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**IALA Recommendation V-128**

**On**

**Operational and Technical Performance Requirements for VTS Equipment**

**Edition 4.0 draft**

**XXX 2013**

**Edition 1.0 – June 2004**

**Edition 1.1 – June 2005**

**Edition 2.0 – December 2005**

**Edition 3.0 – June 2007**

**Edition 4.0 – xxxx 2013**

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***AISM***Association Internationale de Signalisation Maritime ***IALA***

International Association of Marine Aids to Navigation and Lighthouse Authorities

Document Revisions

Revisions to the IALA Document are to be noted in the table prior to the issue of a revised document.

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| --- | --- | --- |
| Edition / Date | Page / Section Revised | Requirement for Revision |
| Edition 1.1  June 2005 | Addition of Annex 6 – Hydrological and Meteorological equipment | Annexes added as they are completed to ensure all aspects of VTS equipment are covered. |
| Edition 2.0  December 2005 | Restructured to include operational performance requirements.  Annex 2 amended to reflect new annex on operational performance requirements.  Annex 6 renamed to Annex 5  Annex 1,3,4,6 added | Annexes added as they are completed to ensure all aspects of VTS operations and equipment are covered. |
| Edition 3.0  June 2007 | Editorial changes to correct errors in paragraph numbering, cross references etc.  Structure of annexes harmonised, part of Annex 2 moved to new IALA Guideline (Establishment of Radar Services)  Clarification of text, few sentences in annex 1 and 2. | Inconsistence in cross references, table of contents etc. in edition 2.0  Varying structure of individual annexes  Users of the document provided ideas to clarification of text on some subjects. |
| Edition 4.0  Xxxx 2013 | Document rewritten and updated to improve user friendliness, to include additional considerations and to include new technology  Annex 7-13 added  Local Port Services added | New technology emerging  Feedback from users indicated need to make the document more user friendly, and to include additional considerations for ports, inland waterways and offshore |
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**Recommendation on Operational and Technical Performance Requirements for VTS Equipment**

(Recommendation V-128)

THE COUNCIL:

**RECALLING** the function of IALA with respect to safety of navigation, the efficiency of maritime transport and the protection of the environment;

**NOTING** that Chapter V (12) of the International Convention for the Safety of Life at Sea 1974 (SOLAS 74 as amended) requires Contracting Governments planning or implementing VTS wherever possible to follow the guidelines adopted by the Organization by Resolution A. 857(20);

**NOTING ALSO** that IMO Resolution A.857(20), Annex section 2.2.2recommends that in planning and establishing a VTS, the Contracting Government or Governments or the competent authority should *inter-alia* establish appropriate standards for shore and offshore-based equipment;

**NOTING FURTHER** thatNational Members provide shore infrastructure to support the aim of IMO to improve the safety of navigation and the protection of the environment;

**RECOGNISING** that IALA fosters the safe, economic and efficient movement of vessels through improvement and harmonisation of aids to navigation, including vessel traffic services, worldwide;

**RECOGNISING ALSO** that harmonisation of vessel traffic services would be enhanced by the introduction of international technical performance requirements for VTS;

**HAVING CONSIDERED** the proposals by the IALA VTS Committee on Operational and Technical Performance Requirements for VTS;

**ADOPTS** the Operational and Technical Performance Requirements for VTS as set out in this recommendation as follows:

Annex 1 – Core Operational requirements

Annex 2 – Radar

Annex 3 – Automatic Identification System (AIS)

Annex 4 – Environmental Monitoring

Annex 5 – Electro-Optical equipment

Annex 6 – Radio Direction Finders

Annex 7 – Long Range sensors

Annex 8 – Radio Communications

Annex 9 – Data Processing

Annex 10 – Human Machine Interface (HMI)

Annex 11 – Decision Support

Annex 12 – External Information Exchange

Annex 13 – Verification and Validation

RECOMMENDS that Competent Authorities providing Vessel Traffic Services take into consideration the appropriate Operational and Technical Performance Requirements contained in the Annexes to this recommendation when establishing appropriate standards for shore and offshore-based VTS.

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Abbreviations

|  |  |
| --- | --- |
| º | Degree |
| ± | Plus or minus |
| > | Greater than |
| ≤ | Less than or equal to |
| ≥ | Greater than or equal to |
| µs | microsecond |
| A R and M | availability, reliability and maintainability |
| AIS | Automatic Identification System |
| AREPS | Advanced Refractive Effects Prediction System |
| ASL | Above Sea Level |
| AtoN | Aid to Navigation |
| CARPET | Computer Aided Radar Performance Evaluation Tool |
| CAT | Customer Acceptance Test |
| CCTV | Closed-Circuit Television |
| COG | Course over Ground |
| COSPAS/SARSAT | Search and Rescue Satellite-Aided Tracking |
| CPA | Closest Point of Approach |
| CW | Continuous Wave |
| dB | deciBel |
| dBi | deciBel isotropic |
| dBm | deciBel milliWatt |
| DF | Direction Finder |
| D-GNSS | Differential GNSS |
| ECDIS | Electronic Chart Display and Information System |
| ECS | Electronic Chart System |
| EIA | Electronics Industry Association |
| ELT | Emergency Location Transmitter |
| EMI/EMC | Electromagnetic Interference/Electromagnetic Compatibility |
| EO | Electro-Optical |
| EOS | Electro-Optical Sensor |
| EPIRB | Emergency Position Indicating Radio Beacon |
| ETA | Estimated Time of Arrival |
| FAT | Factory Acceptance Test |
| FATDMA | Fixed-Access Time-Division Multiple Access |
| FMCW | Frequency Modulated Continuous Wave |
| FoV | Field of View |
| GHz | GigaHertz |
| GIT | Georgia Institute of Technology |
| GLOSS | Global Sea Level Observing System |
| GMDSS | Global Maritime Distress and Safety System |
| GNSS | Global Navigation Satellite System |
| GOOS | Global Ocean Observing System |
| GPS | Global Positioning System |
| HMI | Human/Machine Interface |
| IALA | International Association of Marine Aids to Navigation and Lighthouse Authorities |
| ICAO | International Civil Aviation Organization |
| ID | Identification |
| IDC | International Data Centre (for LRIT) |
| IEC | International Electro-Technical Commission |
| IEEE | The Institute of Electrical and Electronic Engineers |
| IETF | Internet Engineering Task Force |
| IMO | International Maritime Organization |
| INS | Information Service |
| IOC | Intergovernmental Oceanographic Commission |
| IP | Ingress Protection |
| IP | Internet Protocol |
| IT | Information Technology |
| ITU | International Telecommunication Union |
| kHz | kiloHertz |
| Ku-band | 12.0 – 18.0 GHz |
| Ka-band | 26.4 – 40 GHz |
| kW | kiloWatt |
| LNFE | Low Noise Front End |
| LPS | Local Port Services |
| LRIT | Long Range Identification & Tracking |
| m | metre |
| m/s | metre/second |
| m2 | square metre |
| MDS | Minimum Detectable Signal |
| MHz | MegaHertz |
| MKD | Minimum Keyboard and Display |
| mm/h | millimetre per hour |
| MMSI | Maritime Mobile Service Identity |
| MOB | Man over board |
| MPEG | Moving Pictures Expert Group |
| MRCC | Maritime Rescue Co-ordination Centre |
| MSC | Maritime Safety Committee (of IMO) |
| MTBF | Mean Time Between Failure |
| MTI | Moving Target Indication |
| MTTR | Mean Time to Repair |
| NAS | Navigational Assistance Service |
| N/A | Not applicable |
| nm | Nautical Mile (also nmi) |
| NMEA | National Marine Electronics Association |
| PD | Probability of Detection |
| PFA | Probability of False Alarm |
| POB | Persons on-board |
| PRF | Pulse Repetition Frequency |
| PSS | Practical Salinity Scale |
| PTZ | Pan, Tilt, Zoom |
| PW | Pulse Width |
| R | Range |
| RAID | Redundant Array of Independent Disks |
| RATDMA | Random Access Time-Division Multiple Access |
| RCS | Radar Cross Section |
| RF | Radio Frequency |
| RDF | Radio Direction Finder |
| RMP | Recognized Maritime Picture |
| RoHS | Reduction of Hazardous Substances |
| SAIS | Satellite AIS |
| SAR | Search and Rescue |
| SART | Search and Rescue Transponder |
| SAT | Site Acceptance Test |
| S-band | 2.0 – 4.0 GHz (Note: military designation is F-band) |
| SOG | Speed over Ground |
| SOLAS | Safety of Life at Sea |
| SOTDMA | Self-Organising Time-Division Multiple Access |
| TBA | To Be Advised |
| TBC | To Be Confirmed |
| TCPA | Time to Closest Point of Approach |
| TDMA | Time-Division Multiple Access |
| TOS | Traffic Organization Service |
| UPS | Uninterruptable Power Supply |
| UTC | Universal Time Co-ordinated |
| UTM | Universal Transverse Mercator |
| VDL | VHF Data Link |
| VHF | Very High Frequency |
| VoIP | Voice over Internet Protocol |
| VTMIS | Vessel Traffic Management and Information System |
| VTS | Vessel Traffic Services |
| VTSO | Vessel Traffic Services Operator |
| WMO | World Meteorological Organization |
| X-band | 8.0 – 12.0 GHz (Note: military designation is I-band) |
| XML | Extensible Mark-up Language |
|  |  |

# Core Operational Requirements

## Introduction

In 1997 the IMO Maritime Safety Committee adopted Regulations for Vessel Traffic Services (VTS) that have since been included in SOLAS Chapter V (Safety of Navigation) as Regulation 12.This Regulation specifies the responsibilities of contracting governments to arrange for the establishment of VTS in certain vulnerable areas under their control.

The purpose of this Recommendation is to assist the VTS authority in the definition, establishment and upgrades of a VTS system. The document addresses the relationship between the Operational Requirements and VTS system performance requirements. More specifically:

* Core Operational requirements
* Radar
* Automatic Identification System (AIS)
* Environmental Monitoring
* Electro-Optical equipment
* Radio Direction Finders
* Long Range sensors
* Radio Communications
* Data Processing
* Human Machine Interface (HMI)
* Decision Support
* External Information Exchange
* Verification and Validation

In addition relations to systems for Local Port Services are discussed where appropriate and the guidance may also be used in that context.

### Prerequisites

As stated by the VTS manual the prerequisites for Vessel Traffic Services (VTS) and Local Port Services (LPS) are:

Vessel Traffic Services

* Authorised by the Competent Authority;
* Staffed by V-103 certificated personnel;
* Equipped as appropriate to provide an Information Service (INS), Navigational Assistance Service (NAS) and/or Traffic Organization Service (TOS);
* Interacts with traffic; and
* Responds to traffic situations.

Local Port Services

* No authorisation needed from the Competent Authority;
* Staffed and trained appropriate to task; and
* Equipped appropriate to task

## References

|  |  |
| --- | --- |
| IMO | Safety Of Life At Sea (SOLAS 1974) Convention |
| IMO Resolution A.857(20) | Guidelines for Vessel Traffic Services (1997) |
| IMO Resolution A.915(22) | Maritime Policy for the Future Global Navigation Satellite System (GNSS) |
| IALA | Vessel Traffic Services Manual, Edition 5 (2012) |
| IALA Recommendation V.127 | On Operational Procedures for Vessel Traffic Services, Edition 1 (2004) |

## Capabilities for a VTS System

The main functions of a VTS are to mitigate risks associated with shipping and to improve efficiency. The different types of risks and environments have led to various types of VTS including coastal and offshore, port, estuary or inland VTS.

For instance a coastal VTS assist the safe and expeditious passage of shipping through coastal waters, particularly where there is a high density of maritime traffic or an area of environmental sensitivity or through difficult navigation conditions. Similarly, a port, estuarial or inland VTS support shipping when entering or leaving ports and harbours or when sailing along rivers or through restricted waters.

An important task of an offshore VTS is to avoid ships collisions with offshore structures e. g. oil platforms and wind farms.

All VTS types may offer, in principle, all services as defined in the IMO resolution A.857(20). When determining the required performance of a VTS system, the following should be taken into account:

* The identified risks
* The type of VTS (coastal and offshore, port, estuary or inland VTS)
* The VTS services to be provided (INS, TOS, NAS)
* Requirements from Allied Services
* Types and number of targets
* The geographical area
* Prevailing meteorological conditions

### Levels of Capabilities

All the above factors determine the complexity of the traffic situation. In addition, specific operational requirements, such as the need to detect small targets in adverse conditions or ice monitoring, may increase the required performance.

In order to facilitate the definition of required performance, three levels of capabilities for VTS are defined as follows:

**Basic** – performance for a VTS area with low complexity, where an Information Service and/or a Navigational Assistance Service will be provided.

**Standard** – performance for a VTS area with low or medium complexity, where an Information Service, Navigational Assistance Service and /or a Traffic Organisation Service will be provided.

**Advanced** – performance for a VTS area with high complexity and/or specific operational requirements.

A risk assessment and the determination of the specific operational conditions shall be made by the VTS authority prior to the allocation of capabilities

Special cases are:

**Ports and inland waterways**

**Offshore**

**Local Port services**

#### Ports and Inland Waterways

VTS for ports and inland waterways will typically be subject to high demand to handle targets in close vicinity of each other and with large nearby structures and obstructions, but reduced requirements to sea condition.

#### Offshore

A VTS system, used for the protection of oil platforms and other offshore installations, typically has advanced target detection requirements, but reduced requirements with respect to target separation, due to the expected low traffic density.

#### Local Port Services

As stated in the VTS manual, Local Port Services (LPS) are applicable to those ports where it has been identified from their Formal Risk Assessment that a VTS is excessive or inappropriate. It does not imply, however, that these systems adhere to a lower level of standards or provide a lower level of service to their customers.

The main difference, arising from the provision of LPS, is that it does not interact with traffic, nor is it required to have the ability and/or the resources to respond to developing traffic situations. Also, there is no requirement for a vessel traffic image to be maintained.

It should be noted that LPS are outside of the scope of VTS, as they are not required to meet international standards, although they will invariably meet the standards of capability sufficient to meet local needs.

### Allocation of Capabilities to Meet Operational Requirements

Requirements of the VTS equipment may have a high impact on acquisition and life-cycle costs of a VTS system and therefore is paramount to properly allocate capabilities to satisfy Operational Requirements.

A specific capability could be assigned to an entire VTS area or to particular subsections as illustrated in the example given by figure 1



Figure 1 Example of assigned capabilities in a Generic VTS area, by the VTS authority

Advanced capability was chosen in areas (A, B and C) for the following reasons:

* Dangerous cargo imposes a high risk to environment and populated areas
* Security, including the need for detection of small targets
* Dense traffic in a complex separation scheme including a bridge crossing

Standard capability was chosen in areas (D, E and F) for the following reasons:

* Wind farm close to a traffic lane imposes a navigational hazard
* Traffic in confined areas such as Ports and Inland waterways

Basic capability was chosen for the remainder of the VTS area (G)

## VTS System Considerations

### Objectives

The purpose of vessel traffic services is to improve the safety and efficiency of navigation, safety of life at sea and the protection of the marine environment and/or the adjacent shore area, worksites and offshore installations from possible adverse effects of maritime traffic.

The benefits of implementing a VTS are that it allows identification and monitoring of vessels, strategic planning of vessel movements and provision of navigational information and assistance. It can also assist in prevention of pollution and co-ordination of pollution response.

The efficiency of a VTS will depend on the reliability and continuity of communications and on the ability to provide good and unambiguous information. The quality of accident prevention measures will depend on the system's capability of detecting a developing dangerous situation and on the ability to give timely warning of such dangers.

### Types of Vessel Traffic Services

As stated in the VTS manual an authorised VTS will be capable of offering an Information Service, Traffic Organisation Service and/or Navigational Assistance Service as defined per IMO Resolution A.857(20)



### Site Survey

Prior to establishment or extension of a VTS system, comprehensive site surveys should be performed, including but not limited to:

* The potential sensor and radio coverage
* Site access
* Availability of essential infrastructure, such as power and data lines
* Protection of the environment
* Other environmental issues such as electromagnetic issues (EMI/EMC), wind (be aware of high / asymmetrical loads on antennas), influence from sea, precipitation and ice.
* Applicable regulations and required licenses
* And, not in the least, that installation sites are selected with due respect to neighbours

Added value from the site survey is the involvement of stakeholders early in the process, design awareness and early awareness of performance issues, e.g. as a result of missing site availability.

### System Architecture

A VTS System should have the capability to be flexible and easily upgraded and maintained alongside the routine operations of the VTS Centre without the need for interrupting the service.

Any VTS should, as a minimum, be equipped with a means to build a traffic surveillance picture, voice communication and reporting facilities, however several other features will often be included, as illustrated by the example in **Error! Reference source not found.**

Guidelines for the overall user requirements can be found in the IALA VTS manual, the following annexes and many other IALA guidelines, how to cope with traffic density and specify overall/regional capacity, declaration of supported services, ship support in an emergency situation, how many user seats are required, what are the requirements to operational skills, decision support, language and training. The same apply to data collection, data processing, data fusion, data management and data presentation.

Shipping data and port (berth planning etc) and/or waterway management data is normally an integral part of the VTS, so may management of tugs, management of pilotage, protection of static bridges, management of moveable bridges etc. be.

#### Communication Infrastructure

Reliable communications is of outmost importance for any VTS and the infrastructure (e.g. line of sight radio communications, IP networks and public wide area network) should be robust and reliable. Therefore, the VTS Authority should carefully consider the related issues, such as redundant data paths, techniques to overcome link outages, selection of data where multiple versions of the same data exist, bandwidth requirements and possible data compression, data integrity, data link security and data encryption, data link integrity and possible error correction techniques, internet protocols and other communication standards to be used.

#### System Boundary

The typical VTS system consist of equipment, functions and services and interfacing to the exterior, preferably utilising generic interface standards for

* 1. Providing the VTS operators the necessary tools
  2. Interaction with ships
  3. Cooperation with adjacent VTS
  4. Obtaining information from external sources e.g. satellites (LRIT), met office weather data and external hydrographical data.
  5. Information exchange with other agencies (allied services) using the VTS data (coastguard, homeland security, police, customs etc.)

#### System States and Modes

Fundamentally, there is one operational state of a VTS (24/7 or less in some circumstances). In addition supporting states, modes for graceful degradation, redundancy and maintenance shall be defined.

