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RAdars for loNG distance maritime surveillancE and Search and Rescue opeRations

Alignment with regulations and environmental standards

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Editors	JACQUIN François	DXT
Contributors	Name	Partner
	IMART Michel	DMA/Cerema
	SOLDI Giovanni	NATO
Peer Reviewers	Name	
	TYNI Jaakko	LAU
	SOLDI Giovanni	NATO
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Executive Summary

This document provides information on rules to comply with, when designing the RANGER system in order to maximise its acceptability. This document corresponds to a deliverable of task 3.1(Alignment with Regulations and Environmental standard) of WP3 (RANGER compliance framework) of RANGER Project. This task will be lead from the early beginning until the end of the project.

It analyses and summarises the regulations and guidelines related to HF radiofrequencies allocations; as any governmental organization willing to use surveillance HF radars shall start a validation process in conformity with international agreements defined by ITU-R.

It also studies and summarises the EMF public and worker radiofrequency exposure regulations as well as those related to the protection of the environment.

This document version is an input for the design phase of both OTH and PE-MIMO radars. Simulation phases of the project will allow the choice of the best solutions.

Table of Contents

1. Introduction

High accuracy for radars is synonym of high constraints on technical specifications. The first ones to come to mind are the size of the antenna networks and the power of the transmitters; however, the main one is the spectrum availability.

In parallel, environmental rules, like urbanism and electromagnetic exposure, exist without any considerations about radar needs.

As a consequence, the design of a new type of radar has to balance between technical constraints and regulations. The proposed approach is structured in 3 domains:

- Spectrum
- Safety at work and around
- Environment

The list order is pragmatic: Spectrum is the fundamental parameter for the best performance and it defines the radar's parameters to take into account to work safe and to be well integrated in the environment.

This report is only a first step. During this project, it will be our priority to identify solutions in France and Greece to allocate spectrums for radar application complying with RANGER's high level objectives. Based on these first cases, a generic proposal applicable to European level will be made in the final version of this report.

1.1. Frequency management

Both radars developed in the RANGER project, are using radio frequency waves to support Search And Rescue (SAR) activities especially on small ships. Radio frequencies are regulated by strong international agreements due to the fact that propagation laws are without regards for territorial borders.

Radio waves have been in use for a long time, spectrum occupancy is high and the introduction of a new type of radar needs to take into account existing services and their international priority. The organizations in charge of the spectrum are:

- ITU-R for international level
- CEPT ECC for regional level (Europe)
- National administration

Practically, it is the national administration who wishes to implant a radar which manages the search for frequency allocation. European Administrations (CEPT) coordinates the frequency assignment between them and can develop rules of sharing at European level. Work starts with its national frequency table, followed by an analysis of regional agreements. All the process is based on the methodology and international agreements of the shared frequencies defined in the ITU-R.

The purpose of the project is being of possible use on all the maritime borders of Europe. The search for frequencies does not have to limit itself to French and Greek need for pilots (experimentations), but feasibility has to spread at least to a European level (ie CEPT). Once established, a second step could be to identify new frequency bands and then to develop proposals of evolution of the Table of the frequencies of the ITU to guarantee an international protection.

The goals to achieve with these two radars developed in the project, are in one hand the detection of small vessels in different sea states at very long ranges beyond the horizon, and on the other, using this detection to achieve the identification of a ship in direct sight; these actions demand the use of very different wavebands:

- Radars over-the Horizon (OTH) of maritime surveillance require a wave which propagates on the surface of the sea without too much loss, which is possible physically only below 30 MHz. (200 Nautic Miles range at 4 MHz, 50Nm range at 20 MHz)

- Radars for identification purpose require a very good resolution of details, which calls to work with above 1 GHz.

Few wavebands in the HF spectrum have been identified since World Radio Conference 2012, but the constraints are strong (see further paragraph). Furthermore, the studies undertaken in WP5 must identify the best scenario to establish an agreement which allows the achievement of a permanent monitoring of small size ships.

Many wavebands, in GHz bands, do exist; however, these bands have been shared for specific radar technologies. The PE-MIMO radar has to find the good technical criteria to be compatible with at least one of the existing technologies.

Answering the following questions will help understand how the radars of the project could be authorized internationally:

- Which are the essential technical parameters to study the search for frequencies?
- Which are the most relevant band candidates?
- Which is the necessary level of protection (on the spectrum) to trust the reliability of the service?

Like any international regulation, very precise terms and standardized approaches are used which must be explained to avoid misinterpretations.

2. ITU-R Radio Regulations

The ITU-R Radio regulation [1] (RR) is the international reference for spectrum use. Last version was edited in 2016. As any international regulation, the RR uses very precise terms and a standardized approach which must be explained to avoid misinterpretations.

2.1. Definitions

The definition of "radar" makes it possible to attach the equipment to the field of the radiodetermination and the subfield of « radiolocation ».

radar: A radiodetermination system based on the comparison of reference signals with radio signals reflected, or retransmitted, from the position to be determined.

primary radar: A radiodetermination system based on the comparison of reference signals with radio signals reflected from the position to be determined.

radiolocation: Radiodetermination used for purposes other than those of radionavigation.

radiodetermination: The determination of the position, velocity, and/or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves.

radionavigation: Radiodetermination used for the purposes of navigation, including obstruction warning.

It is also necessary to know other terms, related to the procedure of authorization of the frequency:

Allocation (of a frequency band): Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services, or the radio astronomy service under specified conditions. This term shall also be applied to the frequency band concerned.

Assignment (of a radio frequency or radio frequency channel): Authorization given by an administration for a radio station to use a radio frequency or radio frequency channel under specific conditions.

