 7 400-7 450 kHz are also allocated to the fixed service on a primary basis.* *(WRC-12)*

5.143D *In Region 2, frequencies in the band 7 350-7 400 kHz may be used by stations in the fixed service and in the land mobile service, communicating only within the boundary of the country in which they are located, on condition that harmful interference is not caused to the broadcasting service. When using frequencies for these services, administrations are urged to use the minimum power required and to take account of the seasonal use of frequencies by the broadcasting service published in accordance with the Radio Regulations.* *(WRC-12)*

7 450-13 360 kHz

Allocation to services		
Region 1	***Region 2***	***Region 3***
7 450-8 100	*FIXED* *MOBILE except aeronautical mobile (R)* *5.144*	
8 100-8 195	*FIXED* *MARITIME MOBILE*	
8 195-8 815	*MARITIME MOBILE 5.109 5.110 5.132 5.145* *5.111*	
8 815-8 965	*AERONAUTICAL MOBILE (R)*	
8 965-9 040	*AERONAUTICAL MOBILE (OR)*	
9 040-9 305 *FIXED*	***9 040-9 400*** *FIXED*	***9 040-9 305*** *FIXED*
9 305-9 355 *FIXED* *Radiolocation 5.145A* *5.145B*		***9 305-9 355*** *FIXED* *Radiolocation 5.145A*
9 355-9 400 *FIXED*		***9 355-9 400*** *FIXED*
9 400-9 500	*BROADCASTING 5.134* *5.146*	
9 500-9 900	*BROADCASTING* *5.147*	
9 900-9 995	*FIXED*	
9 995-10 003	*STANDARD FREQUENCY AND TIME SIGNAL (10 000 kHz)* *5.111*	
10 003-10 005	*STANDARD FREQUENCY AND TIME SIGNAL* *Space research* *5.111*	
10 005-10 100	*AERONAUTICAL MOBILE (R)* *5.111*	
10 100-10 150	*FIXED* *Amateur*	
10 150-11 175	*FIXED* *Mobile except aeronautical mobile (R)*	
11 175-11 275	*AERONAUTICAL MOBILE (OR)*	
11 275-11 400	*AERONAUTICAL MOBILE (R)*	
11 400-11 600	*FIXED*	
11 600-11 650	*BROADCASTING 5.134* *5.146*	
11 650-12 050	*BROADCASTING* *5.147*	

Allocation to services		
Region 1	***Region 2***	***Region 3***
12 050-12 100	*BROADCASTING 5.134* *5.146*	
12 100-12 230	*FIXED*	
12 230-13 200	*MARITIME MOBILE 5.109 5.110 5.132 5.145*	
13 200-13 260	*AERONAUTICAL MOBILE (OR)*	
13 260-13 360	*AERONAUTICAL MOBILE (R)*	

5.143E *(SUP - WRC-12)*

5.144 *In Region 3, the stations of those services to which the band 7 995-8 005 kHz is allocated may transmit standard frequency and time signals.*

5.145 *The conditions for the use of the carrier frequencies 8 291 kHz, 12 290 kHz and 16 420 kHz are prescribed in Articles **31** and **52**. (WRC-07)*

5.145A *Stations in the radiolocation service shall not cause harmful interference to, or claim protection from, stations operating in the fixed service. Applications of the radiolocation service are limited to oceanographic radars operating in accordance with Resolution **612 (Rev.WRC-12)**. (WRC-12)*

5.145B *Alternative allocation: in Armenia, Belarus, Moldova, Uzbekistan and Kyrgyzstan, the frequency bands 9 305-9 355 kHz and 16 100-16 200 kHz are allocated to the fixed service on a primary basis. (WRC-15)*

5.146 *Additional allocation: frequencies in the bands 9 400-9 500 kHz, 11 600-11 650 kHz, 12 050-12 100 kHz, 15 600-15 800 kHz, 17 480-17 550 kHz and 18 900-19 020 kHz may be used by stations in the fixed service, communicating only within the boundary of the country in which they are located, on condition that harmful interference is not caused to the broadcasting service. When using frequencies in the fixed service, administrations are urged to use the minimum power required and to take account of the seasonal use of frequencies by the broadcasting service published in accordance with the Radio Regulations. (WRC-07)*

5.147 *On condition that harmful interference is not caused to the broadcasting service, frequencies in the bands 9 775-9 900 kHz, 11 650-11 700 kHz and 11 975-12 050 kHz may be used by stations in the fixed service communicating only within the boundary of the country in which they are located, each station using a total radiated power not exceeding 24 dBW.*