#### Set-up and Maintenance

In order to achieve and maintain the required availability, any VTS shall include set-up and maintenance facilities. For larger systems this will typically include maintenance console(s), facilities for replay, facilities for calibration of sensors and facilities for alignment of the total system, e.g. alignment of overlapping sensors to a common reference in terms of compass, mapping and time

### Availability

Availability is defined in IMO Resolution A.915 (220 Ref.40) as:

*“The percentage of time that an aid, or system of aids, is performing a required function under stated conditions. The non-availability can be caused by scheduled and/or unscheduled interruptions”.*

Typically, several sources of information are available to the VTS operator, resulting in reduced requirements to availability of each sensor individually. Overlap between sensors can also reduce availability requirements for the individual sensor.

The recommended availability for VTS services available to the operators are defined by Table 1‑1

Table 1‑1 Recommended availability figures



The figures apply to systems and, thus, are requirements for both hardware and software operation. Scheduled maintenance activities, with significant disturbance to the VTS operation, are also included in these availability figures.

It should be noted that VTSs, operating in very critical areas, may call for more than 99.95% availability, in which case redundant servers and communication systems may be needed - or even duplicated operational centres.

#### Calculation of Availability

Administrations may choose to calculate service availability using one of two methods:

* waterway model
* sensor combination model

**Waterway model:** In this model administrations need to define which waterways are high risk and which waterways are low risks. Separate calculations for high and low risk are required, providing both exist within the coverage area. Individual waterway availability calculations are then averaged to produce one figure for each waterway risk category. If desired, a figure for each waterway may be reported.

**Sensor combination model:** In this model, administrations should define which sensors serve low risk waterways and which serve high risk waterways. The overall availability is calculated by combining the availability of the associated individual sites.

##### Redundancy

The system availability can be improved by the following redundancy measures

1. By duplicating equipment at individual sensor sites and in the communication with sensors. In such cases parameter hand over form active to stand by equipment should be considered.
2. Between sensors, where overlap can provide redundancy, possibly with reduced performance.
3. Between various types of sensors, where overlap can provide redundancy, possibly with reduced performance.

##### Graceful Degradation

The system availability can be improved by adding graceful degradation capabilities to individual equipment, but with reduced performance.

### Precautionary Measures to Extreme Events

VTS Authorities, responsible for VTS in areas subject to extreme events such as earthquake and tsunami, should specify requirements to construction accordingly.

This will typically include special requirements to equipment shock resistance, alignment capabilities, civil works and power supply.

### Recording, Archiving and Replay

Provision should be made for the storage, security, retrieval and presentation of this information.

The data type, resolution and period of time for which information gathered by a VTS is required to be stored should be identified in internal procedures. This time period should be such that it allows for the full retrieval of data post-incident/accident, in compliance with national requirements and those of the incident/accident investigation procedures of the VTS authority and other authorised parties. This type of information should include:

* Communications, internal and external as defined in IALA Recommendation V.127
* Sensor data, i.e. data used to generate the traffic image such as radar, CCTV, AIS and long-range sensor data.
* Shipping information data, i.e. vessel and cargo data, including vessel movement information.
* Meteorological and hydrological data; and
* Data from other sources if relevant.
* Synchronization of voice / track data

The IMO recommends a minimum of 30 days for the time-period to allow for the full retrieval of data post-incident/accident. The VTS authority should define the period of time and temporal resolution of sensor data and other tracking performance parameters depending on traffic density and types of tracks.

If required by the VTS Authority, the data should be recorded automatically and capable of being replayed onto a separate replay system.

## Design, Installation and Maintenance Considerations

### Establishing and Updating VTS

Refer to the IALA manual for guidance on the establishment of VTS and related project work including integration planning.

In addition, given the complexity of VTS solutions, VTS authorities are advised to seek expert guidance on particular aspects of VTS design and specification.

Equipment siting, design trade-offs and maintenance precautions are discussed in this recommendation where relevant.

### Climatic Influence

Based on MIL-STD-810, IALA defined simplified climatic categories suitable for stationary VTS systems, Very Hot, Normal and Severe Cold.

Allowance for daily cycles, primarily based on variations in temperature and relative humidity levels is included.

#### Normal Climatic Category

The Normal Climatic Category covers a broad range of climatic conditions in which equipment materiel should operate and survive storage and transportation. This includes the most densely populated and heavily industrialized parts of the world as well as the humid tropics. The entire range of associated design conditions does not necessarily occur in any one place; however, a single condition (high temperature, low temperature, high humidity) occurs in a wide area. When taken together, the recommendations for the Normal Climatic Category should be valid for equipment used throughout the corresponding area.

The conditions for individual zones of the category are described as follows.

**a. Humid tropic zone.** Humid tropic areas are included in the Normal Climatic Category rather than being considered an extreme category because humid tropic temperatures are moderate and their humidity levels are equaled at times in some of the other mid-latitude areas. The feature of the humid tropics most important for materiel system design is the persistence of high humidity coupled with moderately high temperatures throughout the year. This combined environmental condition not only promotes corrosion, but also greatly increases insect and microbiological damage.

**b. Intermediate zone.** These are mid-latitude areas that do not combine higher temperatures with higher humidity throughout the year, and at the same time are not climatically extreme enough to meet the conditions for neither Hot nor Cold Climatic Categories. This zone includes the daily cycles shown in table CI, plus a condition known as "cold-wet" which can occur within the mild cold daily cycle at or near the freezing point (2 to -4°C (35 to 25°F)) with relative humidity tending toward saturation (100 to 95% RH) and negligible solar radiation.

**c. Cold zone.** In the Cold zone, the temperature during the coldest months, extremes may be very low; however, at open waters cold extremes below -30°C are unlikely.

#### Very Hot Climatic Category

This Climatic Category includes coastlines and inland waterways at the hot-dry low-latitude deserts of the world. During summer in these areas, outdoor ambient air temperatures above 43°C (110°F) occur frequently. However, except for a few specific places, outdoor ambient air temperatures will seldom be above 49°C (120°F). These approximate temperatures of the free air in the shade approximately 1.5 to 2 meters (about 5 or 6 feet) above the ground (in an instrument shelter).

The thermal effects of solar loading can be significant for materiel exposed to direct sunlight, but will vary significantly with the exposure situation. The ground surface can attain temperatures of 17 to 33°C (30 to 60°F) higher than that of the free air, depending on the type/colour of the ground surface, radiation, conduction, wind, and turbulence.

Air layers very close to the surface will be only slightly cooler than the ground, but the decrease in temperature with height above the surface is exponential. Temperatures at approximately 0.5 to 1 meter (about 2 to 3 feet) will be only slightly warmer than that observed in an instrument shelter at about twice that height.1

In winter, temperatures are likely to be in the same range as for the Normal Climatic Category.

Littoral regions are sometimes subject to very high absolute humidity. However, in these hot-wet areas, the highest outdoor ambient air temperatures and highest dew points do not occur at the same time.

#### Severe Cold Climatic Category

In the Severe Cold areas, the temperature during the coldest month in a normal year may be colder than -46°C (-50°F). Temperatures colder than -51°C (-60°F) occur no more than 20% of the hours in the coldest month of the coldest part of northern Siberia where temperatures as low as -68°C (-90°F) have been recorded. Because extremely low temperatures are not controlled by a daily solar cycle, they persist for a long enough period of time to cause materiel to reach equilibrium at extremely low temperatures.

It is recommended to seek assistance in military standards for design to such conditions.

### Climatic Considerations

#### Normal Climatic Considerations

All outdoor systems should be designed for at least the Normal Climatic Category, meaning that design temperatures will include the outdoor ambient air temperatures range of -30°C through +45°C. Allowance for sun radiation should be made in addition to that.

#### Extreme Climatic Considerations

Equipment intended to be installed and used in extreme climates (very hot and severe cold), in areas with extreme non-thermal weather conditions such as corrosive agents from oil installations, blowing sand and dust will require additional planning, design, and testing considerations.

#### Special Considerations

**a. Storage and transit**. Environmental conditions for storage and transit modes may be more severe than those of operational modes because of the possibility of induced/combined environments (e.g., heat, humidity, shock, vibration, etc.), higher levels of some factors (e.g., high temperature in temporary open storage or during delays between transit modes), or greater materiel exposure times.

**b. Design of sheltered equipment.** The shelter becomes the materiel platform, and the environmental characteristics that the sheltered materiel will see depend upon the location and design of the shelter.

### Wind Considerations

Wind specifications will have an impact on the cost of equipment and civil works and it is therefore recommended only to specify that required for operation + add a safety margin for survival in the extreme situation. Data, including those for extreme situations are normally available from local metrological services

Additional complications for VTS is that equipment often is located where wind loads are asymmetrical with horizontal as well as vertical components and turbulence caused by wind gradient, venturi effects, air density (temperature) obstructions or tropical cyclones as described in the following.

This all affect the wind load on equipment and structures.

Furthermore, increased wind speed due to such effects and especially vertical wind components can be dangerous to equipment and especially to rotating antennas and this may call for reinforcements or restrict physical location.

#### The Beaufort Scale

The Beaufort scale was originally devised in 1805 by [Francis](http://en.wikipedia.org/wiki/Francis_Beaufort)  Beaufort although similar scales were in use much earlier. The scale numbers 0-12 were standardized in 1923 as given by table 1‑2

Note that wave heights in the scale are for conditions in the open [ocean](http://en.wikipedia.org/wiki/Ocean), not along the shore. Sea bed characteristics and sounding topology affect the sea state and the wind speed can, in most VTS areas, not be directly related to the sea condition.

Also note that numerous sea state models exist. In this recommendation, the GIT model, and NOT the Beaufort scale and NOT the Douglas scale has been adapted to this recommendation.

Table 1‑2 The Beaufort scale

| **Beaufort number** | **Wind Description** | **Wind speed** | **Land**  **conditions** | **Sea**  **conditions** | **Significant Wave height, fully developed sea at open ocean** |
| --- | --- | --- | --- | --- | --- |
| **0** | [Calm](http://en.wikipedia.org/wiki/Calm) | < 0.3 [m/s](http://en.wikipedia.org/wiki/Metre_per_second) | Calm. Smoke rises vertically. | Flat. | 0 [m](http://en.wikipedia.org/wiki/Metre) |
| **1** | [Light air](http://en.wikipedia.org/wiki/Light_air) | 0.3–1.5 m/s | Smoke drift indicates wind direction and wind vanes cease moving. | Ripples without crests. | 0–0.2 m |
| **2** | [Light breeze](http://en.wikipedia.org/wiki/Light_breeze) | 1.6–3.4 m/s | Wind felt on exposed skin. Leaves rustle and wind vanes begin to move. | Small wavelets. Crests of glassy appearance, not breaking | 0.2–0.5 m |
| **3** | Gentle breeze | 3.4–5.4 m/s | Leaves and small twigs constantly moving, light flags extended. | Large wavelets. Crests begin to break; scattered whitecaps | 0.5–1 m |
| **4** | Moderate breeze | 5.5–7.9 m/s | Dust and loose paper raised. Small branches begin to move. | Small waves with breaking crests. Fairly frequent [whitecaps](http://en.wikipedia.org/wiki/Wind_wave). | 1–2 m |
| **5** | Fresh breeze | 8.0–10.7 m/s | Branches of a moderate size move. Small trees in leaf begin to sway. | Moderate waves of some length. Many whitecaps. Small amounts of spray. | 2–3 m |
| **6** | Strong breeze | 10.8–13.8 m/s | Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic garbage cans tip over. | Long waves begin to form. White foam crests are very frequent. Some airborne spray is present. | 3–4 m |
| **7** | High wind, Moderate gale, Near gale | 13.9–17.1 m/s | Whole trees in motion. Effort needed to walk against the wind. | Sea heaps up. Some foam from breaking waves is blown into streaks along wind direction. Moderate amounts of airborne spray. | 4–5.5 m |
| **8** | [Gale](http://en.wikipedia.org/wiki/Gale), Fresh gale | 17.2–20.7 m/s | Some twigs broken from trees. Cars veer on road. Progress on foot is seriously impeded. | Moderately high waves with breaking crests forming spindrift. Well-marked streaks of foam are blown along wind direction. Considerable airborne spray. | 5.5–7.5 m |
| **9** | Strong gale | 20.8–24.4 m/s | Some branches break off trees, and some small trees blow over. Construction/temporary signs and barricades blow over. | High waves whose crests sometimes roll over. Dense foam is blown along wind direction. Large amounts of airborne spray may begin to reduce visibility. | 7–10 m |
| **10** | [Storm](http://en.wikipedia.org/wiki/Storm),[[7]](http://en.wikipedia.org/wiki/Beaufort_scale#cite_note-forcenamenote-6#cite_note-forcenamenote-6) Whole gale | 24.5–28.4 m/s | Trees are broken off or uprooted, saplings bent and deformed. Poorly attached asphalt shingles and shingles in poor condition peel off roofs. | Very high waves with overhanging crests. Large patches of foam from wave crests give the sea a white appearance. Considerable tumbling of waves with heavy impact. Large amounts of airborne spray reduce visibility. | 9–12.5 m |
| **11** | Violent storm | 28.5–32.6 m/s | Widespread damage to vegetation. Many roofing surfaces are damaged; asphalt tiles that have curled up and/or fractured due to age may break away completely. | Exceptionally high waves. Very large patches of foam, driven before the wind, cover much of the sea surface. Very large amounts of airborne spray severely reduce visibility. | 11.5–16 m |
| **12** | [Hurricane](http://en.wikipedia.org/wiki/Hurricane) Force[[7]](http://en.wikipedia.org/wiki/Beaufort_scale#cite_note-forcenamenote-6#cite_note-forcenamenote-6) | ≥ 32.7 m/s | Very widespread damage to vegetation. Some windows may break; mobile homes and poorly constructed sheds and barns are damaged. Debris may be hurled about. | Huge waves. Sea is completely white with foam and spray. Air is filled with driving spray, greatly reducing visibility. | ≥ 14 m |

The Beaufort scale was extended in 1946, when Forces 13 to 17, intended to apply only to special cases, such as tropical cyclones. Nowadays, the extended scale is only used in Taiwan and mainland China

#### Tropical Cyclones

Tropical systems are officially ranked on one of several tropical cyclone scales according to their maximum sustained winds and in what oceanic basin they are located as Table 1‑3 from the Wikipedia show.

Today, hurricane force winds are sometimes described as Beaufort scale 12 through 16, very roughly related to the respective category speeds of the Saffir–Simpson Hurricane Scale, by which actual hurricanes are measured, where Category 1 is equivalent to Beaufort 12. However, the extended Beaufort numbers above 13 do not match the Saffir–Simpson Scale.

Table 1‑3 Classification of Tropical Cyclones

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tropical Cyclone Classifications (all winds are 10-minute averages)** | | | | | | | | | | |
| [**Beaufort scale**](http://en.wikipedia.org/wiki/Beaufort_scale) | **10-minute sustained winds** | | | **N Indian Ocean (**[**IMD**](http://en.wikipedia.org/wiki/Indian_Meteorological_Department)**)** | **SW Indian Ocean (**[**MFR**](http://en.wikipedia.org/wiki/M%C3%A9t%C3%A9o-France)**)** | **Australia (**[**BoM**](http://en.wikipedia.org/wiki/Bureau_of_Meteorology_(Australia))**)** | **SW Pacific (**[**FMS**](http://en.wikipedia.org/wiki/Fiji_Meteorological_Service)**)** | **NW Pacific (**[**JMA**](http://en.wikipedia.org/wiki/Japan_Meteorological_Agency)**)** | **NW Pacific (**[**JTWC**](http://en.wikipedia.org/wiki/Joint_Typhoon_Warning_Center)**)** | **NE Pacific & N Atlantic (**[**NHC**](http://en.wikipedia.org/wiki/National_Hurricane_Center)**,** [**CHC**](http://en.wikipedia.org/wiki/Canadian_Hurricane_Centre)**, &** [**CPHC**](http://en.wikipedia.org/wiki/Central_Pacific_Hurricane_Center)**)** |
| [**knots**](http://en.wikipedia.org/wiki/Knot_(unit)) | **km/h** | **mph** |
| 0–6 | <28 | <52 | <32 | Depression | Tropical Disturbance | Tropical Low | Tropical Depression | Tropical Depression | Tropical Depression | Tropical Depression |
| 7 | 28-29 | 52-56 | 32-35 | Deep Depression | Tropical Depression |
| 30-33 | 56-63 | 35-39 |
| 8–9 | 34–47 | 63-89 | 39-55 | Cyclonic Storm | Moderate Tropical Storm | Tropical Cyclone (1) | Tropical Cyclone (1) | Tropical Storm | Tropical Storm | Tropical Storm |
| 10 | 48–55 | 89-104 | 55-64 | Severe Cyclonic Storm | Severe Tropical Storm | Tropical Cyclone (2) | Tropical Cyclone (2) | Severe Tropical Storm |
| 11 | 56–63 | 104-119 | 64-74 |
| 12 | 64–72 | 119-135 | 74-84 | Very Severe Cyclonic Storm | Tropical Cyclone | Severe Tropical Cyclone (3) | Severe Tropical Cyclone (3) | Typhoon | Typhoon | Hurricane (1) |
| 13 | 73–85 | 135-159 | 84-99 | Hurricane (2) |
| 14 | 86–89 | 159-167 | 99-104 | Severe Tropical Cyclone (4) | Severe Tropical Cyclone (4) | Major Hurricane (3) |
| 15 | 90–99 | 167-185 | 104-115 | Intense Tropical Cyclone |
| 16 | 100–106 | 185-198 | 115-123 | Major Hurricane (4) |
| 17 | 107-114 | 198-213 | 123-132 | Severe Tropical Cyclone (5) | Severe Tropical Cyclone (5) |
| 115–119 | 213-222 | 132-138 | Very Intense Tropical Cyclone | Super Typhoon |
| >120 | >222 | >138 | Super Cyclonic Storm | Major Hurricane (5) |

For VTS it may not be feasible to continue full operation at very high wind speeds e.g above Beaufort scale 12 and it may e.g be advisable to stop radar antennas to reduce the risk of damage in severe conditions.

#### Air Density

When air becomes warm, the molecules moves faster and the air expands and causes the air's volume to increase. Because density is the mass of the air divided by the volume of the air, and since the mass remains the same, the density decreases.

Table 1‑4 Air Density versus Temperature

| **Temperature [°C]** | **Air density [kg/m3]** | **Normalized 20 °C = 1** |
| --- | --- | --- |
| 35 | 1.15 | 0.95 |
| 30 | 1.16 | 0.97 |
| 25 | 1.18 | 0.98 |
| 20 | 1.20 | 1.00 |
| 15 | 1.23 | 1.02 |
| 10 | 1.25 | 1.04 |
| 5 | 1.27 | 1.05 |
| 0 | 1.29 | 1.07 |
| -5 | 1.32 | 1.09 |
| -10 | 1.34 | 1.11 |
| -15 | 1.37 | 1.14 |
| -20 | 1.39 | 1.16 |
| -25 | 1.42 | 1.18 |

The load on outdoor structures vary accordingly and this should be taken into consideration when establishing VTS

#### Gradient Wind Effect

Wind data from meteorological services normally are for measurements in 10 meter elevation, however, even conditions near metrological stations may differ substantially, one of the reasons being the gradient wind effect.

