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Foreword

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

Executive summary

Due to the development of new systems and applications supporting maritime operations related to off-shore activities, there is an increasing need for high speed digital communication links between the units engaged in such activities.

A high speed maritime broadband radio system provides short range links between several vessels and fixed structures are cooperating in complex operations at sea. Basic VHF communication services, satellite communication and state of the art WLAN systems do not support the high speed and data throughput needed in such advanced and demanding operations.

Therefore, there is a need to develop new radio communication systems with higher capacity and link type characteristics to meet the new requirements for data capacity, speed and throughput.

A high speed Maritime Broadband Radio (MBR) working in the 5 GHz to 8 GHz range may be implemented with adaptive antenna arrays that will enable beam forming and high directivity. A radio communication system with advanced beam forming and digital processing may greatly increase the capability and capacity of the radio system compared to state of the art systems.

In order to achieve these benefits, however, it is necessary to operate typically in the 5 GHz band or higher in order to implement antenna arrays of practical size. Due to the high directivity used and thereby relatively high EIRP, a suitable frequency allocation is necessary to avoid interference problems with current WLAN systems and similar kind of equipment.

The main use for a Maritime Broadband Radio system is data communication between vessels and between vessels and fixed structures, typically oil installations at sea. As the system is totally digital, it can be used for voice, video and data transmission. Data rates will typically be in the order of 10 Mbit/s or more. The communication content will typically be different kind of operational data, navigational data, administration data, update of chart data, messaging, live video from cameras, etc.

Transmission of data rates like this, at long distance over sea, is by no means a trivial matter. Problems due to sea-reflections and reflections from structures may frequently occur and should be mitigated by suitable processes in the digital processing platform. Moreover, the high directivity obtained with phasing of antenna arrays makes it possible to establish a dynamic link communication system between several entities. The antenna directivity and pointing angle can be dynamically adjusted both in azimuth and elevation thereby optimizing the link budget under different conditions. Moreover, phasing of antennas can be used to create antenna nulls in directions which should not be illuminated with high EIRP, or to suppress interfering signals from specific directions.

The present document describes a novel broadband digital communications system which makes use of highly directional antennas in order to achieve the desired system performance. This feature also facilitates co-frequency sharing with other systems by minimizing interference for other services.

The described system has initially been designed to be capable of operating in two 20 MHz blocks of contiguous spectrum in the 5 GHz band or higher.

Introduction

The present document has been developed to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

Status of pre-approval draft

The present document has been developed by BRAN. The information in it has undergone coordination by ERM/TG26.

1 Scope

The present document describes a maritime mobile broadband system which may require an additional frequency utilization within CEPT for the proposed band(s).

Although the technology is capable of operating in the range 5 GHz to 8 GHz, the preferred regulatory approach would be for this system to operate on a non-interference and unprotected basis within the higher end of the 5 GHz band.

The present document includes, in particular:

- Market information.
- Technical information.
- Regulatory issues.

2 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 reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

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] International Convention for the Safety of Life at Sea (SOLAS), 1974.

NOTE: Available at http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx.

[i.2] ERC Report 25: "The European table of frequency allocations and applications in the frequency range 9 kHz to 3 000 GHz (ECA Table).

[i.3] ITU Radio Regulations.

3 Symbols and abbreviations

3.1 Symbols

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

dB_c Level (dB) below carrier

3.2 Abbreviations

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

BFWA	Broadband Fixed Wireless Access
BRAN	Broadband Radio Access Networks (ETSI TC)
CDMA	Code Division Multiple Access
CEPT	Conference Européenne des administrations des Postes et Télécommunications
ECC	Electronic Communications Committee
EIRP	Equivalent Isotropically Radiated Power (dBm, dBW)
ERC	European Radiocommunications Committee
ERM	Electromagnetic compatibility and Radio spectrum Matters (ETSI TC)
FSS	Fixed Satellite Services
GMDSS	Global Maritime Distress and Safety System
GMSK	Gaussian Minimum Shift keying
ID	Identity
IMO	International Maritime Organization
IP	Internet Protocol
IPR	Intellectual Property Rights
ISM	Industrial, Scientific and Medical
ITS	Intelligent Transport Systems
ITU	International Telecommunication Union
LAN	Local Area Network
LHC	Left Hand Circular polarization
MAC	Media Access Control layer

NOTE: Layer 2 in OSI stack.