5.148 *(SUP - WRC-97)*

13 360-18 030 kHz

Allocation to services		
Region 1	***Region 2***	***Region 3***
13 360-13 410	*FIXED* *RADIO ASTRONOMY* *5.149*	
13 410-13 450	*FIXED* *Mobile except aeronautical mobile (R)*	
13 450-13 550 *FIXED* *Mobile except aeronautical mobile (R)* *Radiolocation 5.132A* *5.149A*	***13 450-13 550*** *FIXED* *Mobile except aeronautical mobile (R)* *Radiolocation 5.132A*	
13 550-13 570	*FIXED* *Mobile except aeronautical mobile (R)* *5.150*	
13 570-13 600	*BROADCASTING 5.134* *5.151*	
13 600-13 800	*BROADCASTING*	
13 800-13 870	*BROADCASTING 5.134* *5.151*	

Allocation to services		
Region 1	***Region 2***	***Region 3***
13 870-14 000	*FIXED* *Mobile except aeronautical mobile (R)*	
14 000-14 250	*AMATEUR* *AMATEUR-SATELLITE*	
14 250-14 350	*AMATEUR* *5.152*	
14 350-14 990	*FIXED* *Mobile except aeronautical mobile (R)*	
14 990-15 005	*STANDARD FREQUENCY AND TIME SIGNAL (15 000 kHz)* *5.111*	
15 005-15 010	*STANDARD FREQUENCY AND TIME SIGNAL* *Space research*	
15 010-15 100	*AERONAUTICAL MOBILE (OR)*	
15 100-15 600	*BROADCASTING*	
15 600-15 800	*BROADCASTING 5.134* *5.146*	
15 800-16 100	*FIXED* *5.153*	
16 100-16 200 *FIXED* *Radiolocation 5.145A* *5.145B*	***16 100-16 200*** *FIXED* *RADIOLOCATION 5.145A*	***16 100-16 200*** *FIXED* *Radiolocation 5.145A*
16 200-16 360	*FIXED*	
16 360-17 410	*MARITIME MOBILE 5.109 5.110 5.132 5.145*	
17 410-17 480	*FIXED*	
17 480-17 550	*BROADCASTING 5.134* *5.146*	
17 550-17 900	*BROADCASTING*	
17 900-17 970	*AERONAUTICAL MOBILE (R)*	
17 970-18 030	*AERONAUTICAL MOBILE (OR)*	

5.149 *In making assignments to stations of other services to which the bands:*

13 360-13 410 kHz,
25 550-25 670 kHz,
37.5-38.25 MHz,
73-74.6 MHz in Regions 1 and 3,
150.05-153 MHz in Region 1,
322-328.6 MHz,
406.1-410 MHz,
608-614 MHz in Regions 1 and 3,
1 330-1 400 MHz,
1 610.6-1 613.8 MHz,
1 660-1 670 MHz,
1 718.8-1 722.2 MHz,
2 655-2 690 MHz,
3 260-3 267 MHz,
3 332-3 339 MHz,
3 345.8-3 352.5 MHz,
4 825-4 835 MHz,
4 950-4 990 MHz,
4 990-5 000 MHz,
6 650-6 675.2 MHz,
10.6-10.68 GHz,
14.47-14.5 GHz,
22.01-22.21 GHz,
22.21-22.5 GHz,
22.81-22.86 GHz,
23.07-23.12 GHz,
31.2-31.3 GHz,
31.5-31.8 GHz in Regions 1 and 3,
36.43-36.5 GHz,
42.5-43.5 GHz,
48.94-49.04 GHz,
76-86 GHz,
92-94 GHz,
94.1-100 GHz,
102-109.5 GHz,
111.8-114.25 GHz,
128.33-128.59 GHz,
129.23-129.49 GHz,
130-134 GHz,
136-148.5 GHz,
151.5-158.5 GHz,
168.59-168.93 GHz,
171.11-171.45 GHz,
172.31-172.65 GHz,
173.52-173.85 GHz,
195.75-196.15 GHz,
209-226 GHz,
241-250 GHz,
252-275 GHz

are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. ***4.5*** *and* ***4.6*** *and Article* ***29****).* *(WRC-07)*

5.149A *Alternative allocation: in Armenia, Belarus, Moldova, Uzbekistan and Kyrgyzstan, the frequency band 13 450-13 550 kHz is allocated to the fixed service on a primary basis and to the mobile, except aeronautical mobile (R), service on a secondary basis.* *(WRC-15)*

5.150 *The following bands:*

13 553-13 567 kHz (centre frequency 13 560 kHz),

26 957-27 283 kHz (centre frequency 27 120 kHz),

40.66-40.70 MHz (centre frequency 40.68 MHz),

902-928 MHz in Region 2 (centre frequency 915 MHz),

2 400-2 500 MHz (centre frequency 2 450 MHz),

5 725-5 875 MHz (centre frequency 5 800 MHz), and

24-24.25 GHz (centre frequency 24.125 GHz)

are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. ***15.13****.*

5.151 *Additional allocation: frequencies in the bands 13 570-13 600 kHz and 13 800-13 870 kHz may be used by stations in the fixed service and in the mobile except aeronautical mobile (R) service, communicating only within the boundary of the country in which they are located, on the condition that harmful interference is not caused to the broadcasting service. When using frequencies in these services, administrations are urged to use the minimum power required and to take account of the seasonal use of frequencies by the broadcasting service published in accordance with the Radio Regulations.* *(WRC-07)*