The wind speed drops the closer to the earth it is, this is because as the wind passes over the earth (or sea) it's movement generates friction or drag, causing the speed to drop.

The more uneven the earth (or sea) surface is, the greater the effect of this friction is, and the higher the difference between the wind speed at ground level and the wind speed higher up in the radar mast or tower. This phenomenon is called the Gradient wind effect. The earth generally causes more friction than the sea as illustrated by Figure 2.



**Figure 2 Average wind speed profiles over terrain with three different roughness characteristics for 45 m/s in higher altitude**

#### The Venturi Effect

The Venturi effect is a jet effect; as with a funnel the velocity of the air increases as the cross sectional area decreases, with the static pressure correspondingly decreasing. According to the laws of fluid (or air) dynamics, the velocity must increase as it passes through a constriction to satisfy the principle of continuity, while its pressure must decrease to satisfy the principle of conservation of mechanical energy.



Figure 3 Simplified illustration of the venturi effect on a slope



Figure 4 Simplified illustration of the venturi effect around a building

This means that if the wind passes upwardly on a slope or around a building as illustrated by figure 3 and figure 4, it generates a venturi effect and provide a strong increase in the wind velocity at a given height above the surface. The height can be determined by local measurement, but may vary with wind speed and direction. As an example, it is not recommended to install radar antennas directly in the venturi.

#### Turbulence

Turbulence is a phenomenon that occurs when an interruption or impediment is introduced into the air (or liquid) flow.



Figure 5 Turbulence around a building

Turbulence is characterized by apparently random and chaotic three-dimensional vortices, and the agitated, irregular motion usually involves movement at various rates of speed.

Turbulence can be very difficult to predict and it is recommended to minimise installation of sensitive equipment in turbulent areas.

#### Lee Side Mountain Wind

Mountain ranges can modify strong winds aloft to create waves and large eddies on the lee side of the mountains. Winds dip down due to the difference in pressure on the lee side, thus initiating wave actions in strong winds. Lens-shaped clouds (altocumulus lenticularus) may develop in the tops of these waves.

The clouds are usually high, and the resulting winds may not be felt at the surface. However, occasionally these strong winds aloft may dip to the surface, or eddy winds may reverse the direction of usual winds. Depending on your location, surface winds can be significantly modified by this process.



Figure 6 Lee side mountain winds

An example of the lee side phenomenon is the changeable Bora gust wind that exists over the Adriatic east coast. It blows in gusts and is most common during the winter

In severe Bora cases mean hourly wind speeds rarely exceed 17 m/s, while gust may reach values to 69 m/s !

### Lightning Protection

Lightning protection is often subject to national or local legislation taking local conditions, severity, earth conductivity, power grid constraints etc. into account. The guidance from country to country differs depending of lightning frequency and severity. As a consequence requirements to the number and type of lightning arrestors, number of earthling points and cross section of lightning conductors vary.

Furthermore, the individual equipment design may set special requirements.

In general principles are:

1. Lightning arresters shall be higher than other equipment and be designed to protect the entire installation. They should have separate down conductor(s) on the exterior of buildings and the down conductors should not be connected to metal parts of buildings such as steel reinforcements, handrails and antenna masts.
2. Safety grounding of equipment should be kept separate from lightning protection
3. Potential equalization should be done in earth and never at the top of the equipment

### Warning Lights

Note that high structures may include warning lights at the radar towers for air traffic. It is recommended to consult local aviation authorities on that subject.

### Access

As part of the design of VTS or VTS equipment locations, the VTS authority should analyse the needs for access for installation and service. Fencing and other protective means against illegal intrusion will also be needed in many cases.

### Electrical Power

VTS equipment is often installed in harsh environments and lack of reliable power may require back up and/or Uninterruptable Power Supplies (UPSs).

The VTS authority should analyse the needs at the installation and assure that the availability of electrical power is included in the availability considerations.

## Marking and Identification

All equipment should be marked with manufacturer name, type and serial number

Local or national legislation may require signposts etc.

National and/or local regulations may require the posting of signs to notify the public that they are under surveillance.

## Safety and Security Precautions

For each installation the VTS authority should perform a hazard analysis and determine requirements in accordance to that.

A safety analysis should at least include:

* safety switch to stop rotating antennas,
* precautions regarding electromagnetic radiation, rotating machinery and electrical shock, railings on masts etc.
* instructions to personnel performing maintenance
* protection of the general public

Security measures should at least consider:

* access restrictions
* alarm systems
* protection of data

## Documentation

Documentation should be provided in electronic and/or paper format, at least including:

* Certificates and permissions as required by law (e.g. CE marking, permission to radiate, permit to build and acoustic noise certificate)
* Instructions to health care (e.g regarding radiation, electrical safety and rotating machinery)
* Test procedures, test certificates, "As build" documentation, etc
* Operating instructions
* Maintenance instructions (preventive and corrective) inclusive of procedures and spare parts catalogue.

## Design Standards Applicable to VTS Equipment

VTS equipment is subject to a variety of local, regional and international standards and it is the responsibility of the VTS authority to make sure that these standards are met.

The following tables summarise general recommendations for specification levels and corresponding standards. Local regulations or requirements, however, may impose additional or alternative requirements for an individual VTS system or location.







### Regional and National Standards

In addition to international standards, regional (e.g. EU) or national standards are often mandatory.

## Legal Requirements to Type Approvals

Legal requirements vary from country to country, they are in continuous development and it is the responsibility of the VTS authority to ensure compliance.

National requirements imposed upon the VTS authority shall, of course, be met. There is a tendency, however, to adopt international and regional standards and the following sections reflect the most commonly used legislations and methods to ensure compliance.

On some aspects, applicable law may require conformance testing by accredited institutions; on other aspects, the VTS Authority is free to decide on the test procedure.

At the time of editing of this document (2013), the following status on legal requirements to type approvals was obtained:

### Electrical Safety

Refer to Low Voltage Directive (LVD) 73/23/EEC or equivalent.

Compliance is required in order to obtain CE marking (mandatory within EU) and best ensured through fulfilling standard IEC60950-1, 2nd ed.

### Mechanical Safety

Refer to Machinery Directive 2006/42/EC; applies to mechanical parts of the VTS system components, i.e. antennas, gearboxes or equivalent.

Compliance is required in order to obtain CE marking (mandatory within EU) Compliance can be documented by a mechanical safety analysis.

### Radiation Safety (Radar)

Refer to Physical Agents Directive 2004/40/EC or equivalent.

Compliance is required in order to obtain CE marking (mandatory within EU)

Compliance can be documented through measurement of RF power densities from transmitting radio equipment and radar.

However, for pulsed energy, measurement of power densities require sophisticated test equipment and it is commonly accepted to verify worst case radiation levels and determine corresponding safety distances through an engineering report on power densities around the antenna, utilizing the guidelines laid down by the International Commission on Non-Ionizing Radiation Protection.

### Electromagnetic Compatibility

Refer to EMC Directive 2004/108/EC or equivalent.

Generic EMC standards used:

* Immunity as industrial equipment acc. to IEC 61000-6-2
* Emission as residential equipment acc. to IEC 61000-6-3.
* Compliance is required in order to obtain CE marking (mandatory within EU)

### Radio Spectrum Requirements

#### EU Requirements:

Refer to R&TTE Directive 1999/5/EC or equivalent.

No harmonized test standards exist, it is recommended to follow the below guidelines:

* ECC/Recommendation (02)05 (2004): “Unwanted emissions”
* ERC/Recommendation 74-01 (2011): “Unwanted emissions in the spurious domain”

#### ITU Recommendations:

* ITU-R Recommendation SM.1541-3 (2011): “Unwanted emissions in the out-of-band domain”
* ITU-R Recommendation SM.329-11 (2011): “Unwanted emissions in the spurious domain”

#### US Federal Requirements

NTIA - Manual of Regulations and Procedures for Federal Radio Frequency Management

#### Chinese Radio Transmission Type Approval

Chinese Authorities require dedicated Chinese Type Approval, Compliant to ITU recommendations.

Special rules apply for Hong Kong (OFTA approval required)

### Reduction of Hazardous Substances

VTS systems shall be designed to comply with the RoHS directive 2011/65/EU (RoHS II) by July 22. 2017.

China RoHS is also becoming a national requirement, but e.g. not affecting design of radar transceivers yet, but already requiring additional marking and documentation.

### Chemical Substances

REACH Directive (Regulation (EC) No 1907/2006)

Where applicable, manufacturers should provide a compliance statement that no banned substances are present in their product with concentrations exceeding the set limits.

# Radar

## Introduction

The purpose of this Annex is to support VTS authorities and integrators in the selection of radar sensors for new and existing VTS systems. The radar solution to a given VTS application may consist of one or more networked radar sensors. Unlike other applications, VTS radars normally need to operate simultaneously on short and long range and this leads to receiver dynamic range requirements that far exceed, for example, those required on board a ship. However, in some cases marine navigational radar may fulfil requirements in a VTS area with low complexity or as gap filler within a radar sensor network.

Weather-related phenomena pose significant challenges to the design and specification of radar sensors. Ducting, for example, may influence VTS radars more than ships’ radars. Additionally, more effective clutter suppression for sea, rain and land may be required than that normally associated with a conventional shipboard radar.

Specific security objectives also introduce particular challenges to the radar sensor where there could be a need to detect small targets in heavy clutter conditions or where small versus large target discrimination is essential.

The use of multi-sensor integration, including radar, AIS and other sensors, imposes additional demands on radar sensor performance and accuracy. False and inaccurate information from the radar sensors, when improperly associated with information from other radars or sensors, may lead to increased risks to safe navigation and security-related decisions. Such false and inaccurate information can arise from antenna side lobes, time side lobes, Doppler side lobes, ghost targets (multiple reflections), range ambiguous returns and inappropriate data processing. Appropriate assessment of data integrity and accuracy from the radar sensor(s) is a vital requirement arising from the overall VTS solution.

It is recommended that the VTS Authority should specify the Operational and associated Validation Requirements rather than Technical Specifications of radar sensor(s).

## Definitions and Clarifications

### Definitions

For general terms used throughout this annex refer to:

IEEE Std 686-1997 IEEE Standard Radar Definitions.

Specific terms are defined as follows:

**Azimuth (Antenna) Side Lobes** - antenna responses (in azimuth) outside the intended radiation beam. Weighting of the illumination function allows a significant reduction of these lobes, but some response outside the intended direction is unavoidable, normally presenting an irregular pattern with "peaks" and "nulls". The side lobes may produce responses from targets in unwanted directions, allowing disturbing signals (intentional or not) to enter the receiver, and in addition makes the radar detectable by receivers which are not illuminated by the main beam.

**Availability** is the probability that a system will perform its specified function when required.

**Blind Spots** – typically resulting from either blind range (the Range corresponding to an echo delay of one or more pulse repetition intervals: the echo then arrives at the receiver while the radar is transmitting a new pulse and the receiver is blanked) or Blind speed (target speeds which produce Doppler shift which are integer multiples of the radar pulse repetition frequency (PRF), which are therefore aliased to zero Doppler and cancelled by the clutter rejection filtering). Blind spots can also arise behind significant obstructions in the field of view (buildings, land masses, oil tankers)

**Chirp** - frequency modulation of the carrier frequency applied within the radar pulse to increase its bandwidth and therefore the range resolution (see also pulse compression)

**Coherence** - capability of a system to keep a stable phase reference during the target illumination time in order to properly exploit the received phase information for moving target indication (MTI), pulse Doppler processing or other purposes

**Doppler** - shift in frequency of a wave due to the relative motion between the transmitter and the receiver. Frequency shift is relative target velocity/wavelength. Radar echoes are shifted twice this value because this shift must be accounted for in both the forward and the return path.

**Doppler Side Lobes** - when using Doppler processing (or MTI) the integrated ideal pulse always presents a response outside the integration peak (across all Doppler filters) known as Doppler side lobes. Their main effect is to limit the capability to discriminate weak returns in proximity of strong returns (with side lobes of the same order of magnitude as the primary response of the weak return).

**FMCW - Frequency Modulation - Continuous Wave** - A type of radar where a continuous wave instead of pulse is transmitted. The range information is derived by frequency modulating the carrier with a saw tooth waveform and comparing the echo FM modulation envelope with the reference

**Ghost Targets (Ghost Echoes)** – undesirable radar echoes resulting from a number of sources. For example multipath related wave reflections caused by large structures or surface reflections, time sidelobes, antenna azimuth sidelobes, and Doppler sidelobes.

**Interference rejection** - this function is included to seek to reduce or eliminate interference received from transmitters utilising the same or nearby frequencies. One common technique is to compare adjacent range cells in the present "live" video signal with the video signal from the previous sweep. The output video signal to the display device is inhibited should the comparison indicate the presence of interference.

**Normal weather and propagation conditions** are the conditions not exceeded 99% to 99.9 % of the time as defined by the individual VTS authority. The rest of the time is considered having **adverse weather and propagation conditions**.

**Plot extraction –** the process of determining the likely target related radar returns from the radar video signal. This typically consists of comparing the video level with a threshold which can be (dynamically) adapted to local background noise and clutter conditions.

**Polarisation** of a radar signal is determined by the orientation of the electrical field. In the case of **circular polarisation** the field rotates left or right.

**Pulse** – typically a pulse (modulated in the case of pulse compression radar) of RF energy transmitted from the radar

**Pulse Compression** – A technique used to achieve a wide pulse bandwidth (and, therefore, enhanced range resolution) using long pulse (for high pulse energy with limited peak power) by introducing an intrapulse modulation (e.g., chirp frequency modulation or Barker discrete phase modulation) and performing a correlation on the received echo.

**Radar** - as referred to in this document relates to all aspects of the radar from sensor through to the presentation of radar information from one or more radar sensors to the VTS operator.

**Radar Cross Section** **(RCS)** – an assessment of the cross sectional area presented by a reflector (typically a target or unwanted “clutter”) to the transmitted radar energy. The RCS can vary with frequency and target attitude,

**Radar information** – a generic term potentially referring to the radar picture/video, target data, clutter data, topographical data, navigation aids, SARTs etc.

**Radar PD** – is the probability of target detection at the output of a radar, subsequent to plot extraction, but prior to tracking, and presentation. Note, in some systems the boundary of the radar and its achieved PD complicate this definition – clarification may be required to avoid misunderstanding arising from, for example, data compression or video processing.

**Radar PFA** – isthe probability of false alarm at the output of a radar, subsequent to plot extraction, but prior to tracking, and presentation. In this context, the PFA is defined as relating to the number of false target declarations per radar cell (range cell x azimuth cells), arising from a noise plus clutter environment (only). Note, in some systems the boundary of the radar and its achieved PFA complicate this definition – clarification may be required to avoid misunderstanding arising from, for example, noise related threshold crossings vs. unwanted radar energy reflections (unwanted targets, ghost targets etc.).

**Radar Plots** - A likely target report resulting from integration of the received echoes inside the antenna beamwidth. Each target report contains range and bearing information

**Radar video** – a time-varying signal, proportional to the sum of the radio frequency (RF) signals being received and the RF noise inherent in the receiver itself. Traditionally, radar video is an analogue signal with associated azimuth reference information. Recently, radar systems have become available which provide equivalent data in digital format.

**Radar tracks** - A target report resulting from the correlation, by a special algorithm (tracking) of a succession of radar-reported positions (radar plots) for one object. The report normally contains filtered position, speed vector information, identity, (e.g. track number). Additional information may include, for example, track uncertainties, the associated plot, timestamp, track quality.

**Range ambiguous returns** – the measured range of a target typically assumes that the target true range is less than the first range ambiguity (the Range corresponding to an echo delay of one pulse repetition interval) whereas large targets beyond this range can be detected but typically with (incorrect) ambiguous range measurement. Techniques exist for the resolution of range ambiguity if required. See also blind spots above.

**Range Side lobes –** see time side lobes (below)

**Reliability** - the probability that a system, when it is available performs a specified function without failure under given conditions for a given period of time.

**Sea characteristics** – often described by sea state but additional parameters can also be of interest. Sea characteristics include wave/swell height, direction and speed of waves/swell, distance between waves/swell, salinity etc.

**Standard Atmospheric Condition** - The International Commission of Air Navigation uses a definition for a standard atmosphere, defining temperature and pressure relative to the height. In the troposphere (0 meters to 11,000 meters), the temperature is defined to be 15 °C at the surface and changing -6.5 °C/km.

**Squint** - the potential angular difference between the beam pointing direction at different transmission frequencies. When present, this effect is measured and calibrated during radar sensor commissioning.

**Target fluctuations** – (also known as Glint or Swerling characteristic) - Fluctuation of a target radar cross section (RCS) (and, therefore, of the received echo amplitude) due to changes in the target attitude and illuminating frequency. For complex targets (consisting of a number of reflecting surfaces), RCS is normally strongly dependent on the angle of observation

**Target Separation** – (also known as Target resolution) – the ability to successfully identify two discrete detectable, similarly sized targets when closely spaced in either range or azimuth.

**Track swapping** –the (usually unwanted) transfer of a track identity (track label) to another track. This can break the intended association between a track and a physical object.

**Time Side Lobes** - when using pulse compression the correlated pulse always presents responses outside the correlation peak (before and after it) known as time (or range) side lobes. Their main effect is to limit the capability to discriminate weak returns in proximity of strong returns (with side lobes of the same order of magnitude as the primary response of the weak return).

### IALA Target Types for Range Coverage Modelling

For calculation purposes, the IALA simplified target types are defined in Table 2‑1.

Typical targets of interest are modelled as point targets with conservative estimate of Radar Cross Section and height. This is normally sufficient for estimation of detection range for consideration in VTS radar sensor coverage. However, further considerations are required for the overall design of radar systems as discussed later in this annex.

Radar performance estimation, including concerns regarding fluctuations, is discussed later in this annex.