Assigned frequency band: The frequency band within which the emission of a station is authorized; the width of the band equals the necessary bandwidth plus twice the absolute value of

the frequency tolerance. Where space stations are concerned, the assigned frequency band includes twice the maximum Doppler shift that may occur in relation to any point of the Earth's surface.

Assigned frequency: The centre of the frequency band assigned to a station.

The allocated services have two levels of protection in relation to the other services:

- **"primary" services** : services whose names are printed in "capitals" in the ITU-R Table of Frequency Allocations (see net paragraph) **"secondary" services** : services whose names are printed in "normal characters" in the ITU-R Table of Frequency Allocations; by nature, they are protected from other services.
  Stations of a secondary service:
  a) shall not cause harmful interference to stations of primary services to which frequencies are already assigned or to which frequencies may be assigned at a later date;
  b) cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or may be assigned at a later date;
  c) can claim protection, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date.

2.2. Spectrum management

On the basis of the preceding definitions, it is now possible to examine the principal rules of the frequency management which relate to the project (the classification of the paragraphs is that of the RR):

4.1 Member States shall endeavor to limit the number of frequencies and the spectrum used to the minimum essential to provide in a satisfactory manner the necessary services. To that end they shall endeavor to apply the latest technical advances as soon as possible.

4.2 Member States undertake that in assigning frequencies to stations which are capable of causing harmful interference to the services rendered by the stations of another country, such assignments are to be made in accordance with the Table of Frequency Allocations and other provisions of these Regulations.

4.3 Any new assignment or any change of frequency or other basic characteristic of an existing assignment shall be made in such a way as to avoid causing harmful interference to services rendered by stations using frequencies assigned in accordance with the Table of Frequency Allocations in this Chapter and the other provisions of these Regulations, the characteristics of which assignments are recorded in the Master International Frequency Register.

4.4 Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the expressed condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations.

This last paragraph seems to offer insight to help identify spectrum bands for the radars. But, as the spectrum in HF bands is very congested, it is not usable for even a medium term use.

8.1 The international rights and obligations of administrations in respect of their own and other administrations' frequency assignments shall be derived from the recording of those assignments in the Master International Frequency Register (the Master Register) or from their conformity, where appropriate, with a plan. Such rights shall be conditioned by the provisions of these Regulations and those of any relevant frequency allotment or assignment plan.

8.3 Any frequency assignment recorded in the Master Register with a favourable finding under No. 11.31 shall have the right to international recognition. For such an assignment, this right means that other administrations shall take it into account when making their own assignments, in order to avoid harmful interference. In addition, frequency assignments in frequency bands subject to coordination or to a plan shall have a status derived from the application of the procedures relating to the coordination or associated with the plan.

8.4 A frequency assignment shall be known as a non-conforming assignment when it is not in accordance with the Table of Frequency Allocations or the other provisions of these Regulations. Such an assignment shall be recorded for information purposes, only when the notifying administration states that it will be operated in accordance with No. 4.4

The first three quoted points (4.1 to 4.3) correspond to the general case of authorization of a frequency. Items 4.4 intervene only if the general case is not relevant: Paragraph 4.4 makes it possible for the administration to authorize experimental radars; it is thus this point of the international regulation which should be used for the pilots in France and Greece.

The time of assignment of a new service can be very long because it requires studies of division of frequency or refitting of the spectrum (displacement of frequencies to release a continuous zone for the new service). In the frequencies HF of radars OTH, the perimeter is multinational and can even evolve to an international coordination with the ITU-R.

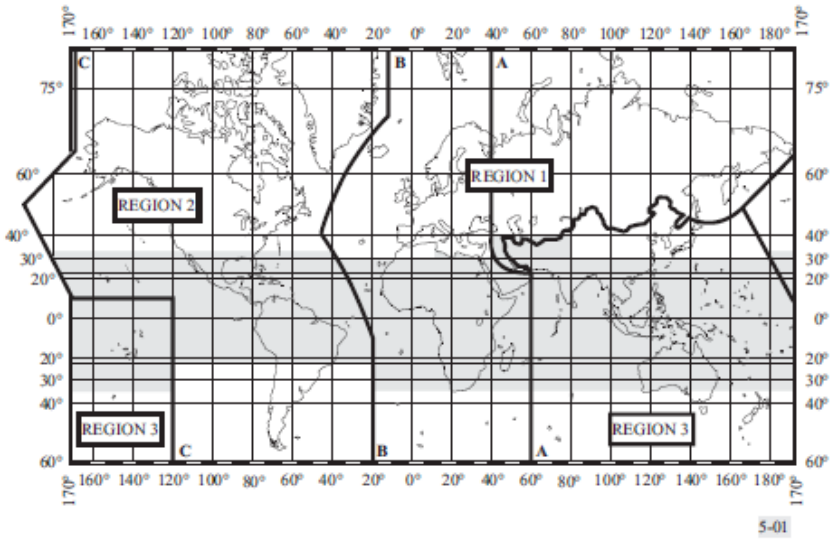
The opening of a new service in a band is enrolled in the cycle of the world conferences. The point 10 of the conference "n" examines the diverse submissions and proposes in the RPC through resolutions, the objectives to achieve (WRC N+1 even N+2) and decide on groups of studies in charge of working on it. According to the previous result of the works, the RPC project is presented to the WRC. If a consensus is acquired there, the RR will accordingly be revised and if there is not a positive result, further work will be pursued. If no consensus is obtained, the previous resolution is modified or the point is abandoned.

The minimum cycle is of four years but the global order of magnitude of the necessary delay to register a new service in the international tables is about 10 years. It is thus imperative to seek a solution in the existing table, possibly by asking an installation in the short run (widening of an existing allowance, limitation of the constraints) through a local or regional agreement, and, in the long run, setting in motion a procedure of evolution of the table at the ITU.