5.152 *Additional allocation: in Armenia, Azerbaijan, China, Côte d'Ivoire, the Russian Federation, Georgia, Iran (Islamic Republic of), Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan and Ukraine, the band 14 250-14 350 kHz is also allocated to the fixed service on a primary basis. Stations of the fixed service shall not use a radiated power exceeding 24 dBW.* *(WRC-03)*

5.153 *In Region 3, the stations of those services to which the band 15 995-16 005 kHz is allocated may transmit standard frequency and time signals.*

18 030-23 350 kHz

Allocation to services		
Region 1	***Region 2***	***Region 3***
18 030-18 052	*FIXED*	
18 052-18 068	*FIXED* *Space research*	
18 068-18 168	*AMATEUR* *AMATEUR-SATELLITE* *5.154*	
18 168-18 780	*FIXED* *Mobile except aeronautical mobile*	
18 780-18 900	*MARITIME MOBILE*	
18 900-19 020	*BROADCASTING 5.134* *5.146*	
19 020-19 680	*FIXED*	
19 680-19 800	*MARITIME MOBILE 5.132*	
19 800-19 990	*FIXED*	
19 990-19 995	*STANDARD FREQUENCY AND TIME SIGNAL* *Space research* *5.111*	

Allocation to services		
Region 1	***Region 2***	***Region 3***
19 995-20 010	*STANDARD FREQUENCY AND TIME SIGNAL (20 000 kHz)* *5.111*	
20 010-21 000	*FIXED* *Mobile*	
21 000-21 450	*AMATEUR* *AMATEUR-SATELLITE*	
21 450-21 850	*BROADCASTING*	
21 850-21 870	*FIXED 5.155A* *5.155*	
21 870-21 924	*FIXED 5.155B*	
21 924-22 000	*AERONAUTICAL MOBILE (R)*	
22 000-22 855	*MARITIME MOBILE 5.132* *5.156*	
22 855-23 000	*FIXED* *5.156*	
23 000-23 200	*FIXED* *Mobile except aeronautical mobile (R)* *5.156*	
23 200-23 350	*FIXED 5.156A* *AERONAUTICAL MOBILE (OR)*	

5.154 *Additional allocation: in Armenia, Azerbaijan, the Russian Federation, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Ukraine, the band 18 068-18 168 kHz is also allocated to the fixed service on a primary basis for use within their boundaries, with a peak envelope power not exceeding 1 kW.* *(WRC-03)*

5.155 *Additional allocation: in Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Kazakhstan, Moldova, Mongolia, Uzbekistan, Kyrgyzstan, Slovakia, Tajikistan, Turkmenistan and Ukraine, the band 21 850-21 870 kHz is also allocated to the aeronautical mobile (R) service on a primary basis.* *(WRC-07)*

5.155A *In Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Kazakhstan, Moldova, Mongolia, Uzbekistan, Kyrgyzstan, Slovakia, Tajikistan, Turkmenistan and Ukraine, the use of the band 21 850-21 870 kHz by the fixed service is limited to provision of services related to aircraft flight safety.* *(WRC-07)*

5.155B *The band 21 870-21 924 kHz is used by the fixed service for provision of services related to aircraft flight safety.*

5.156 *Additional allocation: in Nigeria, the band 22 720-23 200 kHz is also allocated to the meteorological aids service (radiosondes) on a primary basis.*

5.156A *The use of the band 23 200-23 350 kHz by the fixed service is limited to provision of services related to aircraft flight safety.*

23 350-27 500 kHz

Allocation to services		
Region 1	***Region 2***	***Region 3***
23 350-24 000 *FIXED* *MOBILE except aeronautical mobile 5.157*		
24 000-24 450 *FIXED* *LAND MOBILE*		
24 450-24 600 *FIXED* *LAND MOBILE* *Radiolocation 5.132A* *5.158*	***24 450-24 650*** *FIXED* *LAND MOBILE* *RADIOLOCATION 5.132A*	***24 450-24 600*** *FIXED* *LAND MOBILE* *Radiolocation 5.132A*
24 600-24 890 *FIXED* *LAND MOBILE*	***24 650-24 890*** *FIXED* *LAND MOBILE*	***24 600-24 890*** *FIXED* *LAND MOBILE*
24 890-24 990 *AMATEUR* *AMATEUR-SATELLITE*		
24 990-25 005 *STANDARD FREQUENCY AND TIME SIGNAL (25 000 kHz)*		
25 005-25 010 *STANDARD FREQUENCY AND TIME SIGNAL* *Space research*		
25 010-25 070 *FIXED* *MOBILE except aeronautical mobile*		
25 070-25 210 *MARITIME MOBILE*		
25 210-25 550 *FIXED* *MOBILE except aeronautical mobile*		
25 550-25 670 *RADIO ASTRONOMY* *5.149*		
25 670-26 100 *BROADCASTING*		
26 100-26 175 *MARITIME MOBILE 5.132*		
26 175-26 200 *FIXED* *MOBILE except aeronautical mobile*		
26 200-26 350 *FIXED* *MOBILE except aeronautical mobile* *Radiolocation 5.132A* *5.133A*	***26 200-26 420*** *FIXED* *MOBILE except aeronautical mobile* *RADIOLOCATION 5.132A*	***26 200-26 350*** *FIXED* *MOBILE except aeronautical mobile* *Radiolocation 5.132A*
26 350-27 500 *FIXED* *MOBILE except aeronautical mobile* *5.150*	***26 420-27 500*** *FIXED* *MOBILE except aeronautical mobile* *5.150*	***26 350-27 500*** *FIXED* *MOBILE except aeronautical mobile* *5.150*