Table 2‑1 IALA Target Types



### References

|  |  |  |
| --- | --- | --- |
| [1] | IEEE Std 686-1997 | IEEE Standard Radar Definitions |
| [2] | Merrill I Skolnik | Introduction to Radar Systems, McGraw-Hill Higher Education, ISBN 0-07-290980-3 |
| [3] | P.D.L. Williams, H.D, Cramp and Kay Curtis | Experimental study of the radar cross section of maritime targets, ELECTRONIC CIRCUITS AND SYSTEMS, July 1978. Vol. 2. No 4. |
| [4] | Ingo Harre | RCS in Radar Range Calculations for Maritime Targets.  <http://www.mar-it.de/Radar/RCS/RCS_18.pdf> |
| [5] | International Maritime Organisation (IMO) | Performance Standards for radar reflectors (latest edition) |
| [6] | International Telecommunications Union (ITU) | ITU-R SM.1541 Unwanted emissions in the out-of-band domain |
| [7] | International Telecommunications Union (ITU) | ITU-R SM.329-9 Spurious emissions |
| [8] | The International Organisation for Standardisation( ISO) | ISO 8729 Ships and marine technology – Marine radar reflectors |
| [9] | International Commission for Air Navigation | Definition of the Standard Atmosphere |

### Software tools

|  |  |
| --- | --- |
| CARPET | Computer Aided Radar Performance Tool  TNO (Toegepast Natuurkundig Onderzoek) Physics and Electronics Laboratory, P.O. Box 96864, 2509 JG The Hague, Netherlands, <http://www.tno.nl> |
| AREPS | Advanced Refractive Effects Prediction System  Space and Naval Warfare Systems Center, San Diego, <http://sunspot.spawar.navy.mil>. |

Note that the use of off-the-shelf performance tools for assessment of the latest radar sensors, employing complex multiple pulse waveforms, may require specialist assistance to obtain appropriate and valid performance predictions.

## Radar System solutions

The radar coverage required for a VTS service may consist of multiple radar sensors either co-located or distributed to optimise availability, radar data integrity, security constraints and equipment access considerations. With this in mind, there are a number of design decisions regarding the cost, complexity, location and detailed design of the radar sensors within a VTS.

In addition, there are design decisions and trade-offs to be considered for each radar sensor. These might include magnetron vs. solid state, transmission power, antenna size, receiver technology, signal processing and waveform design, all of which need to be considered together in the specifications of each radar sensor within the VTS network. This detailed assessment of radar design should not be undertaken by the VTS authority.

Therefore, the VTS Authority should keep options open, avoiding detailed technical specifications, and requiring that VTS vendors propose solutions to meet the specified operational and functional requirements based on the recommendations in this document.

## Radar types

VTS radars could be of the following types:

* Pulse Radar (usually Magnetron based)
* Pulse Compression radar (usually Solid State)
* Frequency Modulated Continuous Wave, FMCW (usually Solid State)

A general explanation of each radar type will follow.

### Pulse Radar

A pulse radar typically transmits high peak power RF pulses (10 to 50 kilowatt) of very short duration (50 to 1000 nano seconds). The transmission is made with a pulse repetition frequency (PRF) of typically 1000 to 4000 pulses per second. Upon reception, the returned signal is amplified, demodulated and processed.

Main characteristics include:

* It is a well-known and proven technology
* Increased pulse duration translates into longer-range detection, but poorer range resolution and less ability to penetrate adverse weather conditions.
* Normally with a fixed transmission frequency(ies)
* May require wide frequency band allocation for compatibility with adjacent equipment

Additional challenges include:

* The need to reduce out-of-band transmissions. Note that ITU requirements for shipborne radar are less stringent than for land based radar.

### Pulse Compression Radar

A pulse compression radar transmits low peak power modulated chirps (typically up to 200 watts and eventually higher) with a typical pulse duration of up to 100 micro seconds. The transmission is made with a chirp repetition frequency of typically 1000 to 20000 chirps per second. Upon reception, the returned signal is amplified, pulse-compressed and processed

The energy in the chirp of a pulse compression radar is comparable to the energy emitted in a pulse from a magnetron radar, The longer chirps are converted into short pulses upon reception by the process of pulse compression, therefore high range resolution can be maintained at all ranges.

Main characteristics include:

* It is based on well-known and proven principles, but the high power at high frequency solid state amplifier technology relies on recent developments
* No need for magnetron replacement due to solid state power amplifier, reducing the need for periodic maintenance.
* Increased ability to penetrate adverse weather conditions facilitating smaller target detection
* Transmission frequencies can be programmed, which adds flexibility
* Cleaner spectrum than magnetron radars, which means fewer emissions outside the allocated frequency band(s)

Additional challenges include:

* The need for sophisticated interference rejection due to the longer chirps transmitted
* The need for simultaneous short and long range detection increases complexity
* High power solid state amplifiers operate with large currents therefore requiring careful design to obtain high reliability
* By nature the pulse compression radar creates so-called time side lobes. Avoiding such side lobes, requires sophisticated techniques, alternatively side lobes suppression may imply reduced detection of small targets in the vicinity of larger targets

**Note:** There may be legal restrictions (dual use, catch-all etc.) limiting the compression ratio and other parameters when importing (pulse compression) radars to certain countries.

### Frequency Modulated Continuous Wave

Frequency modulated continuous wave radar transmits low peak power continuous wave forms (typically up to 50 watts). The waveforms are repeated with a typical rate of 500 to 2000 per second. Upon reception, the returned signal is amplified, compressed and processed

The energy in a frequency modulated continuous wave radar is comparable to the energy emitted in a pulse from a magnetron radar, The waveforms are converted into pulses upon reception, therefore high range resolution can be maintained at all ranges.

Main characteristics include:

* It is based on well known and proven principles
* No need for magnetron replacement due to solid state power amplifier, reducing the need for periodic maintenance.
* The ability to detect from very short range
* Transmission frequencies can be programmed, which adds flexibility
* Cleaner spectrum than magnetron radars, which means fewer emissions outside the allocated frequency band(s)

Additional challenges include:

* Dynamic limitations restrict the ability to handle small and large targets simultaneously. This also affects long range detection
* Target revisit rate is low compared to typical VTS target kinematics
* The need for sophisticated interference rejection, even more than for pulse compression radars
* By nature FMCW creates so-called time side lobes. Suppressing the side lobes may imply reduced detection of small targets in the vicinity of larger targets
* More complicated antenna system, 2 antennas or complicated antenna feed.

## Antennas

The selection of antenna parameters (height, gain, side lobes, rotation rate, polarisation etc.) for a given installation, is integral to the resulting radar performance and VTS authorities are advised to avoid specifying detailed antenna parameters in favour of identifying operational needs such as coverage area requirements (based on risk assessments), track update rates (based on tracker design and typical target manoeuvres in high density areas), range performance, overlapping and redundant coverage. The identified operational needs will allow the radar designer some flexibility to achieve the best solution within the constraints of cost and location options.

### Antenna Principles

Typically, the VTS radar design includes an antenna which provides a narrow beam in azimuth and a wide beam in elevation. Thus, the VTS antenna is not designed to measure the target elevation (from which target height might be determined) or to separate targets on the basis of elevation angle difference.

The installed antenna height is determined based on avoidance of physical obstructions, and the compromise between the need for close range visibility vs long range performance. (see also section 2.7.1.1)

The radar designer, in his selection of antenna characteristics, needs to optimise the compromise between antenna size (and cost), track update rate, integration time on target (related to rotation rate and azimuth beamwidth and contributing to target detection range) and azimuth target separation and accuracy. In addition, the choice of transmission frequency influences the size vs beamwidth compromise.

In the future (post 2012), there is the possibility that flat face electronic scanning antennas may be introduced to the VTS market. These have advantages in terms of no rotating parts, flexible beam management, no lost time or energy looking over land and the possibility to focus attention (and radar detection time) to enhance detection performance and update rate dynamically to improve radar data in some key directions. Note this antenna technology may also have disadvantages in terms of cost and perceived complexity. Performance (eg gain, blind coverage directions, and beamwidth) at all applicable scan angles should be considered when assessing radar antenna performance.

### Antenna Side Lobes

The antenna designer uses an amplitude weighting function to control the azimuth side lobe levels to a level which recognises the requirements for close in (< 10° from the main lobe peak) azimuth side lobes and the requirements for side lobes beyond this region. Side lobes are specified as a ratio (in dB) relative to the antenna beam peak.

The antenna gain defined from a specific point in the radar system is specified as a ratio above “isotropic” (dB or dBi) and can be increased by increasing the physical size of the antenna. This will also reduce the beamwidth (azimuth, elevation or both).

Elevation side lobes are not typically specified for VTS antennas. They are unlikely to be a major contributor to the performance of the VTS radar system.

Azimuth grating lobes can also be a factor and these should be included in consideration and measurement of side lobe levels.

## Characteristics of Radar Targets

VTS radar targets are defined by their height above sea level, their speed and manoeuvrability, their polarisation characteristics, their radar cross section (RCS) and the fluctuations in RCS.

### Radar Cross Section

A target may be observed when transmitted RF energy is reflected back from the target to the receiver. The amount of energy reflected is directly proportional to the radar cross section of the target.

The RCS is defined as the ratio between the power (in W) scattered by the target back towards the radar receiver and the power density (in W/m2) hitting the target. Thus RCS is measured in m2 and has the dimensions of area.

**Note:** There is no simple relationship between the physical size of the target and the RCS. The reflected energy depends on several factors, such as the radar operating frequency or frequencies, the angle of incidence of the radio waves, target speed, material and geometry.

The RCS of a target will fluctuate as a result of target movements, frequency and environmental effects with consequences on the detection and presentation of the target.

### Polarisation

Radio waves are polarised and objects will often reflect differently for the polarisation used. This can be utilised by radar system designers, where rules of thumb are that:

* Target returns from linear polarisation, (horizontal or vertical) in general will be stronger than returns from circular polarisation
* Normally linear polarisation (horizontal or vertical) will result in substantially higher rain clutter returns than circular polarisation.
* Normally vertical or circular polarisation will result in higher sea clutter returns than horizontal polarisation, especially for lower sea states.
* Non-metallic and natural objects, such as human beings will return linear polarised radio waves much better than circular polarised radio waves.
* Most radar reflectors will be poor reflectors for circular polarised radio waves.
* Distant ships with vertical masts tend to give the strongest return for vertical polarisation, whereas the opposite tends to be the case for modern ship designs without tall masts.

In summary complex designs are possible in which operators may select the polarisation. However, this adds to equipment costs and adds to the VTS operator workload – the resulting performance benefits are unlikely to justify this complexity.

In general the best cost/performance combined with ease of operation is achieved by horizontal polarisation. Circular or switchable may however be appropriate to achieve acceptable performance for operation in areas with extreme (tropical) rainfall.

### Complex Target Models

The point target characteristics in table 2‑1 will normally be sufficient for range calculation of specific targets of interest in VTS.

However, the design of a radar system shall consider the overall characteristics of all objects within coverage range of the individual radar and Table 2‑2 provides an overview of such characterises for targets, typically of interest to VTS radar. Data is primarily based on reference [3] and [4], supplemented by data obtained from the experiences of IALA VTS committee members.

Table 2‑2 Typical Target Characteristics

| Target | | Typical characteristics at X-band | | |
| --- | --- | --- | --- | --- |
| RCS | Height | Fluctuations etc. |
| A | Aids to Navigation without radar reflector. | Up to 1 m2 | 1 to 4 m ASL | Rapidly fluctuating, highly dependent on sea characteristics. Polarisation characteristics will often vary depending on wind. |
| B | Aids to Navigation with radar reflector. | 10 – 100 m2 | Rapidly fluctuating, wind and currents may tilt to blind angles and lobing may cause reflectors to be in blind spots. Most radar reflectors will be poor radar targets in case of circular polarisation |
| C | Small open boat, fibreglass, wood or rubber with outboard motor and at least 2 persons onboard, small speedboat, small fishing vessels or small sailing boats. | 0.5 – 5 m2 | 0.5 to 1 m ASL | Rapidly fluctuating may be hidden behind waves up to 50 % of the time.  Slow moving targets tend to lie lower in the water than fast moving ones and therefore RCS visible to the radar tends to increase with speed.  Humans and non-metallic targets will give poor radar return in case of circular polarisation |
| D | Inshore fishing vessels, sailing boats and speedboats, equipped with radar reflector of good quality. | 3 – 10 m2 | 1 to 2 m ASL | Rapidly fluctuating. |
| E | Small metal ships, fishing vessels, patrol vessels and other similar vessels. | 10 – 100 m2 | 2 to 4 m ASL | Moderately fluctuating. |
| F | Coasters and other similar vessels. | 100 – 1000 m2 | 6 to 10 m ASL | RCS is highly dependent on aspect angle of the individual vessel. Rate of fluctuations is typically moderate. |
| G | Large coasters, Bulk carriers, cargo ships and other similar vessels. | 1000 – 10,000 m2 | 10 to 25 m ASL |
| H | Container carriers, tankers and other similar vessels. | 10,000 – 2,000,000 m2 | 15 to 40 m ASL |
| I | Buildings, cranes. Stacks of containers and other large structures. | Up to 1,000,000 m2 | Depends on site | Insignificant. |
| J | Floating items, oil drums and other similar items. | Up to 1 m2 | 0 to 0.5 m ASL | Rapidly fluctuating, highly dependent on sea characteristics and target movements. |
| Birds, floating or flying. | Sea level and up |
| K | Flocks of birds. | Up to 3 m2 | Sea level and up | Rapidly fluctuating, flight paths tend to be characteristic of given species in given areas of interest. |
| L | Jet Skis and other personal water craft | Up to 0.5 m2 | 0 to 1 m ASL | Rapidly fluctuating but virtually independent of aspect angle |
| M | Wind turbines (onshore and offshore) | Up to 1,000,000 m2 |  | Fluctuations for towers are insignificant. Rotating parts give a wide spectrum of Doppler shifts with RCS up to hundreds of m2 |

Note: Modern warship design seeks to minimise RCS and as a result the above figures cannot be related to such vessels.

RCS on targets using S-band is typically 40 % of the RCS in X-band except for small non-metallic targets where difference between the 2 bands can be much higher.

To determine RCS on targets using other radar bands, such as Ka and Ku the standard radar textbooks should be consulted to scale from the X-band figures in tables 2-1 and 2-2.

### Target speed and manoeuvrability

When assessing the requirements for both the tracking function and the radar sensor, the VTS Integrator needs to understand the range of target speeds and manoeuvres that might reasonably be expected and, where appropriate, any particular coverage areas in the VTS where extreme manoeuvres are most likely to occur. The VTS Authority should ensure that the range of target speeds and manoeuvres is specified as part of the operational needs.

## Specification of Operational Requirements

It is recommended that the VTS Authority should specify the Operational and associated Validation Requirements rather than Technical Specifications of radar sensor(s).

The operational requirements may be determined by:

1. Definition of the radar coverage of the VTS area, based on possible radar location(s), the navigation characteristics, and the subdivision into requirements for Basic, Standard and/or Advanced capability derived from the assessment of risks (as described in Annex 1).
2. Definition of targets to be detected
3. Determination of environmental capabilities and constraints
4. Determination of other influencing factors, radar location(s), obstructions
5. Definition of targets detection requirements in weather and propagation conditions normal for the VTS area.
6. Definition of radar dynamic capabilities and constraints

This might be an interactive task involving iterations including evaluation of achievable performance versus overall system cost. It might for example be better to start with simpler solutions, meeting the available budget, than to be left without any radar coverage.

### Radar Coverage

Depending on the declared services of a VTS, the radar coverage can be:

* nil (automatic identification systems, voice communication and reporting only)
* partly (covered areas with some intentionally blind areas)
* totally by one radar sensor (without any blind areas)

In the case of large VTS areas, and/or to mitigate shadow effects of other vessels, multiple radar sensors may be required. Combined processing of images from 2 or more radars may also be utilised for elimination of false (ghost) echoes.

### Subdivision of the Area

The VTS area should be subdivided into requirements for Basic, Standard and/or Advanced capability as discussed in ANNEX 1, paragraph 1.3.2 and the need for radar and other sensors coverage shall be defined on the basis of a risk assessment.

The selected location of radar(s) and their height should ensure that the desired coverage requirements are met.

#### Antenna Height

The figures below illustrate how the height of the antenna above the water surface affects the maximum and minimum detection range performance.

Careful consideration should be given to optimise radar location(s) and antenna height(s) to ensure appropriate coverage of the VTS area.



**Figure 7 Target range and visibility**

### Targets to be Detected

The radar in a VTS should be capable of detecting and tracking all types of surface objects defined by the VTS authority in weather conditions normal for the individual site.

Table 2‑3 lists the IALA target types to be detected for Basic, Standard and advanced Capability. Refer to Table 2‑1 for IALA target definitions. Obviously, smaller targets at close range are detectable by radars in any of the 3 categories, but table 2-3 indicates the minimum requirement.

Table 2‑3 Targets to be Detected



In addition any special objects of interest should be specified separately.

### Determination of Environmental Capabilities and Constraints

The environmental conditions of the VTS area should be described, including the annual cycle. This should include conditions to be expected as normal over a 12-month period as well as extreme events.

Restrictions with respect to operation and access to site(s) due to weather should also be included.

It is highly recommended that individual assessments are made for each VTS site separately. A standard set of specifications for environmental requirements cannot be made to cover all VTS installations, and the tables included in this paragraph are only indicative, giving performance obtainable by traditional magnetron radars.

New technology radars may allow for additional performance within economical reach.

#### Precipitation

Information about precipitation over the VTS areas should be obtained from meteorological services, and the VTS authority should define the required radar performance requirements in clear conditions as well as for normal precipitation conditions.

Note that rising coastline tends to increase precipitation over land at some locations, and normal as well as extreme precipitation over sea may therefore differ substantially from precipitation statistics determined for land-based meteorological stations.

Table 2‑4 provides precipitation data, recommended for use in VTS radar specifications. It should be noted that intensities may exceed these values for brief periods of time, but it might not be economically feasible to design for such occasions.

Table 2‑4 Precipitation (rainfall rate) specification for VTS radar



Note that rainfall is rare in dry/hot regions, maybe only once or twice per year and the VTS Authority should consider if rain shall be specified at all.

Also note that designing a system to perform in tropical rain showers will typically call for S-band radars. However, the worst rain conditions may only be present for a few hours per year, and reduction in performance on other parameters, may not justify the additional investment.

#### Sea Clutter

Numerous Sea clutter models exist. The CARPET models adopted for this recommendation derive the mean sea clutter reflectivity from the clutter model developed by the Georgia Institute of Technology (GIT). The average wave height is derived from the hydro-graphic sea state so that fully developed sea conditions are assumed. The hydrographical sea state scale with the corresponding wind speeds and average wave heights are shown below.

Table 2‑5 Douglas (GIT) Sea state table



This has also been adapted for this recommendation, providing values of the clutter reflectivity under standard propagation conditions for calculation purposes. Note, this mean sea clutter reflectivity is used for performance assessments within the CARPET modelling. Real world experience at a given site may not align with this simplified model.

Table 2‑6 provides recommended sea state requirements used in VTS radar specifications, S and X band.