As example, the inscription in the frequency tables of the oceanographic radars was launched with a resolution of the WRC2007, which implies already at least 2 years of approach, and was carried out at the time of the WRC 2012. Moreover, the publication of report ITU-R M.2321 [4] for the coordination of radars in these bands took place only end of 2014, blocking over this period the possibility of assignment of frequencies of the radars existing.

2.3. International Chart of Frequencies

It belongs to volume 1 of the regulation of the radio-communications (RR) of ITU. The management of the frequencies is made on the basis of 3 areas:



Europe is entirely in area 1, which simplifies partially the research of frequencies.

2.4. Allocated bands for radar

The current wavebands with the RR for the radiolocation are listed in the following tables:

Frequency band			Regions		
			1	2	3
Radiolocation					
70kHz	-	90kHz	X	Secondary	X
110kHz	-	130kHz	X	Secondary	X
1606.5kHz	-	1625kHz	X	X	Primary
1625kHz	-	1635kHz	Primary	Secondary	Primary
1635kHz	-	1705kHz	X	Secondary	Primary
1705kHz	-	1800kHz	X	Primary	Primary
1800kHz	-	1810kHz	Primary	X	Secondary
1810kHz	-	1850kHz	X	X	Secondary
1850kHz	-	2000kHz	X	Primary	Secondary
2160kHz	-	2170kHz	Primary	X	X
3230kHz	-	3400kHz	X	X	X
4438kHz	-	4488kHz	Secondary	Primary	Secondary
5250kHz	-	5275kHz	Secondary	Primary	Secondary
9305kHz	-	9355kHz	Secondary	X	Secondary
13450kHz	-	13550kHz	Secondary	Secondary	Secondary
16100kHz	-	16200kHz	Secondary	Primary	Secondary
24450kHz	-	24600kHz	Secondary	Primary	Secondary
24600kHz	-	24650kHz	X	Primary	X
26200kHz	-	26350kHz	Secondary	Primary	Secondary
26350kHz	-	26420kHz	X	Primary	X
39MHz	-	39.5MHz	Secondary	X	X
39.5MHz	-	40MHz	X	X	Primary
41MHz	-	42MHz	X	X	X
42MHz	-	42.5MHz	Secondary	X	X
42.5MHz	-	44MHz	X	X	X
46MHz	-	68MHz	X	X	X
138MHz	-	144MHz	X	Primary	X
154MHz	-	156MHz	X	X	X
216MHz	-	220MHz	X	Secondary	X
220MHz	-	223MHz	X	Secondary	X
223MHz	-	225MHz	X	Secondary	Secondary
225MHz	-	230MHz	X	X	Secondary
420MHz	-	430MHz	Secondary	Secondary	Secondary
430MHz	-	440MHz	Primary	Primary	Primary
440MHz	-	450MHz	Secondary	Secondary	Secondary
470MHz	-	485MHz	X	X	X
890MHz	-	942MHz	Secondary	Secondary	Secondary
1215MHz	-	1400MHz	Primary	Primary	Primary
2300MHz	-	2500MHz	Secondary	Primary	Primary

Frequency band			Regions		
			1	2	3
2700MHz	-	2900MHz	Secondary	Secondary	Secondary
2900MHz	-	3400MHz	Primary	Primary	Primary
3400MHz	-	3600MHz	Secondary	Secondary	Secondary
3600MHz	-	3700MHz	X	Secondary	Secondary
5250MHz	-	5850MHz	Primary	Primary	Primary
5850MHz	-	5925MHz	X	Secondary	Secondary
8500MHz	-	10.5GHz	Primary	Primary	Primary
10.5GHz	-	10.55GHz	Secondary	Primary	Primary
10.55GHz	-	10.68GHz	Secondary	Secondary	Secondary
13.4GHz	-	14GHz	Primary	Primary	Primary
15.4GHz	-	17.3GHz	Primary	Primary	Primary
17.3GHz	-	17.7GHz	Secondary	Secondary	Secondary
24.05GHz	-	24.25GHz	Primary	Primary	Primary
33.4GHz	-	36GHz	Primary	Primary	Primary
55.78GHz	-	58.2GHz	X	X	X
59GHz	-	64GHz	Primary	Primary	Primary
76GHz	-	81GHz	Primary	Primary	Primary
92GHz	-	100GHz	Primary	Primary	Primary
136GHz	-	148.5GHz	Primary	Primary	Primary
151.5GHz	-	155.5GHz	Primary	Primary	Primary
231.5GHz	-	235GHz	Secondary	Secondary	Secondary
238GHz	-	248GHz	Primary	Primary	Primary

The other services present in this bands have also to be considered. This table lists the bands but doesn't list the other users on the same bands.

It is also necessary to take into consideration the footnotes which are very important because they specify in an imperative way the usual terms. The ITU footnotes regarding bands list are very numerous, so to simplify the reading they will be evoked in this document at the same time as the regional rules. A representative example of this list is the IUT-R footnote 5.132A concerning several HF bands « 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) [5]»

2.5. Technical constraints: ITU-R SM.1541-6 & SM.329-12

In direct link with the allocations, it is necessary to protect the services in the adjacent bands. During the design phase, the necessary measures will be implemented in the design of the radars, by the following rules:

the installation of guard intervals: (§ 4.5 of RR) the frequency assigned to a station of a given service shall be separated from the limits of the band allocated to this service in such a way that, taking account of the frequency band assigned to a station, no harmful interference is caused to services to which frequency bands immediately adjoining are allocated.