5.157 *The use of the band 23 350-24 000 kHz by the maritime mobile service is limited to inter-ship radiotelegraphy.*

5.158 *Alternative allocation: in Armenia, Belarus, Moldova, Uzbekistan and Kyrgyzstan, the frequency band 24 450-24 600 kHz is allocated to the fixed and land mobile services on a primary basis.* *(WRC-15)*

27.5-40.98 MHz

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Radiolocation 5.132A
5.159</td></tr>
<tr><td>39.5-39.986
FIXED
MOBILE</td><td>39.5-39.986
FIXED
MOBILE
RADIOLOCATION 5.132A</td></tr>
<tr><td colspan="2" rowspan="2">39.986-40.02
FIXED
MOBILE
Space research</td><td>39.986-40
FIXED
MOBILE
RADIOLOCATION 5.132A
Space research</td></tr>
<tr><td>40-40.02
FIXED
MOBILE
Space research</td></tr>
<tr><td>40.02-40.98</td><td colspan="2">FIXED
MOBILE
5.150</td></tr>
</table>

5.159 Alternative allocation: in Armenia, Belarus, Moldova, Uzbekistan and Kyrgyzstan, the frequency band 39-39.5 MHz is allocated to the fixed and mobile services on a primary basis. (WRC-15)

40.98-47 MHz

Allocation to services		
Region 1	***Region 2***	***Region 3***
40.98-41.015	*FIXED* *MOBILE* *Space research* *5.160 5.161*	
41.015-42	*FIXED* *MOBILE* *5.160 5.161 5.161A*	
42-42.5 *FIXED* *MOBILE* *Radiolocation 5.132A* *5.160 5.161B*	***42-42.5*** *FIXED* *MOBILE* *5.161*	
42.5-44	*FIXED* *MOBILE* *5.160 5.161 5.161A*	
44-47	*FIXED* *MOBILE* *5.162 5.162A*	

5.160 *Additional allocation: in Botswana, Burundi, Dem. Rep. of the Congo and Rwanda, the band 41-44 MHz is also allocated to the aeronautical radionavigation service on a primary basis.* *(WRC-12)*

5.161 *Additional allocation: in Iran (Islamic Republic of) and Japan, the band 41-44 MHz is also allocated to the radiolocation service on a secondary basis.*

5.161A *Additional allocation: in Korea (Rep. of) and the United States, the frequency bands 41.015-41.665 MHz and 43.35-44 MHz are also allocated to the radiolocation service on a primary basis. Stations in the radiolocation service shall not cause harmful interference to, or claim protection from, stations operating in the fixed or mobile services. Applications of the radiolocation service are limited to oceanographic radars operating in accordance with Resolution* ***612 (Rev.WRC-12)****.* *(WRC-12)*

5.161B *Alternative allocation: in Albania, Germany, Armenia, Austria, Belarus, Belgium, Bosnia and Herzegovina, Cyprus, Vatican, Croatia, Denmark, Spain, Estonia, Finland, France, Greece, Hungary, Ireland, Iceland, Italy, Latvia, The Former Yugoslav Rep. of Macedonia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Norway, Uzbekistan, Netherlands, Portugal, Kyrgyzstan, Slovakia, Czech Rep., Romania, United Kingdom, San Marino, Slovenia, Sweden, Switzerland, Turkey and Ukraine, the frequency band 42-42.5 MHz is allocated to the fixed and mobile services on a primary basis.* *(WRC-15)*

5.162 *Additional allocation: in Australia, the band 44-47 MHz is also allocated to the broadcasting service on a primary basis.* *(WRC-12)*