Table 2‑6 Sea State Specification Levels for VTS radar (Douglas Scale)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| IALA Target type | **Local Port Services** | **Basic** | | **Standard** | | **Advanced** | |
| **General** | **General** | **Ports and inland waterways** | **General** | **Ports and inland waterways** | **General** | **Ports and inland waterways** |
| 1 | NIL | NIL | | NIL | | SS 4 | SS 3 |
| 2 | SS 3 | SS 3 | SS 5 |
| 3 | SS 2 | SS 3 | SS 2 | SS 4 | SS 6 |
| 4 | SS 3 | SS 4 | SS 5 | SS 7 |
| 5 | SS 4 | SS 5 | SS 6 | SS 8 |

### Other Influencing Factors, Obstructions and Interference

Obstructions, e.g. topography, buildings and other man-made structures may block or reflect radar signals. Other radars and sources of electromagnetic radiation may cause interference.

Inland and harbour VTS will often require special considerations as the number of structures, their density and their close ranges can create very complex distortions. Additional care shall be taken to assess and mitigate effects caused by natural and man-made structures such as bridges, buildings, river banks, sheet metal pilings, and steep bends.

#### Shadowing Effects

Radar detection may be blocked by shadowing effects that, to the extent possible, should be avoided. Such effects include:

* Targets being hidden by larger targets or other obstructions
* Masking of small targets by the effects of range and time side lobes

These effects can be minimised by the appropriate siting of radars and selection of equipment with low side lobes.

#### Multipath Effects

The classical radar multipath behaviour associated with air targets and sea surface reflections has limited application and relevance to a system designed for the detection of surface targets. This effect is included within CARPET and, for VTS scenarios, results in shorter detection ranges than might be expected from free- space calculations.

However, multipath conditions resulting from reflections from large buildings and large vessels can still impact on VTS radar performance resulting in the possibility of target signal cancellation or enhancement. This effect is hard to predict and it is unreasonable to expect to model multipath affected performance unless a (potentially expensive) site specific radar model is developed.

In addition, ghost targets can exist. These derive from undesirable radar echoes resulting from multipath related wave reflections caused by large structures, buildings or vessels.

### Interference

Interference can be split into susceptibility (received interference) and compatibility (transmitted interference).

To minimise interference, separation between wanted and unwanted transmissions has to be optimised – this can be achieved by a combination of frequency separation, physical separation of transmission sites, antenna directionality, sector blanking, separation by time and also by ensuring that all the systems competing for the same or adjacent spectrum do not transmit excessive and unnecessary transmit power levels or transmit time periods. The radar receiver design will typically be very sensitive (to achieve the required performance), although gain control techniques (swept gain or STC) offer further resistance. Waveform designs incorporating staggered PRFs and processing schemes designed to reject known interference patterns can also aid the radar receiver to suppress unwanted returns.

#### Radar Susceptibility

In the case of any radar installation, (e.g. a permanent VTS installation of a radar or of each radar in a VTS network), the performance of that radar can be detrimentally affected by received emissions from other radiating sources (physically adjacent VTS radars, maritime shipborne radars, and other users (legitimate or otherwise) of the electromagnetic spectrum. Typically, local legislative regulations and restrictions will control and minimise unwanted received signals but elimination of such signals is likely to be impossible. National spectrum allocation authorities should always be approached by a VTS integrator when considering any changes to a VTS network (radar, microwave link, communications etc.) to enable a holistic view of the changes and how they might affect all users.

The radar design can assist in minimising the susceptibility to unwanted received interference, e.g. by utilising low antenna side lobes, avoiding large reflecting surfaces, minimising receiver front end bandwidth etc.

Note that FMCW and pulse compression radars may typically require larger front end receiver bandwidths than conventional magnetron systems. The multi-pulse waveforms transmitted (and consequently received) by pulse compression radars have to achieve a compromise between pulse chirp bandwidth (related to range cell size and hence range resolution), use of frequency diversity (to optimise performance in clutter), unwanted pulse to pulse interaction etc. vs. spectrum usage and hence unwanted susceptibility with other transmitting spectrum users. FMCW radars transmit and receive (at low levels) for 100% of the time across a swept bandwidth.

#### Radar Compatibility with Other Users

In the case of any radar installation (e.g. a permanent VTS installation of a radar or of each radar in a VTS network), the performance of adjacent systems can be detrimentally affected by transmitted emissions from the radar in question (physically adjacent VTS radars, maritime shipborne radars, and other users (legitimate or otherwise) of the electromagnetic spectrum). Typically local legislative regulations and restrictions will control and minimise unwanted transmitted signals but elimination of the influence of such signals is likely to be impossible. As with susceptibility above, National spectrum allocation authorities should always be approached by a VTS integrator when considering any changes to the RF sub- systems within a VTS network.

The radar design can assist in minimising the impact of transmitted signals, for example by utilising low antenna side lobes, avoiding large reflecting surfaces, minimising transmit power, consideration of peak and mean power levels, sector blanking, physical location of the radar etc.

Note that conventional magnetron radars require larger peak power levels than pulse compression and FMCW radar systems. The magnetron technology can result in unnecessary wideband spectral emissions unless steps are taken to include frequency band pass filtering (which has an inherent loss to the wanted signal). However, pulse compression radars and FMCW radars, although utilising lower peak powers, use techniques which may include frequency modulation, pulse to pulse frequency variation, frequency diversity etc. all of which increase the use of the spectrum and increase the chances of unwanted degradation of adjacent systems.

#### Influence from Wind Farms

Wind turbines produce large static target-like returns which, from a VTS Operator’s perspective, are normally easy to distinguish from vessel traffic.

The complex return from a wind turbine is made up of two key elements

* The tower and generator housing offering a large static zero-Doppler RCS, in some cases up to 1 million square meters.
* The rotating blades of the turbine offering a complex spread of non-zero-Doppler RCS, typically up to 100 square meters, which will vary with wind direction and speed.

This composite return will be seen as a large static target by a conventional pulse radar, whereas FMCW and coherent radars using Doppler processing will see a complex target spread across the Doppler domain.

The influence, independent of the applied radar technology, will be reflections causing unwanted ghost echoes and suppression of nearby targets. The large RCS may also result in antenna side lobe returns, resulting in reduced detectability. The symmetrical layout of wind farms may add further to the disturbances.

#### VTS Radar Network Considerations

When considering the design of a network of radars, such as that required by some complex VTS locations, radar-to-radar interoperability cannot be ignored. Although the probability of the antennas of two radars pointing directly at each other is likely to be small, the receivers should each be protected against such an event. The more likely case is when one radar antenna is pointing at the other whilst the other is pointing somewhere else – a calculation of the unwanted received power reduced by the selectivity of the own radar antenna (its peak to sidelobe ratio) may not be sufficient to avoid unwanted receiver saturation or at least “blindness”. Consequently, the VTS radar network may need to use frequency separation between the unwanted transmission and the wanted receive signals. This is typically known as frequency planning and a competent radar supplier should be able to offer to undertake a study to identify the impacts and assess the need for a transmission plan to ensure that radar interoperability is possible.

Although pulse compression and FMCW radars are typically wider band, the use of digital frequency synthesis enables these radars to offer multiple, selectable transmission centre frequencies, which support the frequency planning, if needed, and therefore the interoperability of radar systems within a VTS radar network. Magnetron radars are typically tuned in the factory to a single transmission frequency.

### Target Detection Requirements

The detection performance of a radar in a VTS should be sufficient to meet the requirement in the individual VTS areas, Basic, Standard and/or Advanced.

The VTS Authority shall ensure that the specified detection performance is achieved. It is strongly advised to consult experts with a sound operational and technical knowledge about the subject.

Factors affecting the detection performance of radar systems including noise, interference, clutter, and propagation shall be taken into account. Special local conditions such as heavy rainfall should be taken into account.

#### Determination of Radar Coverage

The recommended method for determination of radar coverage and range performance is a combination of site inspections and radar system performance predictions.

The evaluation shall include:

* Calculation of range detection performance, focused on the smallest targets of interest in poor weather conditions. All applicable losses shall be included in calculations.
* Evaluation of the effects from propagation conditions and obstructions.
* An evaluation of dynamic requirements.

The calculations may be supplemented by comparison and/or validation test.

It will typically not be possible to encounter all combinations of variables, and calculations are therefore made on the basis of a simplified model of the targets and the environment based on statistical information. It is important to understand the limitations and tolerances this entails.

#### Probability of Detection and Probability of False Alarm

The probability of detection and false alarm rates used for calculations should comply with that required to meet the operational performance required.

At specified maximum coverage ranges, the single scan probability of detection values for VTS will typically lie in the range from 0.7 to 0.9.

It is normally desirable not to have noise and clutter spikes presented to the operator in each scan. Therefore, optimal false alarm rates for VTS applications normally lie in the range from 10-4 to 10-5 for the radar video display.

The false alarms taken into account in the calculations should include unwanted information from noise and clutter, as presented to the operator or to the tracker (after signal processing), but not signals from other unwanted objects.

Different values may apply for the tracking, on condition that the tracking requirements are met.

### Calculation of Radar Detection Performance

The achievable target detection range is highly dependent on several factors including antenna height, target characteristics, weather and atmospheric propagation conditions. In the design of radar systems it is furthermore very important not only to focus on maximum detection range but also on radar quality at all ranges, the ability to handle clutter, the ability to suppress interferences and the ability to simultaneous handling of defined (small and large) targets in the VTS area covered by radar.

Calculation for magnetron radars can be performed by the CARPET program from TNO.

**Warning:** The cumulative detection stated by CARPET can be very misleading if used for determination of VTS detection performance.

CARPET may not be sufficient for determination of performance for pulse compression radars, where it may be necessary to rely on vendor furnished information, possibly supported by performance tests.

The tables below include **typical examples** of detection and tracking ranges for X-band and S-band radar systems, in standard atmospheric propagation conditions.

These tables use different rainfall rates to align with the likely choice of radar band in high rainfall areas.

Table 2‑7 Typical Range Performance Predictions for X-band Radar

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Antenna elevation | IALA Target type | **Local Port Services** | **Basic** | | **Standard** | | **Advanced** | |
| **Clear** | **Clear** | **2 mm/h rain** | **Clear** | **4 mm/h rain** | **Clear** | **10 mm/h rain** |
| 20 m ASL | 1 |  | NIL | | NIL | | 5 NM | NIL |
| 2 |  | 7 NM | 4NM | 7 NM | 6 NM |
| 3 |  | 7 NM | 4NM | 8 NM | 5NM | 9 NM | 7 NM |
| 4 |  | 9 NM | 8 NM | 11 NM | 9NM | 12 NM | 10 NM |
| 5 |  | 12 NM | 10 NM | 13 NM | 11 NM | 14 NM | 13 NM |
| 50 m ASL | 1 |  | NIL | | NIL | | 10 NM | NIL |
| 2 |  | 10 NM | 7 NM | 12 NM | 9 NM |
| 3 |  | 10 NM | 6 NM | 12 NM | 8 NM | 14 NM | 12 NM |
| 4 |  | 13 NM | 12 NM | 15 NM | 13 NM | 17 NM | 15 NM |
| 5 |  | 16 NM | 15 NM | 18 NM | 17 NM | 20 NM | 18 NM |
| 100 m ASL | 1 |  | N/A | | NIL | | 12 NM | NIL |
| 2 |  | 13 NM | 5 NM | 16 NM | 10 NM |
| 3 |  | 17 NM | 10 NM | 18 NM | 16 NM |
| 4 |  | 20 NM | 19 NM | 22 NM | 20 NM |
| 5 |  | 23 NM | 22 NM | 25 NM | 23 NM |
| Sea states as defined per section 2.7.4.2 | | | | | | | | |

Table 2‑8 Typical Range Performance Predictions for S-Band Radar

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Antenna Elevation | IALA Target Type | **Standard S** | | | | **Advanced S** | | | |
| [m ASL] |  | Clear | 10 mm/h | 16 mm/h | 25 mm/h | Clear | 10 mm/h | 16 mm/h | 25 mm/h |
| [NM] | [NM] | [NM] | [NM] | [NM] | [NM] | [NM] | [NM] |
| 20 | 3 | 4.3 | 2.4 | 2.0 | 1.7 | 4.8 | 2.4 | 2.0 | 1.5 |
| 4 | 6.5 | 4.6 | 4.1 | 3.6 | 7.4 | 4.9 | 4.4 | 3.9 |
| 5 | 9.3 | 7.5 | 6.9 | 6.4 | 10.3 | 7.9 | 7.4 | 6.8 |
| 50 | 3 | 6.6 | 3.8 | - | - | 6.8 | - | - | - |
| 4 | 9.9 | 7.7 | 6.8 | 5.9 | 11.1 | 8.3 | 7.4 | 6.5 |
| 5 | 13.5 | 12.0 | 11.2 | 10.4 | 14.7 | 12.7 | 11.9 | 11.0 |
| 100 | 3 | 8.9 | - | - | - | - | - | - | - |
| 4 | 13.7 | 11.0 | 9.1 | 4.0 | 15.3 | 12.1 | 10.3 | 0.9 |
| 5 | 18.3 | 17.2 | 16.5 | 15.4 | 19.8 | 18.3 | 17.5 | 16.5 |
| Calculated for | | Sea State 3 | | | | Sea State 5 | | | |

It is normally sufficient to calculate detection range for small and medium size targets, therefore IALA targets type 6 and 7 are not included in these tables.

Note the influence from sea clutter increases substantially with antenna height with consequent reduction in target detectability.

It should also be noted that radar performance predictions are indications and not guarantees of real world performance. There are many variables within a CARPET-based prediction that can only be considered to be approximations of target, radar and environment behaviour.

**Warning:** The use of radar prediction models requires full understanding of their validity and limitations. Their use as a comparative tool should be performed by radar experts and any predictions may not represent achievable real world performance. It is recommended that performance validation against expectations includes live testing.

Ku band performance indications are not provided due to the limited used of Ku band for VTS. Supplier information may be used for comparative purposes.

### Influence from Propagation

The performance of surface based radar systems is strongly influenced by the electromagnetic properties of the atmosphere and the surface of the Earth. In free space, electromagnetic waves propagate in straight lines from the antenna toward the targets and back. However, radars located near the Earth’s surface should deal with, and adjust to the diffraction and refraction of the propagating wave.

Performance should, in all cases, be evaluated assuming Standard Atmospheric Conditions, combined with precipitation and sea state information for the individual location. Evaluation of the effects from adverse propagation should in addition be included for hot, dry areas of the world, e.g. the Arab Gulf.

#### Propagation in the Standard Atmosphere

An electromagnetic wave observed at a target consists of a summation of an infinite number of contributions from different paths to the target leading to constructive and destructive contributions at the target. The return path suffers from similar effects. For small low targets this results in shorter detection ranges, than the distance calculated by simple line of sight calculations.

In addition, the barometric pressure and water vapour content of the standard atmosphere decreases rapidly with height, and the temperature decreases slowly with height. This causes the electromagnetic waves to bend a little towards the Earth’s curvature.

Radar parameters, losses in transmission lines (not only waveguide), processing losses, clutter and precipitation add to the complexity and, even for the Standard Atmosphere, it is necessary to combine this with propagation factors by radar calculation tools in order to determine the predicted performance for a VTS radar sensor. This is typically modelled by increasing the radius of the Earth by a multiplier (1.33) and assuming straight line propagation.

#### Sub-refraction and Super-refraction

Sub-refraction, bending the electromagnetic waves up, and super-refraction, bending the electromagnetic waves down, exists when the atmosphere deviates from the standard.

Sub-refraction can be caused by fast reduction of temperature and slower reduction of water vapour content with height, bending the electromagnetic waves towards space. However, this phenomenon occurs rarely in nature.

Super-refraction (can be caused by temperature increase with height (generally by temperature inversion) and/or rapid decrease of water vapour with height, decreasing N. Decreasing the refractivity gradient will eventually cause it to reach the critical gradient, at which point an electromagnetic wave will travel parallel to the Earth’s curvature.

#### Ducts and Trapping Layers

Super-refraction will develop into trapping layers, if the refractivity gradient decreases beyond the critical gradient, at which point the electromagnetic wave will be trapped and follow the Earth’s curvature.

Ducts act like waveguides for propagating waves bordered by trapping layers or the Earth’s surface. In order to couple into a duct and remain in a duct, the angle of incidence must be small, typically less than 1°.

Ducting can be categorized into three main types:

* Evaporation duct:
  + Weak, caused by evaporation from the sea surface, and only at low levels (maximum of 40 meter ASL).
  + Generally increasing the radar horizon, especially for low mounted antennas.
* Surface-based duct:
  + Surface ducts caused by low level inversion (increase of temperature /decrease of humidity with height), up to 500 meters ASL.
  + Increase of radar range, depending on duct and antenna height.
* Elevated duct:
  + 0.2-2 km above the surface
  + Typical no effect on surface-based antennas.

The effects are typically increased range but also increased amounts of noise and 2nd / multiple time around returns which may appear as false radar returns..

Notice that the electromagnetic waves are refracted (bent) and not reflected by the trapping layers.

##### Evaporation Ducts

Evaporation ducts exist over the ocean to some degree, almost all the time. A change in the moisture distribution without an accompanying temperature change will lead to a trapping refractivity gradient. The air in contact with the ocean surface is saturated with water vapour, creating a pressure that is decreasing to some value above the surface.

This will cause a steep refractivity gradient (trapping) near the surface, but gradually equalise towards normal refractivity gradient at a certain height, which is defined as the evaporation duct height.

Evaporation ducts are generally increasing the radar detection range and the antenna can be located above the duct and still have extended propagation strength.

For typical coastal radar installations, evaporation duct heights of 6 – 15 meters lead to the longest detection ranges. Evaporation duct heights of more than 10 meters will also introduce an increased amount of clutter, setting additional demands to clutter processing and noise reduction capabilities.

I.e. investigations of weather data from the Arab Gulf area show that evaporation ducts exist all the time with typical duct heights of 5 to 25 meters, resulting in increased radar range in 80% of the time and increased clutter in 50% of the time.



Figure 8 Coverage diagram, in normal atmosphere (left) and including an evaporation duct (right).

##### Surface-based Duct

Surface based ducts can be much stronger than evaporation ducts. They occur when the air aloft is hot (and dry) compared to the air at the Earth’s surface. Over the ocean and near land masses, dry continental air may be advected over the cooler water surface; either directly from leeward side of continental land masses or by circulation associated with sea-breeze.



Figure 9 Example of simulated radar coverage in surface based + evaporation ducting conditions.

In addition to the temperature inversion, moisture is added to the cool marine air by evaporation, increasing the trapping gradient. In costal areas, this leads to surface trapping ducts. However, away from land, this trapping layer may well rise from the surface thereby creating an elevated duct.