MBR	Maritime Broadband Radio Link
PHY	Physical layer

NOTE: Layer 1 in OSI stack.

RTTT	Road Transport and Traffic Telematics
SIMOPS	Simultaneous Operations

NOTE: Maritime term for operations with several vessels and structures working in a coordinated manner.

SOLAS	Safety Of Life At Sea (IMO Convention)
TDMA	Time Division Multiple Access
TLPR	Tank Level Probing Radar
TR	Technical Report
VHF	Very High Frequency

NOTE: 30 MHz to 300 MHz.

WLAN	Wireless Local Area Network

4 Comments on the System Reference Document

No ETSI members raised any comments.

4.1 Statements by ETSI Members

ETSI members are entitled to include a statement at this point in the document, if their concerns cannot be included elsewhere. Such statements should be clearly attributable to the ETSI member(s) making these statements. However, members are encouraged to try to reflect alternative viewpoints within the body of the present document.

5 Presentation of the system or technology

The described broadband radio link system is intended to provide adaptive point to point broadband connectivity between maritime vessels and structures, i.e. rigs and platform in SIMOPS (Simultaneous Operations) during development and operation of maritime oil fields and similar operations. The main object of the system is to provide high speed data communication between units needing fast and secure communication at sea. The overall system connectivity also enables the vessels to share information like databases, management systems, position and speed as well as sharing real time camera and video information.

The system is designed to enable consideration of the option for licence-exempt or lightly licensed operation in the 5 GHz band. From a frequency sharing perspective, an important feature of the described system is the use of highly directive antennas that enable point to point communication between two units. When communication is established, the transmitting antenna and the reception antenna are both aligned towards each other by software controlled antenna lobes. The transmission therefore takes place within a relatively small closed volume. Equipment outside this volume will not be influenced by this transmission as the major part of the EIRP will be in the direct line between the transmitting and receiving antenna.

The use of beam-forming permits the production of shaped and dynamically steerable beams in several directions thereby enabling the desired system performance objectives to be maintained as the vessels move relative to each other and, at the same time, minimizing interference for other co-frequency systems. This is achieved through the benefits of tailored radiation patterns which can be optimized to reduce interference and to allow operation at lower transmit powers than would otherwise be necessary if more conventional fixed antennas were deployed.

The MBR system is intended for voluntary installations for commercial purposes and is not part of any mandatory maritime distress and safety communication system, like the Global Maritime Distress and Safety System (GMDSS) or other systems specified in the SOLAS Convention [i.1].

6 Market information

The potential market for a point to point high capacity data link between vessels and between vessels and other structures was examined when developing the MBR system specification. This showed that there was an increasing expectation amongst maritime stakeholders to have a high speed data communication system that could distribute data from databases, navigation systems and real-time video transmission. A high speed data system will enhance operational efficiency and safety in for example SIMOPS where a number of vessels and structures will cooperate in complex and demanding environments. Transmission of real time video for example, could highly reduce the risk and enhance the safety in maritime operations. Moreover, having accurate real time position data from other vessels is of great importance in operations where large vessels are operating close to each other in cargo handling operations.

So far there has been some real life testing of the concepts and the system has been met with enthusiasm among users in the oil industry. Based on the experience so far there is little doubt that the MBR system will be regarded as a very important tool during SIMOPS and similar operations.

7 Technical information

The described broadband communication system is a maritime system intended for off-shore activities only. This implies that mutual interference with other services is highly unlikely.

7.1 Detailed technical description

The MBR wireless communication system is an ad-hoc system based on electronically steerable antenna beams implemented by phased array digital signal processing beam-forming. The antenna system consists of a large number of antenna elements that provides a high gain on both the transmitter and receiver system. The system is an IP oriented system with Ethernet as the external interface. The MAC/PHY, radio transceivers and antennas are all integrated into the antenna panel as shown in figure 1.