5.162A *Additional allocation: in Germany, Austria, Belgium, Bosnia and Herzegovina, China, Vatican, Denmark, Spain, Estonia, the Russian Federation, Finland, France, Ireland, Iceland, Italy, Latvia, The Former Yugoslav Republic of Macedonia, Liechtenstein, Lithuania, Luxembourg, Monaco, Montenegro, Norway, the Netherlands, Poland, Portugal, the Czech Rep., the United Kingdom, Serbia, Slovenia, Sweden and Switzerland the band 46-68 MHz is also allocated to the radiolocation service on a secondary basis. This use is limited to the operation of wind profiler radars in accordance with Resolution* ***217 (WRC-97)****.* *(WRC-12)*

47-75.2 MHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td rowspan="4">47-68
BROADCASTING

5.162A 5.163 5.164 5.165 5.169 5.171</td><td>47-50
FIXED
MOBILE</td><td>47-50
FIXED
MOBILE
BROADCASTING
5.162A</td></tr>
<tr><td colspan="2">50-54
AMATEUR
5.162A 5.167 5.167A 5.168 5.170</td></tr>
<tr><td>54-68
BROADCASTING
Fixed
Mobile

5.172</td><td>54-68
FIXED
MOBILE
BROADCASTING

5.162A</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="5">68-74.8
FIXED
MOBILE except aeronautical mobile

5.149 5.175 5.177 5.179</td><td>68-72
BROADCASTING
Fixed
Mobile
5.173</td><td rowspan="5">68-74.8
FIXED
MOBILE

5.149 5.176 5.179</td></tr>
<tr><td>72-73
FIXED
MOBILE</td></tr>
<tr><td>73-74.6
RADIO ASTRONOMY
5.178</td></tr>
<tr><td>74.6-74.8
FIXED
MOBILE</td></tr>
<tr><td></td></tr>
<tr><td colspan="3">74.8-75.2 AERONAUTICAL RADIONAVIGATION
5.180 5.181</td></tr>
</table>

5.163 *Additional allocation: in Armenia, Belarus, the Russian Federation, Georgia, Hungary, Kazakhstan, Latvia, Moldova, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan and Ukraine, the bands 47-48.5 MHz and 56.5-58 MHz are also allocated to the fixed and land mobile services on a secondary basis.* *(WRC-12)*

5.164 *Additional allocation: in Albania, Algeria, Germany, Austria, Belgium, Bosnia and Herzegovina, Botswana, Bulgaria, Côte d'Ivoire, Croatia, Denmark, Spain, Estonia, Finland, France, Gabon, Greece, Ireland, Israel, Italy, Jordan, Lebanon, Libya, Liechtenstein, Lithuania, Luxembourg, Madagascar, Mali, Malta, Morocco, Mauritania, Monaco, Montenegro, Nigeria, Norway, the Netherlands, Poland, Syrian Arab Republic, Slovakia, Czech Rep., Romania, the United Kingdom, Serbia, Slovenia, Sweden, Switzerland, Swaziland, Chad, Togo, Tunisia and Turkey, the frequency band 47-68 MHz, in South Africa the frequency band 47-50 MHz, and in Latvia the frequency band 48.5-56.5 MHz, are also allocated to the land mobile service on a primary basis. However, stations of the land mobile service in the countries mentioned in connection with each frequency band referred to in this footnote shall not cause harmful interference to, or claim protection from, existing or planned broadcasting stations of countries other than those mentioned in connection with the frequency band.* *(WRC-15)*

5.165 *Additional allocation: in Angola, Cameroon, Congo (Rep. of the), Madagascar, Mozambique, Niger, Somalia, Sudan, South Sudan, Tanzania and Chad, the band 47-68 MHz is also allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis. (WRC-12)*

5.166 *(SUP - WRC-15)*

5.167 *Alternative allocation: in Bangladesh, Brunei Darussalam, India, Iran (Islamic Republic of), Pakistan and Singapore, the frequency band 50-54 MHz is allocated to the fixed, mobile and broadcasting services on a primary basis. (WRC-15)*

5.167A *Additional allocation: in Indonesia and Thailand, the frequency band 50-54 MHz is also allocated to the fixed, mobile and broadcasting services on a primary basis. (WRC-15)*

5.168 *Additional allocation: in Australia, China and the Dem. People's Rep. of Korea, the band 50-54 MHz is also allocated to the broadcasting service on a primary basis.*

5.169 *Alternative allocation: in Botswana, Lesotho, Malawi, Namibia, the Dem. Rep. of the Congo, Rwanda, South Africa, Swaziland, Zambia and Zimbabwe, the band 50-54 MHz is allocated to the amateur service on a primary basis. In Senegal, the band 50-51 MHz is allocated to the amateur service on a primary basis. (WRC-12)*

5.170 *Additional allocation: in New Zealand, the frequency band 51-54 MHz is also allocated to the fixed and mobile services on a primary basis. (WRC-15)*

5.171 *Additional allocation: in Botswana, Lesotho, Malawi, Mali, Namibia, Dem. Rep. of the Congo, Rwanda, South Africa, Swaziland, Zambia and Zimbabwe, the band 54-68 MHz is also allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis. (WRC-12)*