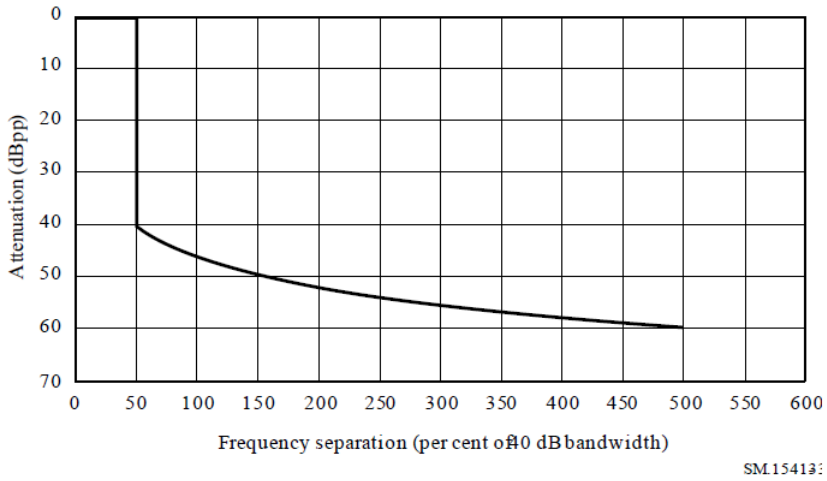
the respect of technical constraints on the signal and unwanted emissions: unwanted emissions consist of spurious emissions and out-of-band emissions.

- **spurious** : Emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

- **out-of-band emission**: Emission on a frequency or frequencies immediately outside the necessary bandwidth which result from the modulation process, but excluding spurious emissions.

The two texts of reference are the recommendation ITU-R SM.1541-6 [2], on "Unwanted emissions in the out-of-band domain" and in particular section §4.2 :

OoB mask for radars using CW, FMCW and phase coded waveforms



And the recommandation ITU-R SM.329-12[3] on Unwanted emissions in the spurious domain

3. Regional rules

The European "regional" organization is CEPT with two sub-entities ECC and ECO. The ECC is the technical interlocutor and the ECO manages the database on the frequencies: the EFIS

CEPT – The European Conference of Postal and Telecommunications Administrations

The European Conference of Postal and Telecommunications Administrations (CEPT) is an organization where policy makers and regulators from 48 countries across Europe collaborate to harmonise telecommunication, radio spectrum, and postal regulations. This committee works to effectively and efficiently coordinate inputs to create a dynamic market in the field of European posts and telecommunications. The CEPT conducts its work through three autonomous business committees (ECC, ComITU and CERP)

ECC – The Electronic Communications Committee

The Electronic Communications Committee (ECC) develops common policies and regulations in electronic communications for Europe, and is a focal point for information on spectrum use. Its primary objective is to harmonise the efficient use of the radio spectrum, satellite orbits, and numbering resources across Europe. It also prepares common proposals to represent European interests in the ITU and other international organisations.

Two of the ECC's main outputs are "Decisions" and "Recommendations" on major harmonization issues. ECC Reports and CEPT Reports are studies which respectively inform ECC Decisions and Decisions of the European Commission; the latter are binding on EU Member States.

ECO – European Communications Office

The European Communications Office (ECO) is the Secretariat of the CEPT.

ECO manages **EFIS** (ECO Frequency Information System, http://www.efis.dk/), a database which contains frequency information for CEPT member countries. EFIS is also the 'European spectrum information portal' in accordance with the European Commission Decision 2007/344/EC on the harmonized availability of information regarding spectrum use in Europe.

Allocations provide information on the regulatory status of a given frequency band.

The registration to EFIS is deeply encouraged but not mandatory for the national administrations. EFIS only accepts allocations from the list of services used by ITU Radio Regulations [1] (see Annex 1 of the ECC/DEC/(01)03 [1]). Only these allocations are valid and can be selected by administrations.

Rights in a given frequency band identified by the RR could be "split" differently at national level in relevant sub bands. Various radio communications services may share the same frequency bands. Multiple allocations could be foreseen in such context in a given band.

As an example, here is an extract from EFIS database on HF bands dedicated to radiolocation. It appears that France has informed EFIS on the allocation of the international bands but not yet Greece and Italy.

We focus on pilotcountries but the request can be made for all European countries.

Frequency band	France	Greece	Italy
4438 kHz - 4488 kHz	• Radiolocation		
5250 kHz - 5275 kHz	• Radiolocation		
9305 kHz - 9355 kHz	• Radiolocation		
13450 kHz - 13550 kHz	• Radiolocation		

In each country there is an administration which coordinates the spectrum and defines which administrations are managing each allocation (Defense, telecom, coast guards…).

As an example, in France, the ANFR coordinates the action of the French representation in committees created by the international authorities (ITU, CEPT) (Article R20-44-11 of the CPCE). The Cerema is an administrator of all the bands useful for the fulfillment of the missions of the State for the maritime and the river.

4. Spectrum for OTH radar

OTH radars work in HF band, a part of a frequency spectrum which historically is very encumbered. In addition, as listed in Report CEPT ECC107 [6], certain security uses (communication with the planes in flight above the ocean, beacons of distress) are critical for safety and certain users, in particular military forces, prefer them to classical networks UHF or VHF for tactical situation.

It is thus not simple for OTH radars to find a place in these wavebands more especially as there are many primary assignments with a channel size typically of 3 kHz to compare with the 25 to 100 kHz of band-width of a OTH waveform.