The electromagnetic wave will be refracted towards the surface of the Earth and be trapped in the duct like in a waveguide. This kind of trapping condition greatly increases the surface detection range - and the amount of noise received. Note that surface detection may occur far beyond the radar horizon with a “dead zone” in between.

Surface based ducts are often combined with evaporation ducts and examples of radar performance in such conditions, as illustrated by Figure 9.

##### Elevated Duct

Generally, elevated ducts occur from descending, compressed and thereby heated air, from anticyclones, approaching the marine boundary layer and causing ducts. Elevated ducts may also occur from elevating surface-based ducts.

Surface detection might also occur in this case far beyond the radar horizon with a “dead zone” in between, adding noise to the radar image.



Figure 10 Coverage diagram, elevated duct

##### Severe Ducting at Coastlines Adjacent to Hot Flat Deserts

The large temperature variation between night and day in desert areas and the associated pressure differences between land and sea tend to cause very strong temperature inversion during night time and result in strong sea breeze in the afternoons. This can result in very severe ducts. This type of duct can be very low, as little as 15 meters has been experienced

Range performance is very different for an antenna positioned inside or above these ducts, and radar systems with an antenna positioned within such a duct will have substantial increase in the detection range for surface targets. If the antenna is positioned above the trapping layer (outside the duct), the electromagnetic wave will be refracted and the detection range for surface targets will be substantially reduced.

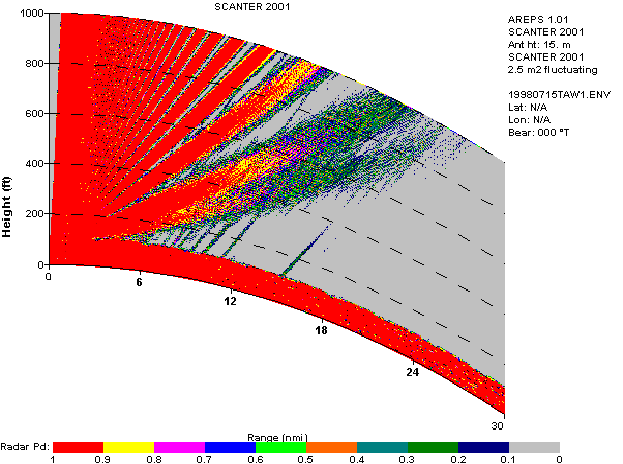
 

Figure 11 Coverage diagram based on a measured condition at a coastlines adjacent to hot flat deserts. The radar detection using antennas positioned inside the duct (left) and above the duct (right) corresponded to the simulated coverage diagram.

The sea breeze also cause eddies over the sea, forming distinctive sea clutter patterns. The eddy results in a “snake” like pattern moving forth and back for a few hours in the afternoon on hot days with strong sea breezes (see Figure 12). Of course, this may disturb display and tracking.



Figure 12 One hour of recordings with trials (snail tracks) shown in red.   
The yellow “snake” at sea is an eddy moving forth and back with a speed of approximately 4 knots.

### Target Separation and Target Accuracy

Target separation (sometimes referred to as discrimination) requirements and target accuracy requirements should be considered separately.

#### Target Separation

In normal weather and propagation conditions, surface objects within the VTS area should be separated in presentation, and individually tracked without track swap, at any applicable target speed when they are positioned apart and with distances as defined by the individual VTS authority.

The system should be designed in such a way that the required radar separations based on risk assessments can be achieved in the identified area(s) covered by the VTS service. At long range, the impact of the height and type of antenna on the resolution performance should be taken into account. The system should also be capable of displaying and tracking all detectable targets of interest simultaneously in normal conditions, preferably without the need for manual adjustments by the operator.

The recommended definition of target separation is to specify the point of intersect between the two returns of point source and similarly sized targets, as being -6dB relative to the peak signal of the smaller target. An operator will normally be able to distinguish between 2 targets on a radar display using this definition.

For the extraction and tracking process more separation is needed, typically double spacing of that achieved at the -6dB points.

Including allowance for tolerances this leads to the recommendations below

**Warning:** Measurement of separation using small floating targets can be unreliable due to target fluctuations. Instead it is recommended to use small radar reflectors placed in a clutter free land area, e.g. a paved area or a beach. It is normally sufficient to measure at one or two points in distance, typically with reflectors placed in the far field beyond 1 nautical miles from the radar. For short range applications a similar test at the range(s) of interest may be more appropriate.

##### Range Separation for Small Point Targets

The range separation is, for traditional magnetron radars, linked to the transmitted pulse length.

Substantially better range separation may be achieved by pulse compression radars, however, this technology may be subject to export restrictions for some countries and, as a result, the figures recommended are achievable by magnetron radars, See Table 2‑9 and Figure 13

Table 2‑9 Range Separation

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Recommended requirements for range separation of small point targets | | | | | | | | | |
|  | | Local Port Services | | Basic | | Standard | | Advanced | |
| -6 dB points | Plot separation | -6 dB points | Plot separation | -6 dB points | Plot separation | -6 dB points | Plot separation |
| Minimum Range Separation  as presented to the VTSO  (in m) | Less than 5 NM instrumented range | 35 | 50 | 25 | 40 | 20 | 30 | 15 | 25 |
| 5-20 NM instrumented range | n/a | | 75 | 100 | 60 | 75 | 30 | 60 |
| More than 20 NM instrumented range | n/a | | n/a | | 100 | 125 | 80 | 100 |

Calculated in metres this gives the following results:

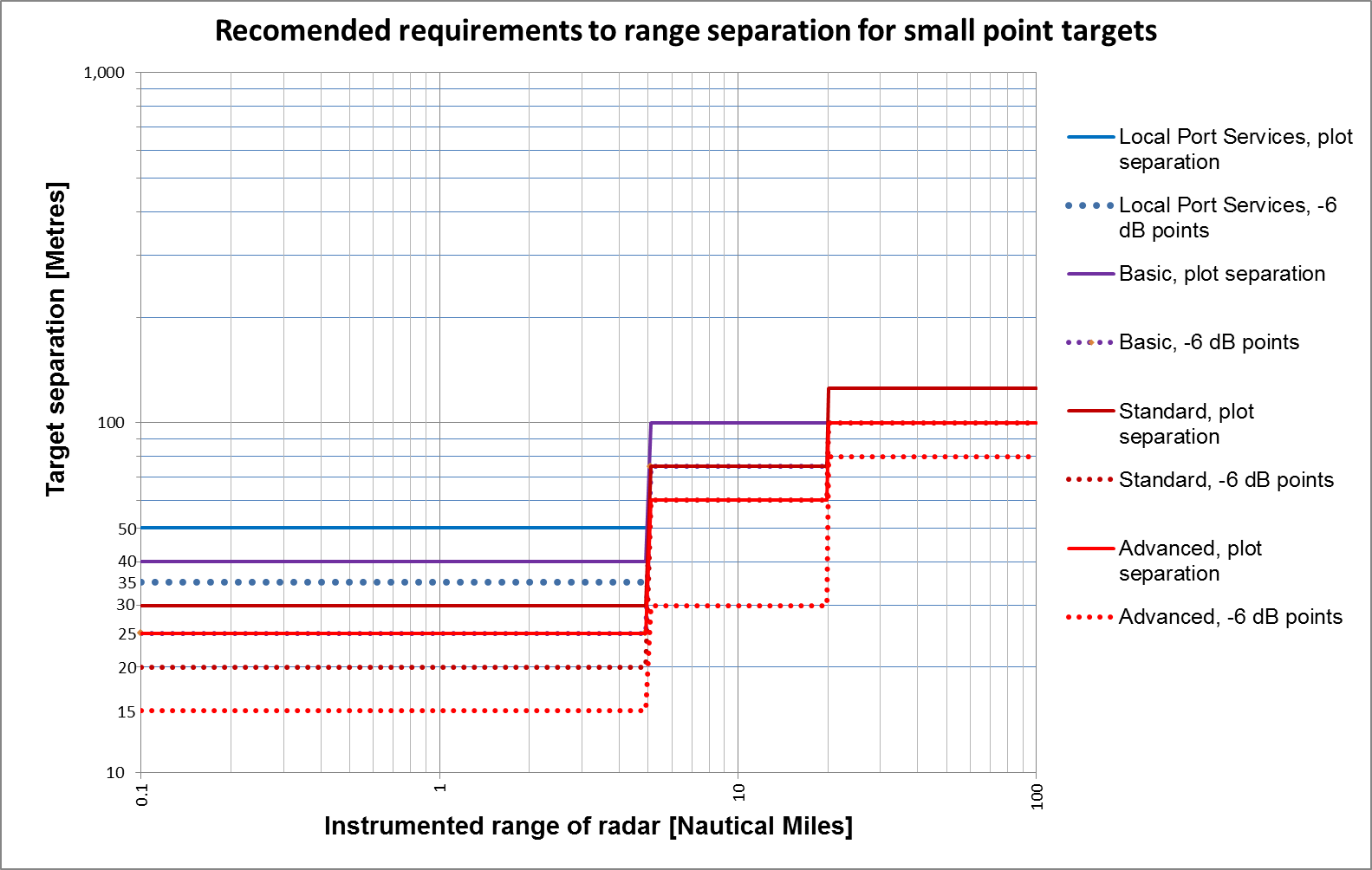


Figure 13 Range Separation

##### Azimuth separation for small point targets

The azimuth separation is, for traditional magnetron and pulse compression radars, directly linked to the antenna size. Recommendations to separation requirements for similar sized, point targets is given by Table 2‑10 and Figure 14 .

Table 2‑10 Azimuth Separation

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Recommended requirements for azimuth separation of small point targets | | | | | | | | | | | | |
|  | X-Band Radar | | | | | | | | S-Band Radar | | | |
| Local Port Services | | Basic | | Standard | | Advanced | | Standard | | Advanced | |
| -6 dB points | Plot separation | -6 dB points | Plot separation | -6 dB points | Plot separation | -6 dB points | Plot separation | -6 dB points | Plot separation | -6 dB points | Plot separation |
| Azimuth separation in angle as presented to the VTSO  (in °) | 1.6 | 3.2 | 1.0 | 2.0 | 0.6 | 1.2 | 0.5 | 1.0 | 2.4 | 4.8 | 1.5 | 2.9 |
| Or distance, whichever is the greater (in m) | 35 | 50 | 25 | 40 | 20 | 30 | 15 | 25 | 20 | 30 | 15 | 25 |
| Maximum corresponding  antenna horizontal  -3dB beam width (in °) | 1.00 | | 0.70 | | 0.45 | | 0.40 | | 2.00 | | 1.25 | |

Calculated in metres this gives the following results:

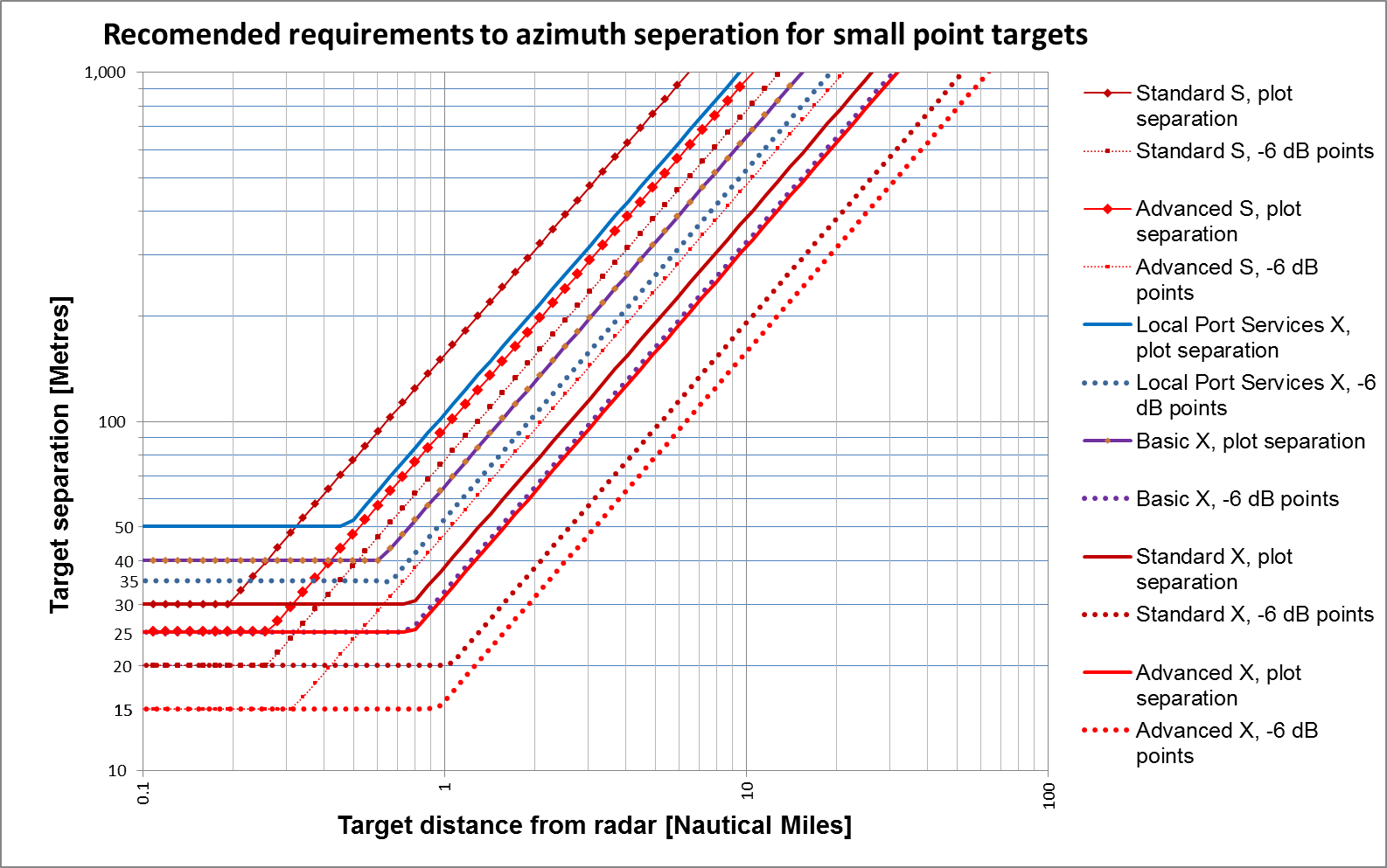


Figure 14 Azimuth Separation

Note that the definition of azimuth separation has been further refined compared to previous editions of this recommendation; however, expectations to radar performance remain unchanged

##### Separation of Larger Targets

Beyond the separation of point targets, the VTS authority is recommended to express target separation requirements in operational terms rather than radar subsystem parameters.

For larger (non-point) targets and for separation of dissimilar sized targets, the definition of separation is highly dependent on physical size, aspect angles, relative return amplitude, pulse stretch, and other radar characteristics. System capability should be assessed by live testing of predefined scenarios, as modelled or predicted performance can give misleading results.

**Note:** In the special case of offshore installations with low traffic density combined with severe consequences of accident, it is recommended that target separation equivalent to Basic capabilities are considered, whereas other operational requirements should be Advanced.

##### Improvement by Doppler Separation

The use of Doppler separation (based on target radial velocity) to achieve successful target separation, can improve performance, however, single targets can create multiple, complex Doppler returns which can lead to confusion when associating track updates with existing tracks. Therefore, it is generally suggested that there should be a separation of at least one Doppler resolution cell when relying on Doppler separation.

Radars incorporating Doppler or MTI processing are subject to Doppler side lobes which in addition can limit Doppler separation of smaller fast moving targets from large targets at the same range.

#### Target Accuracy

The system should be designed in such a way that the defined radar target accuracy is aligned to the core operational requirements derived from the recommendations of Annex 1.

Several elements of a VTS system contribute to the track accuracy and these should be appropriately budgeted before deriving the radar sensor accuracy requirements. The target tracking requirements contained in Table 9-1 should be used in combination with knowledge of the design of the target tracking function to derive the individual radar sensor measurement accuracy requirements. Corresponding recommendations for the minimum radar plot accuracy is provided inTable 2‑11 and Figure 15:

The recommendations for accuracy include the effects of quantisation noise (related to radar cell size), plot extraction, calibration and installation inaccuracies.

The impact of the antenna height on the measuring accuracy (slant range vs plan range) are additional to the figures.