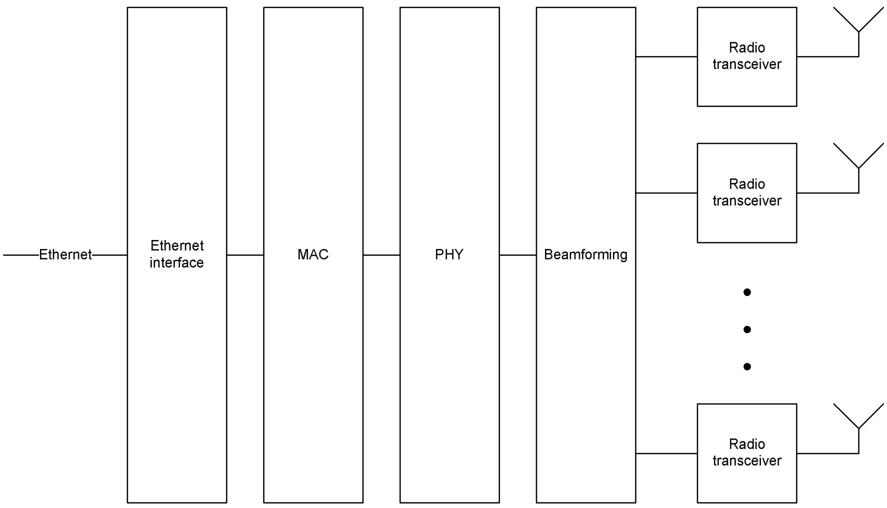

Figure 1: Block diagram of the MBR antenna panel

The system is intended for broadband user data rate throughput in the range 500 kbit/s to 10 Mbit/s.

Examples of physical realization of these antenna panels are shown in figures 2 and 3. The panel in figure 2 is mounted so the surface is horizontal. The steerable antenna lobe is a fan shaped beam, and can be steered 360° around the horizon. The panel in figure 3 is a vertical mounted panel where the antenna lobe is a cone shaped beam, and can be steered ±45° horizontally and ±45° vertically.