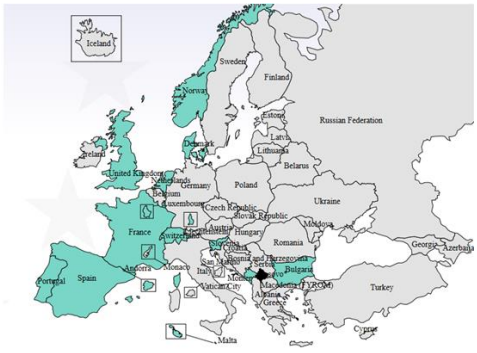
The simplest way to achieve a possible identification of spectrum is to examine the existing tables in European level.

Once provided the sea state, the size of the targets, and the distance of expected detection, the design of the OTH radar has to start with spectrum. The ground wave propagation mode of an OTH decreases strongly with the frequency. In parallel, RCS (Radar Cross Section) of a ship increases with the frequency. Common agreement locates the spectrum needs between 3 to 15 MHz.

Possible existing allocation issued from EFIS database:

Frequency band	- Europe (ECA) -
4438 kHz - 4488 kHz ECA : ECA36	• Radiolocation (5.132A)
5250 kHz - 5275 kHz ECA : ECA36	• Radiolocation (5.132A)
9305 kHz - 9355 kHz ECA : ECA36	• Radiolocation (5.145A)
13450 kHz - 13550 kHz ECA : ECA36	• Radiolocation (5.132A)

And their local allocations: the gray countries have not yet implemented ITU-R decision.



The footnotes are very important: it is a fact that an undisclosed agreement exists between CEPT and NATO regarding band allocation on radar services because the EFIS table states that radiolocation is possibly of military type for 2 of the candidates' bands.

Footnote ECA36

A frequency band, which has been harmonised by NATO and NATO member nations for military use as defined in the NATO Joint Civil/Military Frequency Agreement (NJFA) 2014. Note: A public version of the NJFA 2014 is expected to be provided by NATO to ECO by the end of 2016.

Frequency band	Allocations	Applications
4438 kHz - 4488 kHz (ECA36)	FIXED MOBILE EXCEPT AERONAUTICAL MOBILE (R) Radiolocation (5.132A)	Land military systems Maritime military systems Radiolocation (military) Inductive applications

Frequency band	Allocations	Applications
5250 kHz - 5275 kHz (ECA36)	FIXED MOBILE EXCEPT AERONAUTICAL MOBILE Radiolocation (5.132A)	Land military systems Maritime military systems Radiolocation (military) Inductive applications

Footnote 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 [5] (Rev.WRC 12)

This note of footer relating to Resolution 612 [5] is resulting directly from the ITU-R. It imposes an analysis made in the following pages.

Frequency band	Allocations	Applications
4438 kHz - 4488 kHz (ECA36)	FIXED MOBILE EXCEPT AERONAUTICAL MOBILE (R) Radiolocation (5.132A)	Land military systems Maritime military systems Radiolocation (military) Inductive applications

Frequency band	Allocations	Applications
5250 kHz - 5275 kHz (ECA36)	FIXED MOBILE EXCEPT AERONAUTICAL MOBILE Radiolocation (5.132A)	Land military systems Maritime military systems Radiolocation (military) Inductive applications

Frequency band	Allocations	Applications
13450 kHz - 13550 kHz (ECA36)	FIXED Mobile except aeronautical mobile (R) Radiolocation (5.132A)	Land military systems Inductive applications Railway applications Active medical implants

Footnote 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 [5] (Rev.WRC-12)

This note of footer is very similar to the preceding one; it is just less protective of the mobile service.

Frequency band	Allocations	Applications
9305 kHz - 9355 kHz (ECA36)	FIXED Radiolocation (5.145A)	Land military systems Inductive applications

4.1. Resolution 612 [5]

This resolution answers the request of frequency for oceanographic radars made in 2007: "RESOLUTION 612 (WRC-07) - Use of the radiolocation service between 3 and 50 MHz to support oceanographic radar operations" and reactualized in 2012.

It thus constitutes the lawful base of the existence of the allocated bands and the operating conditions of the services which would be assigned there. Moreover, the work led to the ITU on the subject to identify the bands and to make studies of division, is a rich base knowledge for the future coordination between countries.

Analysis of the document:

In ITU documents, as part of the "Considering" section, the finality of the allowable radars concludes that maritime and disaster mitigation operation, total maritime domain awareness, long-range sensing of surface vessels, maritime safety, these goals fit perfectly with the RANGER project.

RES 612 [5]: "Considering (only the most discerning are listed)

- a) that there is increasing interest, on a global basis, in the operation of oceanographic radars for measurement of coastal sea surface conditions to support environmental, oceanographic, meteorological, climatological, maritime and disaster mitigation operations;
- d) that oceanographic radar technology has applications in global maritime domain awareness by allowing the long-range sensing of surface vessels, which provides a benefit to the global safety and security of shipping and ports;
- e) that operation of oceanographic radars provides benefits to society through environmental protection, disaster preparedness, public health protection, improved meteorological operations, increased coastal and maritime safety and enhancement of national economies;"

It is then stated in "recognizing" terms, the work led to the ITU to evaluate the risks of disturbances between services. One sees appearing report ITU-R M 2234 " The feasibility of sharing sub-bands between oceanographic radars operating in the radiolocation service and fixed and mobile services within the frequency band 3-50 MHz" which can be used for any study of interference.