Table 2‑11 Plot Accuracies

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Recommended requirements to plot accuracies for small point targets | | | | | | | |
|  | | Local Port Services | Basic | Standard | | Advanced | |
| X | X | S | X | S | X |
| Range (Slant range from radar to trailing edge of return) | Maximum fraction of instrumented range | 0.75% | 0.50% | 0.20% | | 0.10% | |
| Or absolute value, whichever is the greater (in m) | 20 | 15 | 10 | | 5 | |
| Azimuth | Maximum angular error (in °) | 0.75 | 0.50 | 1.00 | 0.35 | 0.50 | 0.25 |
| Or absolute value, whichever is the greater (in m) | 20 | 15 | 20 | 10 | 10 | 5 |

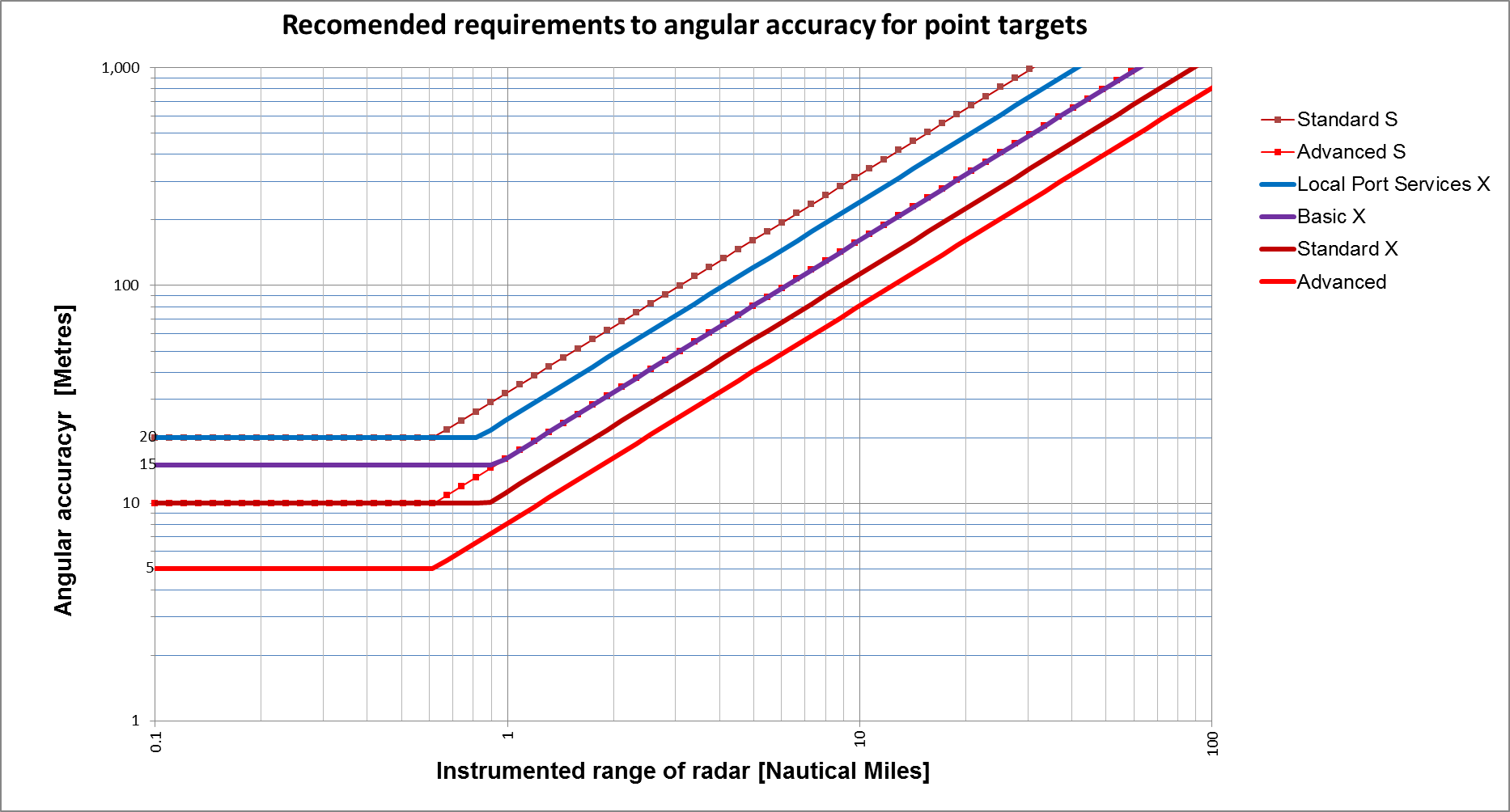


Figure 15 Angular Accuracy

**Warning:** Measurement of accuracy using small floating targets can be unreliable due to target fluctuations. Instead it is recommended to use small radar reflectors placed in a clutter free land area, e.g. a paved area or a beach. It is normally sufficient to measure at one or two points in distance, typically with reflectors placed in the far field beyond 1 nautical miles from the radar. For short range applications a similar test at the range(s) of interest may be more appropriate.

### Radar Dynamic Capabilities and Constraints

#### Dynamic Requirements

The dynamic range of the radar should, in normal weather and propagation conditions, detect and process the surface objects specified by the VTS authority. This should be achieved without significant side lobes, degradation of target appearance, degradation of detection or degradation of separation capability.

The dynamic range is determined by:

* The ratio between the largest nearby objects expected and the smallest distant objects to be detected
* Target return signal fluctuations including multipath

Requirements for the radar(s) can be determined from the characteristics of the objects in the coverage area of the individual radar. Table 2‑2 summarises the characteristics of objects typically considered and the corresponding dynamic range, as a function of RCS and detection range, can be determined from Figure 16



Figure 16 Dynamic characteristics of signal received versus target RCS and target range (in nm) for point targets in free space

The figure represents targets in free space. This is normally sufficient for the determination of VTS radar requirements when combined with 10 dB allowance for target fluctuations.

**Notes:** If more accurate determination than that from the graph in Figure 16 is deemed necessary, this can be performed using performance evaluation tools, combined with evaluations of near range effects.

The off-the-shelf radar performance evaluation tools typically avoid a representation of the receiver dynamic range limitations.

Technology limitations may restrict compliance with the extreme dynamic range that could be derived from fig 2-7. The numbers suggested in the notes in fig. 2-7 are achievable at the time of compilation of this document (2013).

#### Sidelobes

Side lobes (Figure 17) are unwanted, as they will limit the size of a small Radar Cross Section (RCS) target that can be detected next to a large RCS target. The ratio between the peak level of the target and the highest side lobe is called the Peak Side Lobe Ratio (PSLR).

Range (time) side lobes

Antenna side lobes

Target

Target

.

Unwanted side lobes

Clean target echo

Figure 17 Side lobe effects

Typically, azimuth (antenna) side lobes are the only contributor in traditional magnetron pulse radars. FMCW and pulse compression radars are subject to range as well as azimuth side lobes.

Table 2‑12 Maximum Sidelobe Level Relative to Non-saturating Target Signals

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Recommendation level** | | |
| **Basic** | **Standard** | **Advanced** |
| Maximum near side lobe level, within +/- 10° in azimuth and +/- 250 metres in range from any target | - 50 dB | - 55 dB | - 58 dB |
| Maximum far side lobe level, outside +/- 10° in azimuth and +/- 250 metres in range from any target | - 65 dB | - 68 dB | - 70 dB |

Side lobes should be sufficiently low to avoid masking of smaller targets in the proximity of large returns from targets or clutter. In addition, low side lobes minimise the probability of false targets arising from other large returns. Table 2‑12 recommends the maximum allowed signal presented to the display and plot extractor, originating from antenna and range (or time) side lobes.

The figures account for two way propagation, therefore the antenna side lobe requirements (one way) equal half the values indication (dB s divided by 2).

Also note that structures near antennas (in some cases up to 100 meters) tend to distort wave propagation and thereby increase the azimuth side lobe level in the direction of such structures.

##### Doppler Sidelobes

Radars incorporating Doppler or MTI processing are also subject to Doppler side lobes which can limit detectability of smaller targets competing with large clutter, but these radars offer performance benefits when compared to radars without Doppler or MTI processing.

Currently (2013), typical VTS radars do not achieve Doppler side lobe levels which are comparable to the figures in table 2-10 due to cost constraints. 30 to 40dB is a realistic expectation and this imposes a corresponding limitation on the visibility of small targets competing with Doppler side lobes from large returns at the same range.

## Functional Requirements

The radar service in a VTS should, as a minimum, support the operational functions specified by 8.1 as well as the functions listed below.

These functions may be hosted by the radar sensors or other parts of the VTS system.

### Operational Outputs

The output from a radar service should include radar image data and track data. In addition, the output from the radar service may include clutter data to enable identification of, for example; squalls, oil spills, ice detection, wave height, etc.

### Operator Functions

Radar functions should be designed and implemented to optimise performance and minimize operator workload to the level practical. Ideally, the operator should only need to control basic functions such as start and stop.

Each radar site should be designed and equipped to reduce the adverse effects of rain and sea clutter and enhance the probability of target detection and it is recommended to make adaptation to changing weather conditions, etc. automatic to reduce operator workload, However, it might be necessary to implement dedicated operational modes e.g. for adaptation to weather.

Manual override of automatic functions should always be possible

### Clutter and Noise Reduction / Management

Appropriate, clutter reduction or clutter management should be available to meet the performance requirements.

This will typically include:

* White noise suppression
* Interference rejection
* Sea and rain clutter processing
* Adaptation to varying propagation conditions.

The features should preferably be automatic for systems requiring standard or advanced capabilities.

### Elimination of False Echoes

The radar should also be designed and installed so as to eliminate, to the maximum extent possible, false echoes caused by side lobes, reflections from nearby structures or second/multiple time around echoes.

## Radar Design, Installation and Maintenance Considerations

The radar systems shall in general be designed taking the general considerations in 0 and this 0 into account.

Special safety precautions for radar should include but not be limited to those applicable for Rotating Machinery, Radiation Hazards and Electrical Shock.

Special precautions should also consider lightning protection, wind load on antennas and access to the systems, including antennas for installation and maintenance. Turbulence, asymmetrical wind and vertical wind components should be considered with reference to the descriptions in 0.

Waveguides should in general be kept as short as possible. Their length and associated losses need to be included when determining system performance. Waveguides should always be equipped with dehumidifiers or simple desiccators

Concerning the lightning protection it is recommended to place this in a blanked sector or in a direction of low practical importance.

### Service Access

Service access should be possible at the individual radar location.

A local service display at each radar sensor, providing radar control, BITE results and other specified radar information is recommended.

To the extent practical, service access should be possible remotely, for example, at the central monitoring location for the VTS network.

### Antenna Accessibility

When siting a radar, the accessibility should be carefully considered – for example an access ladder and maintenance platform may be required to ease maintenance on a tower or tall building.

### Antenna Robustness

The installation of a radar can introduce problems resulting from high winds. In some cases it may be appropriate to separately specify both the survival wind limits and a lower operational wind limit within which the system shall not be degraded due to the normal weather conditions specified for that location. High winds can affect the motor and gearbox design and can affect the instantaneous rotation rate at varying angles to the predominant wind direction. The build-up of ice in some climates should also be a consideration.

Plot accuracy can be affected by high winds and the overall system azimuth accuracy should consider torsional errors arising from high winds.

In extreme conditions, it may be appropriate to house the rotating radar antenna within a static radome although this can increase costs and RF losses and complicate maintenance of some components.

### Choice of Upmast versus Downmast Transceivers

The radar designer may also have a choice of whether to locate the transceiver upmast or downmast. In the latter case, a waveguide run may be required to link the RF output / input of the transceiver to the antenna. Such a run of waveguide will introduce losses which should be considered as a part of the evaluation of the predicted performance of a given radar installation.

Conversely, an upmast transceiver installation may be more difficult to access for maintenance and servicing than a downmast transceiver which might also benefit from an environmentally controlled location and consequent improvement in equipment reliability.

Further issues might include the need to transfer high bandwidth video (on copper, fibre or microwave link etc) which can influence the radar designer’s selection of whether to use an upmast or downmast transceiver. Incorporation of transceiver redundancy can also influence the choice of transceiver location.

### Built-in Test Features

Built-in test features should include monitoring of functions and performance. Communication of summary alarms and system status to a central monitoring system may be required. It is recommended that detailed BITE results are made accessible for remote monitoring, especially for radars installed in locations that are difficult to access.

### Protection against Extreme Events

Authorities responsible for VTS areas subject to adverse weather such as cyclones, typhoon, hurricane, and tornado should consider the potential impact and specify requirements to equipment survival. Radar operation is normally suspended in such conditions.

Refer to Annex 1 section 1.5 for further guidance

## Verification of Function and Performance Requirements

Refer to ANNEX 13 for general recommendations

### Radar Detection Performance

It is recommended to base acquisition of radars and subsequent verification after installation on the basis of measured performance data using real targets.

Such measurements should be carefully analysed including the influence from weather and propagation.

**Note:** Verification of radars using floating point targets, such as corner reflectors or Lunenburg reflectors, is subject to large inaccuracies due to sea surface movements and variations in propagation.

It is suggested to measure the radar cross section of real targets and use those for actual measurements.

Radar cross section measurement of targets should be made in calm sea conditions, at close range and using stable (not moving) Luneburg reflectors as reference.

# Automatic Identification System

## Introduction

IMO introduced Class-A AIS transponders as a mandatory carriage requirement in 2004 and, consequently, class-A transponders are fitted to all SOLAS vessels. Class-B AIS was introduced in 2008 as a voluntary carriage device, mainly aiming at the recreational market. The characteristics of class-B devices make them less desirable for VTS use. VTS Authorities should consider recommending class-A devices for non-SOLAS vessels that participate in VTS or provide support for VTS operations.

AIS is typically implemented as part of a VTS in one of two configurations:

* As standalone sensor
* Integrated with radar sensors

This Annex will address the features and functions of AIS as they relate to a VTS Authority and, therefore, it will focus on the Ship-to-Shore and Shore-to-Ship AIS communication.

### Objective of AIS

The VTS objectives of AIS are:

* Automatically receive information from AIS-equipped vessels, including the ship’s identity, ship type, position, course and speed over ground, navigational status and other safety-related information
* Monitor and track AIS-equipped vessels
* Exchange data with AIS-equipped vessels
* Support value added functions over AIS infrastructure
* Manage AIS-based Aids to Navigation (including virtual and synthetic AtoNs).

Note: AIS position information is, in principle, obtained through GNSS. There is a possibility of GNSS-sourced positional data being corrupted due to (satellite-) equipment faults and intentional or unintentional interference (of the satellite-originated signals). Where possible, safeguards should be considered within the VTS system to assess the integrity of positional data when two or more sources of such data are available.

## References

|  |  |
| --- | --- |
| IALA Recommendation A-124 | IALA Recommendation A-124 on the AIS Service, ed. 2.1 (2012) |
| IALA Binary message register | Collection of regional applications for AIS application Specific Messages of regional applications for AIS Binary Messages ([www.e-navigation.nl/asm](http://www.e-navigation.nl/asm)). |
| IALA Guideline 1028 | On the Universal Automatic Identification System (AIS) - Volume 1 - Part 1 Operational issues, ed. 1.30 (2004) |
| IMO SN.1/Circ.289 | GUIDANCE ON THE USE OF AIS APPLICATION-SPECIFIC MESSAGES (2 June 2010) |
| ITU-R Recommendation M.1371-4 | Technical characteristics for an automatic identification system using time-division multiple access in the VHF maritime mobile band (2010) |

## Physical Implementation of VTS AIS

### Equipment

A VTS Authority is a shore-based operation and, as such, it should not use the physical (mobile) transponder equipment intended for installation on board a vessel. The Physical Equipment options for a VTS Authority are as follows:

* AIS basestation
* AIS limited basestation
* AIS receiver
* AIS repeater
* AIS Aid to Navigation (AtoN)

An AIS basestation (either full or limited) is the preferred physical equipment for the implementation of a VTS System. For smaller VTS installations in VTS areas of low traffic density, and where the reception of just the core AIS information is sufficient, an AIS receiver could be a more cost-effective solution. In all cases, it should be considered carefully whether the information is sufficient to support the required VTS Operator tasks.

An AIS repeater may be used to extend the AIS coverage area of a VTS system. A repeater provides a simple means of extending the AIS coverage, however, at a cost of halving the capacity of the system! For this reason, AIS repeaters are not recommended for use in areas of high traffic density.

AIS can be an integral part of an Aid to Navigation such that the AtoN position and other AtoN-related data can be transmitted over the AIS network and received by ships.

### AIS Licensing and Siting

An AIS basestation will need to be licensed by the appropriate national Radio Communications or Broadcast Authority in most countries. The licensing process will also determine any restrictions regarding the siting of the AIS basestations and their aerials. Potential AIS basestation sites are determined based upon a cellular mapping of all basestation sites (See section 7 of IALA Recommendation A-124). AIS Cells are 30nm x 30nm square with a limit of two (2) basestations to each cell. One of the AIS basestations within a cell is configured to transmit its Fixed Access TDMA (FATDMA) information on one of the AIS VHF frequencies and the other basestation is configured to transmit its FATDMA information on the other AIS VHF frequency. However, if an adjacent cell has less than 2 basestations (this can include a cell that is adjacent and inland), then additional basestations can be included by borrowing the allocation from the adjacent cell. The cell size also means that AIS VHF aerials should not be positioned higher than approximately 35m above sea level.

The limit of two basestations per cell is to ensure that the number of FATDMA slots is not excessive in any one geographic area. AIS basestations can transmit their own position so that the port appears on the ECDIS display of incoming vessels. However, the position transmission is repeated in a fixed slot on every AIS net cycle and therefore it consumes a fixed amount of the AIS bandwidth. If there are too many timeslots allocated for FATDMA, it reduces the availability of Random Access TDMA (RATDMA) slots which are used by the AIS transponders on board vessels for their normal position and ID transmissions.

*It should also be noted that if the basestation does not need to transmit its own position and therefore does not use FATDMA, then the number of basestations per cell can be increased.*

Every AIS basestation has a MMSI (Maritime Mobile System Identity). Where a VTS system has multiple AIS basestations to cover a large VTS Area, each basestation can be given the same virtual MMSI so that the whole VTS system appears with a single identity. The MMSI will normally be issued by the appropriate national Radio Communications or Maritime Authority when licensing the use of AIS frequencies.

## Operational Requirements

A VTS needs to gather information about the vessel traffic within the VTS area. Vessels need to be identified and monitored as they transit through the VTS area and visit ports. The VTS may use multiple sensors to achieve the necessary data gathering and AIS contributes to this task.

AIS provides timely, relevant and accurate information to VTS Operators to support the compilation of the VTS traffic display. It provides automatic vessel position reports and movement information as it is received at basestation sites. Where radar is installed as part of the VTS sensor suite, the AIS information should be correlated with the radar target data to ensure that each vessel within the VTS area is represented by a single track on the VTS Traffic Display. AIS also provides supporting information about the ship and its current voyage that may be integrated with other port operations.

The provision of information from the VTS to the mariner is supported by AIS through the use of short text messaging and the binary messages within the AIS protocol. Further value added functions may be implemented using the binary messages subject to functional approval through the IALA Binary message register (www.e-navigation.nl/asm).

The key VTS Operational Requirements relating to AIS are, therefore, defined as follows:

* Provision of vessel identification and location information to the VTS traffic image
* Provision of vessel manoeuvring and voyage related data to the VTS
* Provision of facilities to enable transmission of information between the VTS to the mariner

## Functional Requirements

### Support to the VTS Traffic Image

#### Target Tracking

Automatic Identification System (AIS) provides identification and location information to enable the VTS Operator to monitor and track vessels within the VTS Area. AIS transmissions consist of bursts of digital data ‘packets’ from individual stations, according to a pre-determined time sequence. AIS data consists of shipboard information such as position, time, course over ground (COG), speed over ground (SOG), heading, etc.

The AIS position reporting rate is dynamic and will change, depending on the speed of the reporting vessel and whether the vessel is maneuvering or not. For a class-A transponder, the nominal position reporting rate is once every 10 seconds. For a high-speed and/or maneuvering vessel, this rate may increase up to once every 2 seconds. Conversely, for a vessel at anchor, the position report rate may drop to once every 3 minutes.

AIS enhances situational awareness for the VTS by improving the possibility of detecting other vessels that are obscured from direct line of sight. As a cooperative means of tracking, the AIS element of a VTS will receive data from any vessel that is equipped with a transponder even in severe sea and rain clutter conditions.

#### Aids to Navigation

In addition, AIS AtoNs (including real, synthetic and virtual AtoNs) will be presented to the VTS Operator through the Traffic image.

#### Extended Coverage

Where the VTS Area extends beyond the coverage of a single AIS basestation, the recommended approach is to extend the VTS Network with additional basestations such that required coverage is achieved. Where it is not possible to extend the VTS network, AIS repeaters could be used.