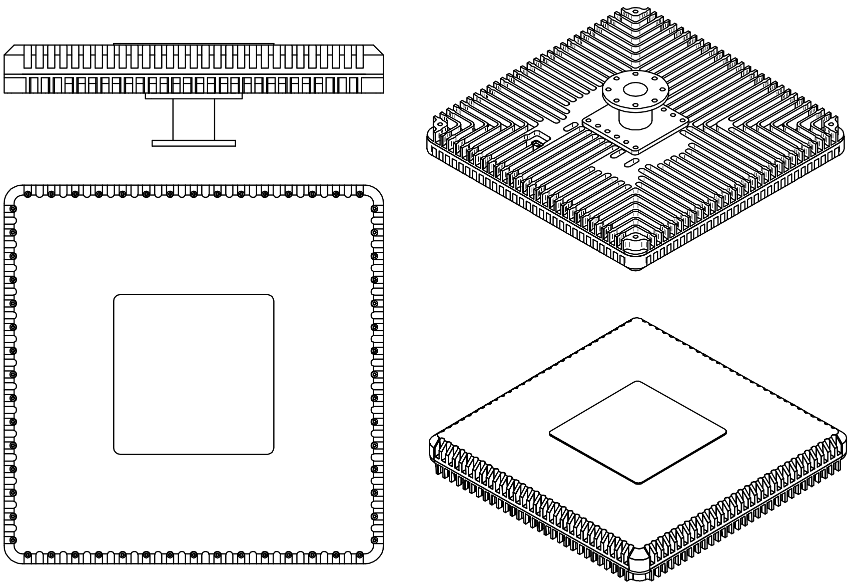

Figure 2: Example of a physical realization of a horizontally mounted panel

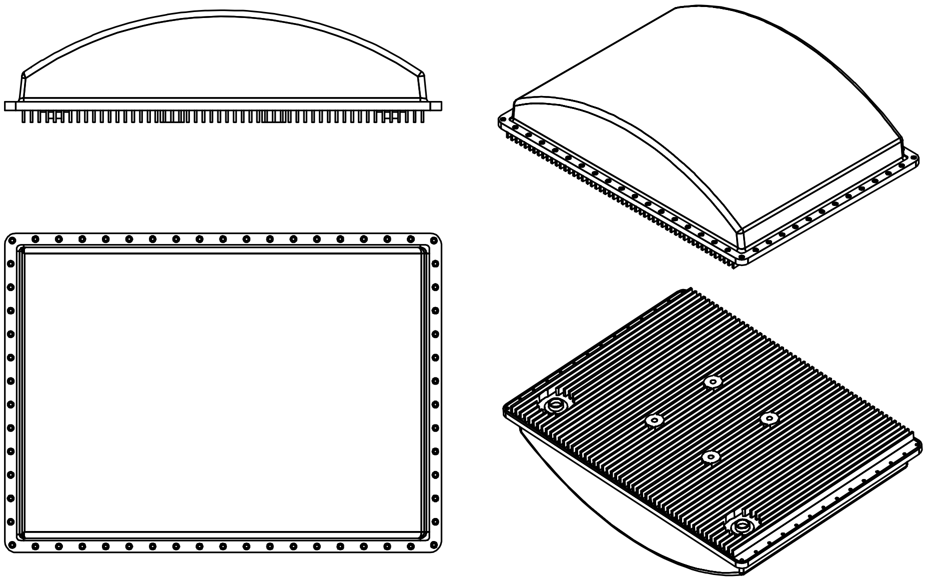

Figure 3: Example of a physical realisation of a vertically mounted panel

The available transmission output power in the narrow antenna lobe (EIRP) of the MBR system is designed to be high to achieve a long communication range with sufficient link margin. The high peak power is achieved by coherent beam forming of a large number of antenna elements where each individual element has a low radiated power. In the far-field the phasing of the antennas form a narrow beam that focus the energy and leads to a high EIRP in the direction of interest. Using a large number of antenna elements will provide low field intensity in the near-field area and an equivalent high power emission in the far-field.

The modulation type is similar to GMSK modulation high tolerance to clipping/saturation. Like CDMA (Code Division Multiple Access) systems it uses code words implemented as a codebook with complex chips in an m-ary codebook with variable codeword length for different modulation rates. The modulation type is selected for optimum spectral efficiency and power amplifier efficiency because of the large number of radios in the phased array antenna system. The system uses a phase coherent modulated code-word as a start for each data frame. The code-word that indicates the start of each data frame is used for exact time and phase synchronization. This physical mrealizationodulator scheme allows for a high precision time-of-arrival determination in the receiver section, channel estimation and a high robustness with respect to interference. The modulation scheme of the MBR system is a phase modulated code-word using a coherent and synchronously rotating code-book with complex modulated phase coded chips. The total code-sequence is very long and a coherent sliding window is used for coding of the symbol. The length of the symbols can be varied for different modulation data rates where long code-words can be used in cases of large propagation attenuation or large delay spread. The codebook has been prepared with codes that having low self and cross correlation properties.

Combined with the coherent sliding window method, inter-symbol interference from following symbols are reduced as well as interference from paths with very long additional delays. Whitening of the modulation data and forward error correction is applied as a part of the physical layer.

The MBR system operates coherently where the transmitter and receiver move the sliding window synchronously and coherently with each other. To achieve this coherent operation each transmitted data frame has to contain a code-word defining the exact start time of the frame. The frame start code-word is a long code-word to provide a precise time-of-arrival and phase-of-arrival measurement compared to the local clock reference. It is the same frame start code-word used for coherent phase front positioning calculations in addition to data demodulation, and contains an embedded ID (identity) so the spatial analysis section and space-time equalizer section can separate frame start code-words from delayed multipath reflections and different stations.

The MBR system uses a time synchronized medium control system to combine critical data transmission and avoid link collisions and reserve time for ad-hoc network traffic. In present art this scheme is known from cell based systems where the base stations defines the up- and downlink time slots, but the MBR system do not have a base station. The MBR units in the mesh network negotiate a common time reference and elect a network coordinator that defines the time-slot services in the system.