RES 612 [5]: "recognizing" (only the most discerning are listed)

- c) that protection of stations of existing services from interference caused by oceanographic radars could be ensured if the interfering signal at the receiving antenna location, assuming rural and quiet rural man-made and natural noise characteristics as defined in Recommendation ITU-R P.372-10, does not result in an I/N ratio of more than −6 dB, and if this value was used to calculate the minimum separation distances for coordination between an oceanographic radar and a potentially affected country;
- d) that for the purpose of protecting existing services from harmful interference, the impact of oceanographic radars via ground-wave propagation can be checked by Report ITU-R M.2234, based on Recommendation ITU-R P.368-9"

On another section of the ITU RES 612 [5], we find stated the "resolves" terms where the formal decisions are made. It is in this paragraph that the technical constraints appear. The principal one is the limit on the radiated power: Equivalent Isotropically Radiated Power (e.i.r.p.). This drastic limitation must be studied within sight of the set objective of the detection of small boats at different sea states. The challenge of the WP5 simulator is to determine the link between e.i.r.p. and capacity of detection, any other parameters having been optimized beforehand.

RES 612 [5] "resolves" (only the most discerning points are listed)

- "2 that the peak e.i.r.p. of an oceanographic radar shall not exceed 25 dBW;
- 4 that oceanographic radars should, where applicable, use techniques that allow multiples of such radars to operate on the same frequency, reducing to a minimum the spectral occupancy of a regional or global deployment of radars;
- 5 that oceanographic radars should use directional antennas, where applicable and as required, to facilitate sharing, thereby reducing the e.i.r.p. in the direction of the transmit antenna backlobe;
- 6 that the separation distances between an oceanographic radar and the border of other countries shall be greater than the distances specified in the following table, unless prior explicit agreements from affected administrations are obtained:

Frequency (MHz)	Land path (km)		Sea or mixed path (km)	
	Rural	Quiet rural	Rural	Quiet rural
5 (± 1 MHz)	120	170	790	920
9 (± 1 MHz)	100	130	590	670
13 (± 1 MHz)	100	110	480	520

"

- Report ITU-R M.2321-0 [4] Guidelines for the use of spectrum by oceanographic radars in the frequency range 3 to 50 MHz

5. Spectrum for PE-MIMO Radar

Radar PE-MIMO is envisaged to function in ultra high frequencies, beyond 5 GHz and requires an important band-width higher than 100MHz. Such band-width requires a band of allowance of/with at least the same order of magnitude.

There exist other categories of radars in these wavebands. Once again, it is simpler to concentrate on the existing bands in the European level.

In accordance with the RR, the sub-bands ranging between 5.250 GHz and 10.65 GHz make it possible to set up many services of radiodetermination but also many other primary education services, which can complicate the search for a harmonized band to many countries. Indeed, the use is to have national agreement to share or split in sub band. A national approach could be needed

There are numerous bands and it is thus necessary to determine the most relevant ones. At this stage, some of these are gathered in the following table:

Frequency bands	Allocations
5250.000 - 5255.000 MHz	- / Radio LANs / Radiodetermination applications / Radiolocation (military) / Maritime radar / Weather radar / Active sensors (satellite)
5255.000 - 5350.000 MHz	Weather radar / Active sensors (satellite) / Maritime radar / Radiolocation (military) / Radiodetermination applications / Radio LANs / -
5350.000 - 5450.000 MHz	- / Radiodetermination applications / Radiolocation (military) / Maritime radar / Active sensors (satellite) / Weather radar

5450.000 - 5460.000 MHz	Active sensors (satellite) / Weather radar / Maritime radar / Radiolocation (military) / Radiodetermination applications / -
5460.000 - 5470.000 MHz	- / Radiodetermination applications / Radiolocation (military) / Maritime radar / Weather radar / Active sensors (satellite)
5470.000 - 5570.000 MHz	Active sensors (satellite) / Weather radar / Maritime radar / Radiolocation (military) / Radiodetermination applications / Radio LANs / -
5570.000 - 5650.000 MHz	- / Radiodetermination applications / Radio LANs / Radiolocation (military) / Maritime radar / Weather radar
5650.000 - 5725.000 MHz	Amateur / Maritime radar / Weather radar / Radiolocation (military) / Amateur-satellite / Radio LANs / Radiodetermination applications / -
5725.000 - 5830.000 MHz	TTT / WIA / BFWA / Non-specific SRDs / Radiodetermination applications / ISM / Amateur / Radiolocation (military) / Weather radar
5830.000 - 5850.000 MHz	Weather radar / Radiolocation (military) / Amateur / ISM / Amateur-satellite / Non-specific SRDs / Radiodetermination applications / WIA / BFWA
5850.000 - 5925.000 MHz	ITS / WIA / DA2GC / Radiodetermination applications / BFWA / Non-specific SRDs / FSS Earth stations / ISM

8500.000 - 8550.000 MHz	Radiolocation
8550.000 - 8650.000 MHz	Earth Exploration-Satellite (active)/Radiolocation/Space Research (active)
8650.000 - 8750.000 MHz	Radiolocation
8750.000 - 8850.000 MHz	Aeronautical Radionavigation/Radiolocation/Space Research
8850.000 - 9000.000 MHz	Maritime Radionavigation/Radiolocation/Space Research
9000.000 - 9200.000 MHz	Aeronautical Radionavigation/Radiolocation/Space Research
9200.000 - 9300.000 MHz	Maritime Radionavigation/Radiolocation/Space Research/Earth Exploration-Satellite (active)
9300.000 - 9500.000 MHz	Space Research (active)/Earth Exploration-Satellite (active)/Radionavigation/Radiolocation
9500.000 - 9800.000 MHz	Earth Exploration-Satellite (active)/Radiolocation/Space Research (active)
9800.000 - 9900.000 MHz	Radiolocation/Space Research (active)/Earth Exploration-Satellite (active)
9900.000 - 10000.000 MHz	Radiolocation/Fixed/Earth Exploration-Satellite (active)
10000.000 - 10400.000 MHz	Fixed/Mobile/Radiolocation/Amateur/Earth Exploration-Satellite (active)
10400.000 - 10450.000 MHz	Fixed/Radiolocation/Amateur/Mobile
10450.000 - 10500.000 MHz	Fixed/Mobile/Radiolocation/Amateur/Amateur-Satellite
10.500 - 10.550 GHz	Fixed/Mobile/Radiolocation
10.550 - 10.600 GHz	Fixed/Mobile except aeronautical mobile/Radiolocation