5.172 *Different category of service: in the French overseas departments and communities in Region 2 and Guyana, the allocation of the frequency band 54-68 MHz to the fixed and mobile services is on a primary basis (see No. **5.33**). (WRC-15)*

5.173 *Different category of service: in the French overseas departments and communities in Region 2 and Guyana, the allocation of the frequency band 68-72 MHz to the fixed and mobile services is on a primary basis (see No. **5.33**). (WRC-15)*

5.174 *(SUP - WRC-07)*

5.175 *Alternative allocation: in Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Kazakhstan, Moldova, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan and Ukraine, the bands 68-73 MHz and 76-87.5 MHz are allocated to the broadcasting service on a primary basis. In Latvia and Lithuania, the bands 68-73 MHz and 76-87.5 MHz are allocated to the broadcasting and mobile, except aeronautical mobile, services on a primary basis. The services to which these bands are allocated in other countries and the broadcasting service in the countries listed above are subject to agreements with the neighbouring countries concerned. (WRC-07)*

5.176 *Additional allocation: in Australia, China, Korea (Rep. of), the Philippines, the Dem. People's Rep. of Korea and Samoa, the band 68-74 MHz is also allocated to the broadcasting service on a primary basis. (WRC-07)*

5.177 *Additional allocation: in Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan and Ukraine, the band 73-74 MHz is also allocated to the broadcasting service on a primary basis, subject to agreement obtained under No. **9.21**. (WRC-07)*

5.178 *Additional allocation: in Colombia, Cuba, El Salvador, Guatemala, Guyana, Honduras and Nicaragua, the band 73-74.6 MHz is also allocated to the fixed and mobile services on a secondary basis. (WRC-12)*

5.179 *Additional allocation: in Armenia, Azerbaijan, Belarus, China, the Russian Federation, Georgia, Kazakhstan, Lithuania, Mongolia, Kyrgyzstan, Tajikistan, Turkmenistan and Ukraine, the bands 74.6-74.8 MHz and 75.2-75.4 MHz are also allocated to the aeronautical radionavigation service, on a primary basis, for ground-based transmitters only. (WRC-12)*

5.180 *The frequency 75 MHz is assigned to marker beacons. Administrations shall refrain from assigning frequencies close to the limits of the guardband to stations of other services which, because of their power or geographical position, might cause harmful interference or otherwise place a constraint on marker beacons.*

Every effort should be made to improve further the characteristics of airborne receivers and to limit the power of transmitting stations close to the limits 74.8 MHz and 75.2 MHz.

5.181 *Additional allocation: in Egypt, Israel and the Syrian Arab Republic, the band 74.8-75.2 MHz is also allocated to the mobile service on a secondary basis, subject to agreement obtained under No. **9.21**. In order to ensure that harmful interference is not caused to stations of the aeronautical radionavigation service, stations of the mobile service shall not be introduced in the band until it is no longer required for the aeronautical radionavigation service by any administration which may be identified in the application of the procedure invoked under No. **9.21**. (WRC-03)o*

Annex B:
Essential parts of CEPT/ERC Recommendation 70-03

Limits cited in CEPT/ERC Recommendation 70-03 [i.2]