The network coordinator defines the access to time slots for critical data that are transmitted with no medium detect mechanism and in a scheduled transmission scheme so no collisions occurs. This increases the link efficiency compared to present art ad-hoc systems, such as Wireless LAN, that uses Aloha medium sharing mechanisms.

The network coordinator also allocates time slots where the communication units can share the medium with conventional Aloha medium sharing mechanisms. The MBR system is hence able to combine both highly efficient disciplined TDMA (Time Division Multiple Access) transmissions with guaranteed latency and use the rest of the link capacity for ad-hoc networking in a system with no defined base station or link master. The common negotiation is based on a method involving a majority ruling combined with random processes to avoid instabilities in case of conflicts of equal weight means so that a fast, stable network base time reference is achieved and maintained.

7.2 Technical parameters and implications on spectrum

7.2.1 Status of technical parameters

7.2.1.1 Current ITU and European frequency allocations

The system is optimized for operation at 2 channels in the 5 GHz frequency range above 5,725 GHz.

Current allocation of candidate bands in the ITU Radio Regulations is shown in table 1, together with actual usage within the CEPT.

Table 1: ITU Allocations and actual usage within CEPT

Frequency band	ITU allocations in Region 1	Actual usage of the band at national level within CEPT
5,725 GHz to 5,830 GHz	RADIOLOCATION FIXED-SATELLITE (EARTH-TO-SPACE)	BFWA, TLPR, Non-specific SRDs, RTTT, Weather radar, ISM, Amateur, Defence systems RTTT (5 795 MHz to 5 815 MHz)
5,830 GHz to 5,850 GHz	RADIOLOCATION FIXED-SATELLITE (EARTH-TO-SPACE)	BFWA, TLPR, Non-specific SRDs, RTTT, Weather radar, ISM, Amateur-satellite, Defence systems
5,850 GHz to 5,925 GHz	MOBILE. FIXED, FIXED-SATELLITE (EARTH-TO-SPACE)	TLPR, FSS Earth stations BFWA, Non-specific SRDs, ISM (up to 5 875 MHz) ITS (5 855 MHz to 5 925 MHz)

Current common allocation of the above bands in Europe is given in ERC Report 25 [i.2].

7.2.1.2 Sharing and compatibility studies (if any) already available

No sharing or compatibility studies exist for the candidate bands identified in table 1.

However, the frequency bands 5 170 MHz to 5 190 MHz and 5 220 MHz to 5 240 MHz have been licensed in Norway and USA and no interference has been reported during 2 years of operation.

The proposed system is technically identical to the system tested and in operation in Norway and USA.

In Norway, the present system maritime broad band link system operates in the same frequency bands as land based Wireless access systems and Radio local area networks without report of any interference, although these land based systems operate in a high number also in coastal areas.

7.2.1.3 Sharing and compatibility issues still to be considered

A number of different sharing/compatibility scenarios will need to be studied for each of the bands under consideration between the new proposed communication system for maritime systems and other systems in the same frequency bands.

Because of the high output power level from the new proposed system, compatibility with other radio systems with a probability to be a victim should be studied, and not only those in adjacent frequency bands.

The parameters to be used for the victim systems should be based on agreed parameters contained within existing ECC and ETSI deliverables, supplemented by the most up-to-date information where available from the expert Project Teams concerned.

The preferred frequency bands for the broadband link system are in the upper part of the 5 GHz band, specifically carrier frequencies at 5 862 GHz and 5 890 GHz. The band above 5 850 GHz has primary allocation also to MOBILE without any specific preferences to any specific services and it may be anticipated that the probability of interference may even be lower than with the present maritime broadband links.

It is fundamentally important for sharing with other services that the direction of the transmitted beam locks and stays locked to the corresponding receiver. The beam width of the emission is very narrow, the -3 dB bandwidth is less than 10° and the -20 dB bandwidth is less than 12°. In addition, as the maritime broadband links generally operate in open sea, they are far outside the interference distance from land based radio systems.