10.600 - 10.650 GHz	Earth Exploration-Satellite (passive)/Fixed/Mobile except aeronautical mobile/Radio Astronomy/Space Research (passive)/Radiolocation

Band 5725-5925 is a particular band because it is used by industrial and medical equipment (ISM) which are large disturbers if they are in the vicinity. It appears that other services and the applications of radiodetermination are allowable there.

- Its **main advantage**: it has a total band of 200 MHz
- Its **principal disadvantage**: many services cohabit without protection, in particular the wifi and the LTE-U. It is thus probable that the level of interference can become important near urban area. It is necessary to know the scenarios of installation to evaluate the risk for radar PE-MIMO.

Several footnotes are relevant:

Footnote ECA22

The band 5250-5850 MHz is utilised for a variety of radiodetermination applications falling within the radionavigation and radiolocation services. This band will be subject to further detailed consideration.

Footnote ECA36

A frequency band, which has been harmonised by NATO and NATO member nations for military use as defined in the NATO Joint Civil/Military Frequency Agreement (NJFA) 2014. Note: A public version of the NJFA 2014 is expected to be provided by NATO to ECO by the end of 2016.

Footnote 5.150

The following bands:13553-13567 kHz (centre frequency 13560 kHz),26957-27283 kHz (centre frequency 27120 kHz), 40.66-40.70 MHz (centre frequency 40.68 MHz), 902-928 MHz in Region 2 (centre frequency 915 MHz), 2400-2500 MHz (centre frequency 2450 MHz),5725-5875 MHz (centre frequency 5800 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.

Footnote ECA24

The band 8500-10000 MHz is utilised for a variety of radiodetermination applications falling within the radionavigation and radiolocation services. This band will be subject to further detailed consideration in conjunction with the band 5250-5850 MHz (see ECA22).

5.1. Technical constraints: ITU-R M 1638 and M 1796

The variety of the applications of radiolocation has forced ITU to define technical criteria to help cohabitation in the various wavebands.

That resulted, in particular, in recommendations which are important to know to be able to describe the characteristics of radar PE-MIMO in a context of authorization of frequencies.

Recommendation ITU-R M.1638-1 [7]

Characteristics and protection criteria for sharing studies for radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars operating in the frequency bands between 5 250 and 5 850 MHz

Recommendation ITU-R M.1796-2 [8]
Characteristics of and protection criteria for terrestrial radars operating in the radiodetermination service in the frequency band 8 500-10 680 MHz

6. Safety and conformity in operation

A minimum requirement for the developed equipment is to respect the European directives on the subjects of conformity and security, which correspond to a civil use of the radars.

However, the specificity of the use of RANGER radars could involve a deployment on military bases or platforms which have particular specifications (sensitivity of the weapons to the electromagnetic fields, for example). A thorough analysis must be carried out within the framework of the project to determine the standard levels to follow to achieve the most adapted one for the operational deployment of the two radars.

Exposure of workers to electromagnetic fields

Regarding the phase of prototyping, the working conditions around radars OTH and PE-MIMO must respect directive 2013/35/EU [9] :

DIRECTIVE 2013/35/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields).

This is an ongoing procedure depending on sites and configurations.

Public exposure to electromagnetic fields

Each EU Member State is responsible for providing adequate health protection for its citizens and for deciding on measures to be implemented. However, to support Member States and to ensure the highest level of health protection for European citizens, the EU asks governments to assess exposure to electromagnetic fields and to take appropriate action when reference levels are exceeded – as laid down in COUNCIL RECOMMENDATION of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) - 1999/519/EC [10]

Reference: http://ec.europa.eu/health/electromagnetic_fields/eu_actions/index_en.htm

6.1. Action plan

First is to identify in France and Greece the regulation for public exposure.

Secondly, it has to be discussed with RANGER partners if worker exposure rules have to be defined for a specific environment.

The document will be enriched in the final version, when the exact pilot configuration will be fixed and the measures will be done. A generic case will be described to allow an easy applicability to other sites and configurations.

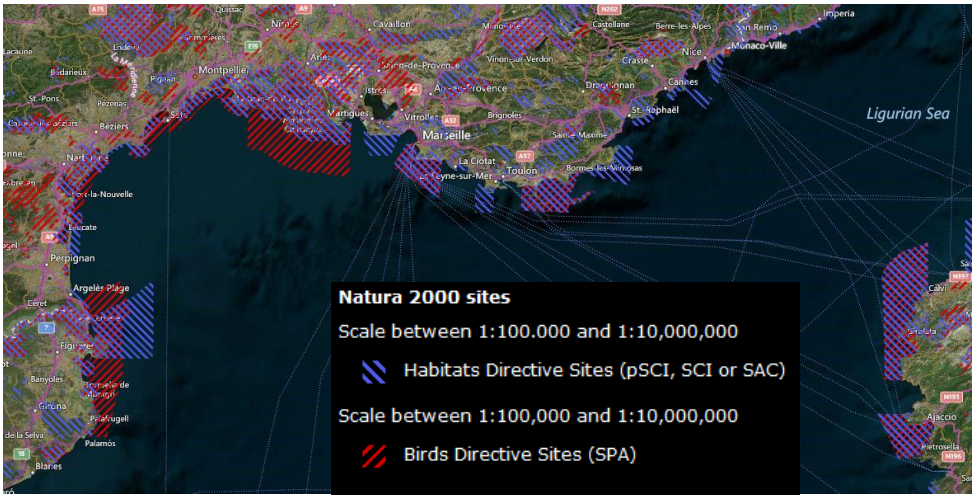
7. Environment Standards

Installation of a new type of radar equipment needs high elevation above the ground for MIMO radar to extend its range and a large surface of flat ground being able to reach 1000m of length, and the proximity with the coast for OTH radar.