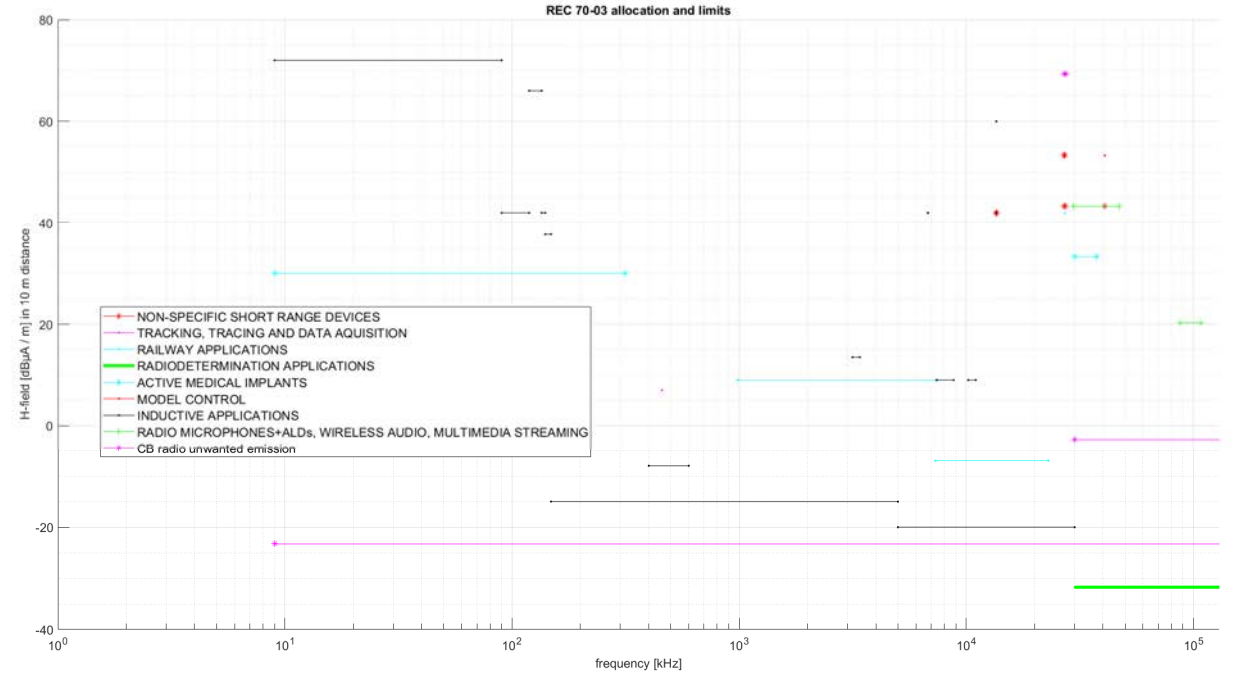

Figure B.1: Allocation situation for frequencies from 0 MHz to 130 MHz

Sources in CEPT/ERC Recommendation 70-03 [i.2] of cited limits

Recommendation/Report/Study	Title	Relevance to NMR frequency range
CEPT/ERC Recommendation 70-03 13 October 2017 [i.2]	Relating to the use of Short Range Devices (SRD)	full range of NMR
Recommendation 74-01E 2001 [i.49]	Unwanted emissions in the spurious domain	full range of NMR
Decision (11)03 17 June 2016 [i.50]	The harmonised use of frequencies for Citizens' Band (CB) radio equipment	unwanted emissions in full range of NMR
ERC REPORT 25 (ECA TABLE) Approved October 2017 [i.11]	The european table of frequency allocations and applications in the frequency range 8,3 kHz to 3 000 GHz	full range of NMR
ECC/DEC/(06)04 amended 9 December 2011 [i.51]	The harmonised conditions for devices using Ultra-wideband (UWB) technology in bands below 10,6 GHz	< 1,6 GHz
ECC/DEC/(06)08 ECC Decision of 1 December 2006 [i.47]	The conditions for use of the radio spectrum by Ground- and Wall- probing radar (GPR/WPR) imaging systems	< 230 MHz
ECC/DEC/(07)01 Corrected 18 November 2016 [i.52]	Building Material Analysis (BMA) devices using UWB technology	< 1,73 GHz
ECC/REC/(11)09 Amended 22 May 2015 [i.53]	UWB Location Tracking Systems TYPE 2 (LT2)	< 1,6 GHz