ETSI ERM TG26 has concluded that there are no other specific maritime radio systems on board ships or platforms that are likely to be interfered with by the broadband link operating in the 5 GHz to 6 GHz band. The broadband system antennas are mounted outside a ship's construction giving at least 25 dB to 30 dB attenuation towards any radio lan systems that may be installed below deck.

7.2.2 Transmitter parameters

7.2.2.1 Transmitter output power / radiated power

The maximum transmission power and EIRP of the system are as follows:

- Transmitter output power for each antenna element: +20 dBm
- Power gain by combining antenna elements in a phased array: + 18 dB
- Antenna radiation gain: +24 dB
- EIRP (+20 dBm + 18 dB + 24 dB): +62 dBm

7.2.2.2 Antenna characteristics

The antenna diagram is not static because of the electronically steerable antenna beam. For the vertical antenna panel the operative sector is ±45° in the azimuth plane and ±45° in the vertical plane. The beam peak direction can be set in any direction within the operative sector. A typical antenna radiation pattern for the vertical panel antenna with the radiation pattern in the azimuth plane is figure 4 and a typical antenna pattern mask in the vertical plane is shown in figure 5.

The shape of the antenna beam shape and direction is highly adaptive and the beam-forming may change the radiation pattern to optimize effects in the radio channel and throughput. Therefore a conventional narrow beam radiation pattern mask is not applicable for systems of this kind.

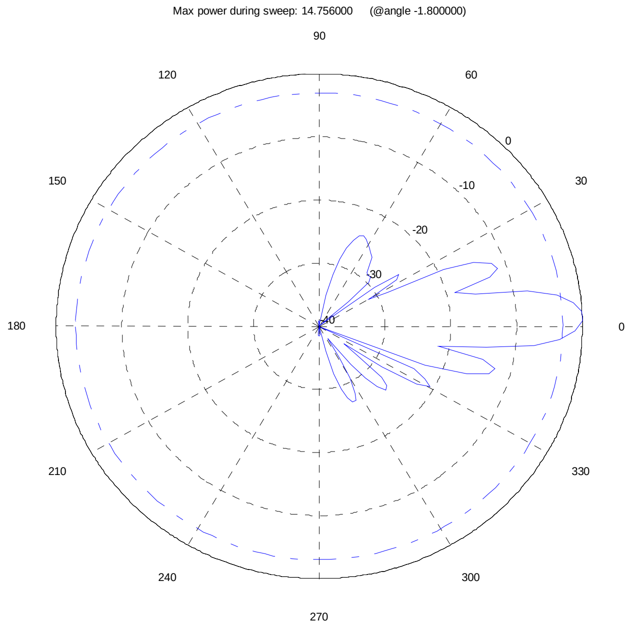

Figure 4: Measured nominal radiation pattern in the vertical plane of the steerable antenna beam in a given direction in the azimuth plane

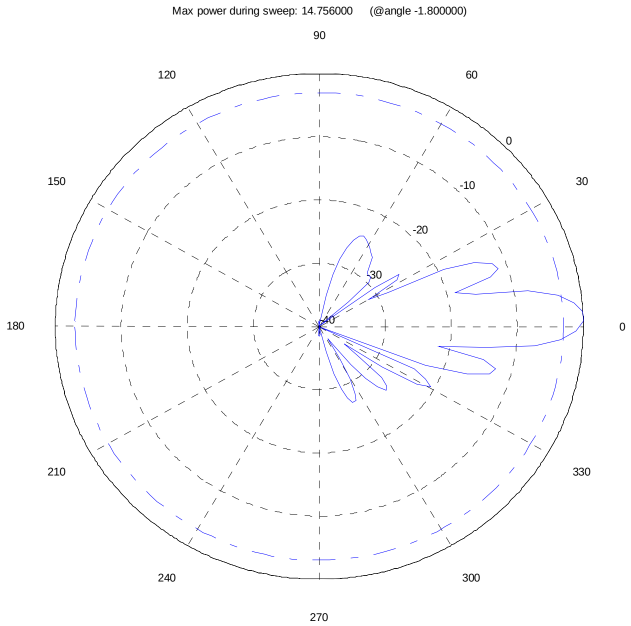

Figure 5: Measured nominal radiation pattern in the vertical plane of the steerable antenna beam in a given direction in the vertical plane

The MBR system has two modes of polarization; left hand circular (LHC) for vertical antenna panels and vertical for horizontal mounted antenna panels and hand-held units.