The rare places being able to correspond to the preceding criteria are often close to those protected to ensure the safeguard of biodiversity : EU-wide Natura 2000 network of protected areas(http://natura2000.eea.europa.eu/#)

The two French sites of the OTH radar are already in activity in Natura 2000 area. They passed the authorization process by limiting the footprint of the antenna arrays, being careful of existing plants and taking into account reproduction period to plan the building of sites.

It was quite impossible to find sites complying with technical specifications (a flat land close to the sea) outside the Natura 2000 areas. The next map shows how they are numerous in France.



The project has the ambition of restricting to a maximum extent the environmental impact. To accomplish this goal it must be taken into account the lawful context associated with the biodiversity and the safeguarding of the habitats.

In complement, the project may be concerned by the conservation of the landscapes (discretion of its antennas) and of the integration of radars in their close environment.

The European regulation on the subject of the environment is based mainly on two directives http://ec.europa.eu/environment/nature/legislation/index_en.htm) :

The EU has been committed to the protection of nature since the adoption of the Birds Directive in April 1979. It provides comprehensive protection to all wild bird species naturally occurring in the Union.

DIRECTIVE 2009/147/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 November 2009 on the conservation of wild birds [11].

The Habitats Directive was adopted in 1992 to help maintain biodiversity. It protects over 1000 animals and plant species and over 200 types of habitat. It also established the EU-wide Natura 2000 network of protected areas.

COUNCIL DIRECTIVE 92 / 43 / EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.[12]

To comply with the environmental regulation means to find a way to create, to install, and to operate a radar without impacting the protected species in accordance with the ecological needs.

7.1. Action plan

Environmental restrictions are an ongoing procedure, which we have to take into account the above mentioned regulations and the experience that we are going to get during the pilots.

It will be done in many steps which are representative of the approach to generalize in RANGER:

- Information of the local and regional authorities
- Site survey to identify the presence or not of protected species (plants, animals) and to select a place free of protected species.
- Planning of installation outside of nesting/birthing periods
- Selection of a configuration for the radar minimizing the surface impacted
- Building phase with environment friendly equipment
- Definition of rules for servicing on site in link with.

8. Conclusion

This document provides information on rules to comply with, when designing the RANGER system in order to maximise its acceptability. The next table summarizes requirements/regulations which will be taken into account during the design phase and in the D2.5.

Domain	Regulation	Main actions to comply
Spectrum	ITU-R Radio Regulation [1] ITU-R SM.1541-6 [2] ITU-R SM.329-12 [3] National specificities	To identify frequency bands common to both pilots To define radar specification taking into account regulation To identify frequencies band for a long term approach
Safety at work and around	Directive 2013/35/EU |9] Council Recommendation 1999/519/EC [10]	To identify national rules for France and Greece. To simulate the EM field based on pilots configuration To measure the EM field and to define access zones around the antenna
Environment	Directive 2009/147/EC [11] Directive 92 / 43 / EEC [12]	- Site survey to identify the presence or not of protected species (plants, animals) and to select a place free of protected species. - Selection of a configuration for the radar minimizing the surface impacted - Assessment with local authorities - Building phase with environment friendly equipment

Annex A - References & Relevant Readings

N°	References and relevant readings
[1]	ITU-R Radio Regulations – ed 2016
[2]	ITU R-REC-SM.1541-6 Unwanted emissions in the out-of-band domain
[3]	ITU-R SM.329-12 Unwanted emissions in the spurious domain
[4]	Report ITU-R M.2321 Guidelines for the use of spectrum by oceanographic radars in the frequency range 3 to 50 MHz
[5]	ITU R Resolution 612
[6]	CEPT ERC REPORT 107 Current and future use of frequencies in the LF- MF and HF bands
[7]	ITU-R M.1638-1 Characteristics of and protection criteria for sharing studies for radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars operating in the frequency bands between 5 250 and 5 850 MHz
[8]	ITU-R M.1796-2 Characteristics of and protection criteria for terrestrial radars operating in the radiodetermination service in the frequency band 8 500-10 680 MHz
[9]	DIRECTIVE 2013/35/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) **http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:179:0001:0021:EN:PDF**
[10]	COUNCIL RECOMMENDATION of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) - 1999/519/EC http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:199:0059:0070:EN:PDF
[11]	DIRECTIVE 2009/147/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 November 2009 on the conservation of wild birds. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0147
[12]	COUNCIL DIRECTIVE 92 / 43 / EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

Annex B - List of Acronyms

Acronym	Meaning
CEPT	European Conference of Postal and Telecommunications Administrations
EIRP e.i.r.p.	Equivalent Isotropically Radiated Power
HF	High Frequency (frequency band)
ITU	United Nations specialized agency for information and communication technologies
OTH	Over The Horizon
RR	Radio Regulations
SAR	Search And Rescue
WRC	World Radio Conference
NATO	North Atlantic Treaty Organization
Cerema	Centre d'études et d'expertises pour les risques, l'environnement, la mobilité et l'aménagement. Cerema is a branch of DMA
ANFR	Agence Nationale des Fréquences