Recommendation/Report/Study	Title	Relevance to NMR frequency range
ECC/REC/(11)10 Approved 21 October 2011 [i.54]	Location tracking application for emergency and disaster situations (LAES)	
ERC Rec 62-01 1997 [i.55]	Use of the Band 135,7-137,8 kHz by the Amateur Service	135,7-137,8 kHz
ERC/DEC/(01)11 Updated 17 November 2017 [i.56]	Short Range Devices for Flying Model Control in 34.995-35.225 MHz	34,995-35,225 MHz
ERC/DEC/(01)12 Updated 17 November 2017 [i.57]	Short Range Devices for Model Control in 40.665, 40.675, 40.685 and 40.695 MHz	40,665, 40,675, 40,685 and 40,695 MHz
ECC/DEC/(05)02 [i.45]	The designation and availability of frequency bands for railway purposes in the 876-880 MHz and 921-925 MHz bands	
ECC/DEC(11)02 [i.48]	Industrial Level Probing Radars (LPR) operating in frequency bands 6 - 8,5 GHz, 24,05 - 26,5 GHz, 57 - 64 GHz and 75 - 85 GHz	
ECC Report 001 February 2002 [i.12]	Compatibility between inductive LF and HF RFID transponder and other radio communications systems in the frequency ranges 135-148,5 kHz, 4,78-8,78 MHz and 11,56-15,56 MHz	135-148,5 kHz, 4,78-8,78 MHz and 11,56-15,56 MHz
ECC Report 007 February 2002 [i.13]	Compatibility between inductive LF RFID systems and radio communications systems in the frequency range 135-148,5 kHz	135-148,5 kHz
ECC Report 012 October 2002 [i.14]	Ultra Low Power Active Medical Implant systems (ULP-AMI)	9 kHz to 315 kHz
ECC Report 024 May 2003 [i.15]	PLT, DSL, CABLE communications (Including CABLE TV), LANS and their effect on radio services	DC to 3 GHz
ECC Report 064 February 2005 [i.16]	The protection requirements of radiocommunication systems below 10,6 GHz from generic UWB applications	0,255 - 137 MHz
ECC Report 067 October 2005 [i.17]	Compatibility study for generic limits for the emission levels of inductive SRDs below 30 MHz	< 30 MHz
ERC Report 069 February 1999 [i.18]	Propagation Model And Interference Range Calculation. For Inductive Systems 10 kHz - 30 MHz	< 30 MHz
ECC Report 073 October 2005 [i.19]	Compatibility of SRD in the FM radio broadcasting band	88 – 108 MHz
ERC Report 074 May 1999 [i.20]	Compatibility Between Radio Frequency Identification Devices (RFID) and The Radio astronomy Service At 13 MHz	13,553-13,567 MHz 13,36-13,41 MHz
ECC Report 081 May 2006 [i.21]	The coexistence between Ultra Low Power - Animal Implant Devices (ULP-AID) operating in the frequency band 12,5-20 MHz and existing radiocommunication systems	12,5 - 20 MHz
ECC Report 098 February 2007 [i.22]	Studying the compatibility issues of the UIC EUROLOOP system with other systems in the frequency band 9,5 to 17,5 MHz	4,5 MHz to 13,5 MHz 9,5 - 17,5 MHz
ECC Report 135 September 2009 [i.23]	Inductive limits in the frequency range 9 kHz to 148,5 kHz	9 - 148,5 kHz
ECC Report 181 September 2012 [i.24]	Improving spectrum efficiency in SRD bands	all
ECC Report 208 January 2014 [i.25]	Impact of RFID devices on radio services in the band 13,56 MHz	13,56 MHz
ERC Report 044 January 1997 [i.26]	Sharing inductive systems and radiocommunication systems in the band 9-135 kHz	9 - 135 kHz
ERC Report 092 June 2000 [i.27]	Sharing inductive Short Range Devices and radio communication systems in 10,2-11 MHz	10,2 - 11 MHz
ERC Report 095 June 2000 [i.28]	The use of 3 155-3 400 kHz for general inductive applications	3 155 - 3 400 kHz
ERC Report 096 June 2000 [i.27]	The use of 290-300 kHz and 500-510 kHz for general inductive applications	290-300 kHz and 500-510 kHz
2007/346/EC [i.58]	Granting a derogation requested by France pursuant to Decision 2006/804/EC on harmonisation of the radio spectrum for **Radio Frequency Identification (RFID)** devices operating in the Ultra High Frequency (UHF) band	
2008/432/EC [i.59]	Amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by **short-range devices**	

Recommendation/Report/Study	Title	Relevance to NMR frequency range
2009/343/EC [i.60]	Amending the Decision 2007/131/EC on the harmonised use of the radio spectrum for equipment using **UWB technology**	
2009/381/EC [i.61]	Amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by **SRD**	
2010/368/EU [i.62]	Amending the Decision 2006/771/EC on harmonisation of the radio spectrum for use by **SRD**	
2011/829/EU [i.63]	Amending Decision 2006/771/EC on the harmonisation of the radio spectrum for use by **SRD**	
2013/752/EU [i.1]	Amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by **short-range devices** and repealing Decision 2005/928/EC	
2014/641/EU [i.46]	Harmonised technical conditions of spectrum use by **programme making and special events** equipment in the Union	
2014/702/EU [i.64]	Amending 2007/131/EC on allowing the use of the radio spectrum for equipment using **ultra-wideband technology** in a harmonised manner in the Community	
2017/1438/EU [i.65]	Amending Decision 2007/131/EC on allowing the use of the radio spectrum for equipment using **ultra-wideband technology** in a harmonised manner in the Community	
2017/1483/EU [i.66]	Amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by **SRD** and repealing Decision 2006/804/EC	

Annex C:
Occupied Bandwidth Calculation

Matlab code used to calculate ocupied bandwidth in request for spectrum access.

```
% based on https://de.mathworks.com/help/signal/examples/signal-generation-and-visualization.html

f_lamor = 13.458e6;     % Lamor Resonance [Hz]
fs = 128*f_lamor;       % 4 times oversampling [Hz]
t = 0 : 1/fs : 10e-3;   % 1 s signal evaluation time

%pulse shaping using trapeziodal function
rise = [0: 1/fs : 5e-7]/5e-7;         % 500 ns sind bei 10 MHz (100 ns) 5 Schwingungen
w90 = ones(1, int32(fs*380e-6));              % width of 90° pulse [s]
fall = 1-rise;
trapez = [rise w90 fall];
off = zeros(1, length(t) - length(trapez));
pulse90 = [trapez off];

% cosine function mulitplied by pulse
yp = cos( 2*pi*f_lamor*t ).*pulse90 ./2;

% Spectrum estimation
[pxx,f] = pwelch(yp,length(yp),0,length(yp),fs,'onesided','power');

% Occupied bandwidth
bw = obw(yp,fs);
```

History

Document history		
V1.1.1	December 2018	Publication