7.2.2.3 Operating frequency

Although the described system has been licensed in Norway and USA for the frequency bands 5 170 MHz to 5 190 MHz and 5 220 MHz to 5 290 MHz, the preferred frequency bands are in the range 5 850 MHz to 5 900 MHz with carrier frequencies at 5 862 and 5 890 MHz.

7.2.2.4 Bandwidth

The necessary bandwidth (as defined by Article 1.152 of the ITU Radio Regulations [i.3]) per channel is 12 MHz. The occupied bandwidth (as defined by Article 1.153 of the ITU Radio Regulations [i.3]) per channel is 14 MHz.

7.2.2.5 Transmitter spectrum mask

The transmitter spectrum mask is shown in figure 6.

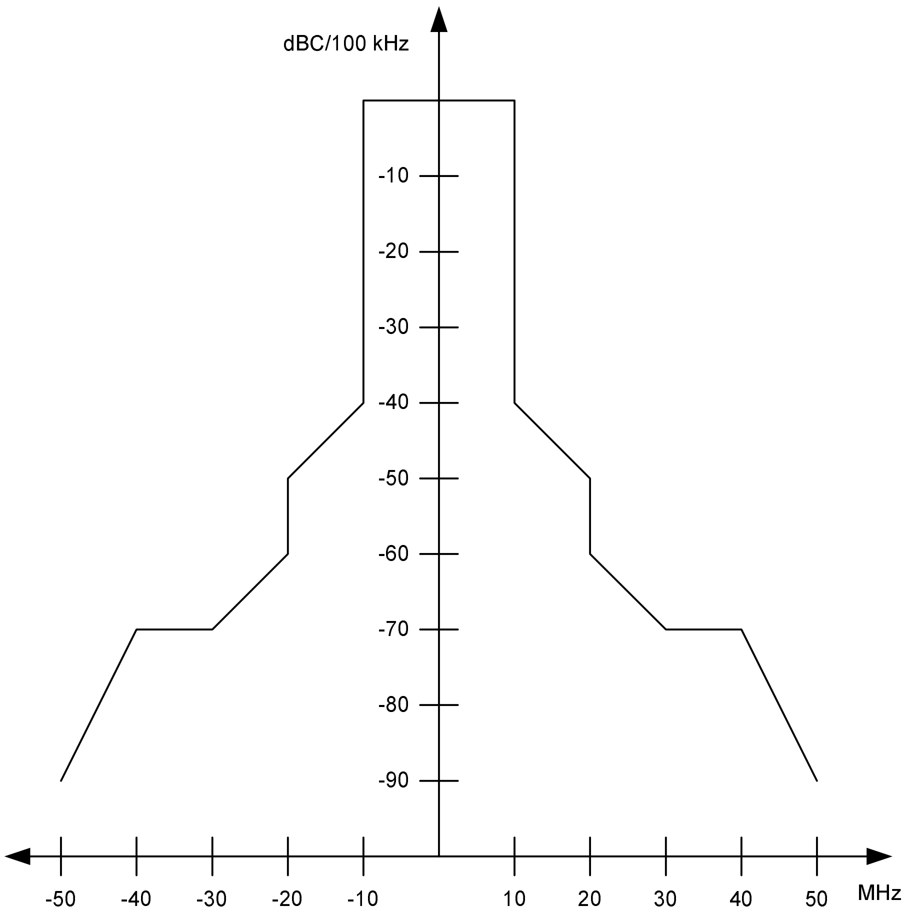

Figure 6: Transmitter spectrum mask

7.2.2.6 Unwanted emissions in the spurious domain

Table 2: Transmitter unwanted emission outside the 5 GHz bands

Frequency range	Maximum power	Bandwidth
30 MHz to 47 MHz	-36 dBm	100 kHz
47 MHz to 74 MHz	-54 dBm	100 kHz
74 MHz to 87,5 MHz	-36 dBm	100 kHz
87,5 MHz to 118 MHz	-54 dBm	100 kHz
118 MHz to 174 MHz	-36 dBm	100 kHz
174 MHz to 230 MHz	-54 dBm	100 kHz
230 MHz to 470 MHz	-36 dBm	100 kHz
470 MHz to 862 MHz	-54 dBm	100 kHz
862 MHz to 1 GHz	-36 dBm	100 kHz
1 GHz to 5,8 GHz	-30 dBm	1 MHz
5,95 GHz to 26 GHz	-30 dBm	1 MHz

7.2.3 Receiver parameters

The sensitivity is better than -83 dBm. Adjacent channel selectivity is 45 dB. The blocking level is shown in figure 7. Co-channel rejection is 6 dB for a user data throughput rate of 3,75 Mbit/s.

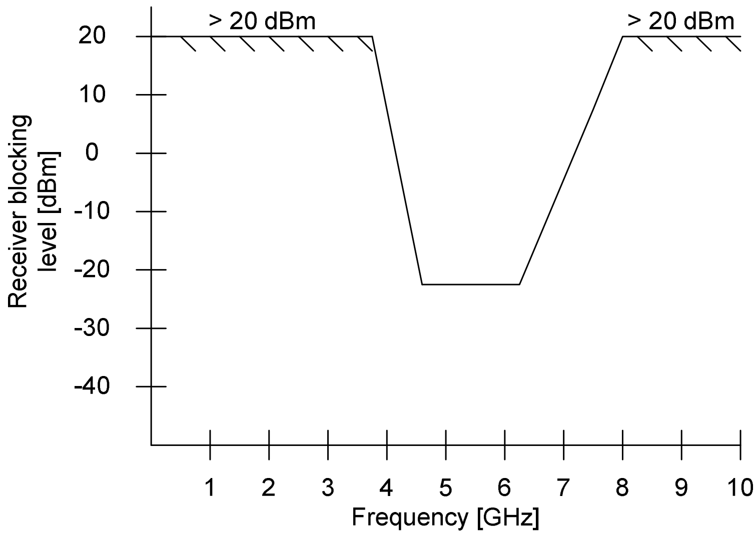

Figure 7: Measured blocking level for each of the receivers in the phased array

7.2.4 Channel access parameters

The system frame duration depends on the payload size and the modulation data rate, and the maximum frame duration can be in the range 170 µs to 60 ms according to the combination of payload size and modulation data rate. The access combines a system synchronous TDMA scheduling with certain defined time slots for Aloha-type of distributed channel access methods. A node can have a transmission duty cycle of up to 95 % according to the network system configuration.

8 Radio spectrum request and justification

A single MBR link utilizes a 20 MHz channel. Due to the narrow antenna beam and the built-in locking facility, a specific ship may at the same channel and at the same time also establish more MBR links with other ships if these ships are separated by more than approximately 15º seen from the specific ship.

However, if two different MBR links are going to be established between units that are geographically so close that there is too little discrimination by the antenna radiation pattern, these links cannot operate on the same frequency.

Further, if there is a need for two different service applications between two units, these cannot operate on the same link and another link operating on another frequency is required.

Therefore there is a need for 2 × 20 MHz channels with minimum carrier separation of 8 MHz. Alternatively, an allocation of a 100 MHz wide band would enable the operation of multiple co-located 20 MHz transmitters with sufficient frequency separation

Frequency bands at the upper part of the 5 GHz band would be preferable.

9 Regulations

9.1 Current regulations

In Europe, there are currently no frequency bands which are specifically designated for MBR use and no specific regulations related to the introduction of such services.

9.2 Proposed regulation and justification

It is proposed, after the finalization of the required sharing and compatibility studies, that an ECC Decision is developed for the designation of spectrum within the frequency band 5,85GHz to 5,9 GHz for the MBR. An ECC Decision would appear to be the most appropriate regulatory instrument, since this would give the highest degree of harmonization across the CEPT region.

History

Document history		
V1.1.1	November 2013	Publication