Every AIS basestation will have a MMSI number. However, when a VTS is operating multiple AIS basestations, it can present a single address, known as a virtual MMSI number. This will enable the ships to send and receive AIS messages in the VTS area using only one MMSI regardless of the number of basestations in use.

### Voyage-Related Data

AIS provides facilities for mariners to enter details of their voyage, ETA and cargo etc. This static data is part of the standard AIS transmissions at 6 minute intervals or on request. The static data may be received by the VTS system and can be used to support VTMIS applications such a Port Information Management databases. Note, however, that, due to absence of any commonly agreed procedure to update this data, it may not be present, outdated or simply incorrect.

### Information Exchange between VTS and Mariner

#### Text Messaging

A VTS Authority could use AIS to send free-format text messages to a vessel at sea. Such messages are intended to be for safety-related purposes. When received, AIS text messages will appear on the Minimum Keyboard Display (MKD) of the on board AIS system. Note, however, that AIS text messages are not a replacement for voice communication; a VTSO should not assume that AIS text messages were received and read on-board.

AIS text messages can be addressed either to a specified destination (MMSI) or broadcast to all ships in the area. The content should be relevant to the safety of navigation, e.g. an iceberg sighted or a buoy not on station. Such messages are limited to a maximum of 156 characters for an addressed message and 161 characters for a broadcast message. Although unregulated, AIS messages should be kept as short as possible (preferable less than 48 characters for an addressed message and less than 53 characters for a broadcast message).

#### Binary Messaging

In addition, AIS has facilities for sending and receiving binary messages (there are 7 binary messages within the AIS protocol) and these can be used for “value added” supporting applications. It should be noted that the approval of the appropriate National Authority may be required for the use of the AIS VHF data link for a supporting application. An example of a supporting application may be: “Persons on board” or “Boarding Card” recording and transmission for passenger vessels.

For further details, see IMO SN.1/Circ.289, dated 2 June 2010, GUIDANCE ON THE USE OF AIS APPLICATION-SPECIFIC MESSAGES.

The AIS infrastructure and protocol provides facilities to enable application developers to produce new functionality and capability though the use of the binary messaging features. All such developments and message sets should be approved by the appropriate national or regional maritime authority and should be consistent with the purpose of AIS in respect to enhancing Safety of Life at Sea.

An overview of approved binary messages and functions is managed by IALA ([www.e-navigation.nl/asm](http://www.e-navigation.nl/asm)).

It is recommended that National Authorities should monitor and coordinate the use of binary messaging within their area of responsibility to ensure that the necessary facilities for ship reporting via the VHF Data Link (VDL) are not compromised.

#### Pilot Port

An on board Class-A AIS transponder includes a pilot port that can be used to display a complete AIS picture on a Pilot’s Portable Display.

### Aids to Navigation

AIS basestations, as part of a VTS System, can be configured to broadcast Virtual and Synthetic Aids to Navigation (AtoN). A virtual AtoN is an AIS signal that marks a navigation point where there is no physical marker. A synthetic AtoN is an AIS signal that marks a position where a physical object is located. Virtual and Synthetic AtoNs will appear on the on board ECDIS.

AIS may be integrated with real AtoNs for monitoring and control purposes and so that other data sources hosted on the AtoN can be managed through the main VTS Traffic Display. AIS AtoNs can also be configured to transmit further virtual or synthetic AtoNs.

### Assigned Mode

VTS may use the AIS Service capability to change the reporting mode (from autonomous to assigned mode, for example) of selected shipboard AIS units. This will enable the ship station to operate according to a specific transmission schedule, as determined by a competent authority.

## Graphical presentation

In the VTS Centre, AIS-data is usually viewed on an electronic chart, either separately or combined with the radar data.

### Symbol Usage

The IALA Guidelines on AIS include a description of the recommended AIS target symbols, but these were originally intended for the on board ECDIS systems. As the guidelines point out, the given symbols are not necessarily adequate in a VTS context. The main difference is that a VTSO may prefer a much wider range of information than is necessary on board a ship. For example traffic management may necessitate the use of symbols which depict different types and sizes of vessels. Furthermore, it may e.g. be necessary to show which vessels have pilots embarked, and which do not.

### Interaction with Radar Tracks

A target that is tracked by radar and also carries an AIS transponder should be displayed with one symbol based on a fusion of the dynamic information received from the two sensor types.

## Specific Design, Configuration, Installation and Maint­en­ance Considerations

### Interference

AIS may be susceptible to interference from adjacent channels. When siting AIS basestations, due consideration should be given to frequency allocations adjacent to AIS channels to avoid possible service disruption.

### Coverage Aspects

In general, AIS design coverage ranges should approximate VHF voice communication ranges. However, actual vessel traffic density or geographic considerations (i.e., mountains or other VHF occlusions) may determine the need for additional base stations.

When estimating the size of the operational coverage (operational cell) for shore facilities, an important consideration is the traffic load – number of mobile AIS stations within the area.

For example, calculations in one port have indicated that an AIS basestation could accommodate less than 300 active AIS units.

For further information, please refer to IALA Guideline A.124 on the Automatic Identification System (AIS).

### Installation and Maintenance

The AIS basestation equipment should be housed indoor and in a controlled environment, as would be used for other IT network components. AIS basestations are typically 19” rack mountable and therefore all network and power connections will normally reside within the 19” equipment rack. Installation should therefore be simple and uncomplicated. For remote sites, where access may take more than 1 or 2 hours, the concept of a duplicated / hot standby configuration should be considered.

Standard maintenance procedures should apply to the basestation and network connectivity. However, for the outdoor aerial equipment, regular checks should be made to ensure that the aerials, and cable runs to the aerials, are not damaged.

# Environmental Monitoring

## Introduction

The protection of the environment is an issue that has grown significantly in importance, both politically and socially, over recent years. The environmental impact of normal commercial activities is analysed such that risk reduction measures can be determined and implemented. Traditionally, VTS Authorities have collected environmental data simply to support their VTS activities however, many VTS Authorities have their VTS areas in, or alongside, marine protected areas or Maritime Reserves where any damage to the environment would potentially result in a considerable media interest and political ramifications.

Therefore, the modern VTS should consider two aspects of environmental monitoring:

* Navigation Data Collection
* Environmental Protection

Navigation Data Collection includes the traditional environment monitoring sensors, typically referred to as the hydrological / meteorological (hydro/meteo) systems. Typical meteo variables are those provided by weather stations and include air temperature and humidity, wind velocity and direction, and visibility. In certain locations, hydro variables such as tidal level, and current direction and velocity may also be required. Hydrological data may be obtained through real sensors or available in predictive tables/databases from national authorities. Sensors providing this data, usually are located at remote sites and communicate data to a VTS centre via a telecommunications or radio link. Alternatively, wave height, direction and surface current could be derived from the main VTS radar through software processing. The accuracy of such measurements from dedicated sensors and from analysis of radar originated data should be evaluated as part of the VTS design process.

An Environmental Protection system would include implementing additional capability that would provide early detection of any polluting incidents that may be caused by visiting vessels. This early detection of pollution could be achieved though the software processing of the VTS radar signals or by specialist sensors that are designed to detect oil, or other pollutants, in the water.

At the VTS centre, detected pollution information should be presented, in graphical or numeric format, for use by the operators.

### Scope

The aim of **Error! Reference source not found.** of this recommendation is to:

* identify functional and operational requirements for gathering, processing and display of environmental data in VTS; and
* provide guidance on design and installation of such equipment

### Objectives

Hydrological, meteorological, Oil Spill and any other environmental information, that the VTS Authority requires, may be integrated into VTS applications to provide the operator a real-time assessment of the environmental situation in the VTS area of responsibility. Information collected from this equipment can be provided to ships to assist in assessment of the prevalent conditions.

A number of countries operate tide gauges and current meters to assist the prediction of tidal heights and streams or for the broadcast of real-time information to shipping. The Intergovernmental Oceanographic Commission (IOC) is responsible for co-ordinating the Global Sea Level Observing System (GLOSS) program to establish global and regional networks of sea level stations for providing essential information for international oceanographic research programmes. GLOSS operates under the Global Ocean Observing System (GOOS) http://gosic.org/ios/GOOS-Main-Page.htm. IALA supports and encourages participation in the GLOSS program.

## References

There are many applicable IMO, IEC, WMO and other requirements. These include, but are not limited to:

|  |  |
| --- | --- |
| IMO Resolution A.686(17) | Code on Alarms and Indicators (and MSC.39(63) Adoption of amendments to the Code on Alarms and Indicators) |
| IMO Resolution A.694(17) | General Requirements for Shipborne Radio Equipment forming Part of the Global Maritime Distress and Safety System (GMDSS) and for Electronic Navigational Aids |
| IMO | SOLAS (i.e. Chapter V, Regulation 12) |
| IEC 529 | Degrees of protection provided by enclosures (IP Code) |
| IEC 721-3-6 | Classification of environmental conditions |
| IEC 60945 | Maritime Navigation and Radio communication Equipment and Systems |
| WMO | International Meteorological Vocabulary  Guide to Meteorological Instruments and methods of Observation |
| IEC 61162 | Digital Interfaces for Navigation Equipment within a Ship |

### Definitions

For general terms used throughout this annex, please, refer to the World Meteorological Organization (WMO).

## Characteristics of Environmental Sensors in VTS

The hydro/meteo sensors used for VTS systems may be installed at VTS centres or other related sites such as radar sites however they might also be sited on third party sites e.g. a navigation buoy/beacon or lighthouse. These sensors measure parameters such as wind speed/direction, barometric pressure, air temperature and current speed/direction in real time. The hydro/meteo data is then transmitted to the VTS centre and presented to the VTSO in order to support decision making associated with the safe navigation of vessels and protection of the environment. In cases of severe weather conditions this information is particularly important.

## Functional Requirements

This section describes the essential functions of the hydro/meteo system for inclusion and integration within the overall VTS system.

Environmental measurements are made by dedicated and/or multipurpose sensors positioned throughout the VTS area (and its approaches) such that an overall environmental picture can be determined, taking account of the possibility of anticipated variations arising from the particular geography of the VTS location.

Measurements are transmitted by the communication system to a VTS centre for analysis, system wide processing and subsequent display to the VTSO in user-selectable format. The measured data is to be presented both numerically and graphically (in chronological order).

The VTS Authority may also require such data to be stored for a predefined period (up to one year).

It is essential that a VTS Centre also has access to external local hydro/meteo information relevant to the VTS area(s). In addition, the VTSO (or automatic processing within the data management processing) can, if required by the VTS Authority, disseminate the available environmental data to the VTS users (shipping etc.) and to external allied services.

A VTS centre can pass the measured hydro/meteo information to vessel(s) in the VTS area(s) by an appropriate communication link.

## Operational Requirements

Briefly, operational requirements have qualitative and quantitative parameters that specify the desired capabilities of a coherent environmental measurement system and serve as a basis for determining operational effectiveness.

Operational requirements may include ergonomics, operational controls and information presentation. Due to the varied nature of hydrological and meteorological equipment in VTS, it is not possible to specify ergonomic or operational control requirements.

### Information Presentation

The results of the measurements should be transmitted in WMO standard units and displayed in user-selectable format.

The measurements should be available to VTS operators through an integrated or dedicated display(s). Data may be presented numerically and/or graphically. A log of the latest 24 hour measurements should be available to the VTS operators either numerically or graphically.

### Malfunctions and Indicators

As a minimum requirement, malfunctions, warnings, alarms and indicators should respond to the requirements of IMO Resolution A.686(17) and MSC.Circ.39(63). Additional requirements may be required, depending on the individual type / purpose of sensor.

In particular, where measurements from a number of sensors overlap or provide coverage for adjacent areas, the identification of potentially anomalous readings should be included within the functionality of the data processing to reduce the possibility of incorrect decisions and to highlight the need for maintenance or inspection of the sensors.

### Accuracy

Where a VTS Authority determines a need to establish their own monitoring stations, it should be noted that the individual VTS Authorities, in conjunction with hydrographical and meteorological experts, should determine the accuracy and availability requirements for each VTS Centre, as these will be based on individual circumstances. Table 4‑1 gives an indication of typical measuring range and minimum accuracy requirements for various common environmental parameters..

Note: The availability requirement should be as prescribed by IMO A.915(22).

Table 4‑1 Environmental Sensor Requirements

| **Parameter** | **Measuring Range** | **Minimum Accuracy** | **Remarks** |
| --- | --- | --- | --- |
| Height of Tide | 0 to 20 m (or greater) | ≤ ± 0.01 m |  |
| Rate of Tidal Stream/ Current | 0 to 10m/s | ≤ ± 1% | Maximum value to reflect local conditions |
| Direction of Tidal Stream/Current | 0° to 360° | ≤ ± 5° |  |
| Wave height | 0 to 20 m | ≤ 0.1 m, for ≤ 5 m  ≤ ± 10%, for > 5 m |  |
| Wave Direction | 0° to 360° | ≤ ± 20° |  |
| Wind speed | 0 to 75 m/s | ± 0.5 m/s, for ≤ 10 m/s  ± 5%, for > 10 m/s |  |
| Wind Direction | 0° to 360° | ≤ ± 3° |  |
| Visibility | 10 to 20,000 m | ≤ 50 m, for ≤ 600 m  ≤ 10%, for 600 m – 1500 m  ≤ 20%, for > 1500 m |  |
| Air Temperature | -10° to +50° C | ≤ ± 0.3° C | The measuring range should be aligned to the applicable Hot, cold climate category area |
| Air Humidity | 0 to 100% RH | ≤ ± 2% RH |  |
| Air Pressure | 920 to 1080 hPa | ≤ ± 0.3 hPa |  |
| Sea Surface Temperature | -2° to + 40° C | ≤ ± 0.5° C | The measuring range should be aligned to the applicable Hot, cold climate category area |
| Ice Coverage | - | - | Typically, measured by satellite remote sensing |
| Ice Thickness | - | - | Typically, measured by satellite remote sensing |
| Oil spill | - | - | Typically measured by satellite or radar remote sensing |
| Salinity | 0 to 70 PSS | ≤ ± 1% |  |

Note: For air temperature, air humidity, air pressure and salinity accuracy. The accuracy values may be sufficient for shipping activities but if the information is to be used for scientific purposes (eg. oil spills, environmental responses etc.) these values may need to be more stringent.

The VTS system requirements should also specify the time periods over which the various data parameters should be updated and may be averaged, if required, as these factors will depend upon the local circumstances pertaining to the VTS Centre.

#### Reliability, Accuracy, Range, Resolution and Units

The reliability, accuracy, range, resolution and units of the measurements should satisfy the minimum requirements as determined by WMO.

### Technical Requirements

For hydro/meteo systems within a VTS system, measurement sensors should be installed and located by the VTS authority in consultation with hydrologist/meteorologist(s) and local authority standards. The Sensor identification and location should be provided.

The measurements/sensors may include:

* Wind speed / Wind direction / Wind gust
* Air temperature / Relative humidity
* Precipitation
* Barometric Pressure (atmospheric pressure)
* Visibility
* Water temperature / Water level
* Height of tide
* Current speed (may be required at various depths)
* Current direction (may be required at various depths)
* Wave height / direction (also used to indicate wave height anomalies that might indicate oil spill)
* Ice coverage / thickness
* Salinity

## Design, Installation and Maintenance Considerations

Key aspects to design and installation include:

* Suitability to meet range, accuracy and update rate requirements
* Location within the VTS area and its approaches
* Durability and resistance to environmental conditions
* Interference
* Power supply requirements /options
* Installation
* Maintenance, and
* Interfacing
* Back-up arrangements
* Safety Precautions

### Suitability to Meet Range, Accuracy and Update Rate Requirements

Individual sensors (multipurpose where appropriate) should be selected to provide the specified range, accuracy and update rate requirements.

### Location within the VTS Area and its Approaches

The network of environmental sensors should be part of a coherent sensor network designed to achieve the VTS system needs (coverage, appropriate accuracy in areas of different assessed risk, redundancy etc.)

### Durability and Resistance to Environmental Conditions

Electronics installed externally should be in a suitable environmental enclosure. IEC requirements for environmental conditions should be applied as practicable.

### Interference

These sensors should comply with applicable international standards and regulations. IEC requirements (IEC 60945) refer.

### Power Supply Requirements / Options

Relevant IEC requirements should be applied. In remote locations, due to the low power, consumption of hydro/meteo sensors, authorities should consider use of alternative power (e.g., solar panels, wind vanes, etc.), in lieu of generators, when commercial power is not available.

### Installation

Requirements concerning the installation of sensors, wiring and the arrangement of the equipment providing hydro/meteo information to the VTS centre should be determined in accordance with national and international standards where applicable. Operational requirements will determine where sensors are to be located and how many are required. Sites for sensors should be selected based upon optimising data relevant to the VTS. Other considerations include:

* availability of power,
* protection against vandalism,
* housing and co-location with existing VTS, AtoN, or other suitable infrastructure

Relevant IEC requirements should be applied. For example:

* IEC 529 "Degrees of protection provided by enclosures (IP Code)"
* IEC 721-3-6 "Classification of environmental conditions, Part 3: Classification of groups of environmental parameters and their severities; Ship environment"
* IEC 60945 "Maritime navigation and radio communication equipment and systems - General requirements, methods of testing and required test results"
* Local national wiring standards / regulations

The environmental requirements for operation and survivability of environmental sensors and associated equipment should be determined by the VTS authority and referred to Annex 1, 1.5 General design, configuration installation and maintenance consideration.

### Maintenance

Possible requirements, in addition to IMO Assembly Resolution A.694(17) concerning maintenance, should be determined. Location considerations for sensors should include maintenance, repair, and accessibility requirements.

### Interfacing

The typical information to be interfaced for the hydro/meteo service are described under the Operational Requirements, see section 4.5’.

For the interfacing of hydro/meteo services to VTS equipment, several different standards are in use. Among those standards, IEC 61162, Digital Interfaces for Navigation Equipment within a Ship (part 1 and part 3), has been applied for these applications. In addition, the WMO has developed an interface standard for hydro/meteo applications.

For the interface between a VTS and its users, hydro/meteo data should follow standardized data exchange formats, e.g., XML. (In addition, a time stamp and source should be provided.)

### Backup Arrangements

Depending on the individual type of the equipment, requirements concerning back-up and fall-back arrangements should be determined based on VTS requirements, availability and risk assessment.

### Safety Precautions

Depending on the individual type of the equipment, requirements in addition to IMO Resolution A.694(17) should be determined based on local occupational health and safety requirements and regulations.

# 

# Electro Optical Equipment

## Introduction

An Electro-Optical System (EOS) consists of imaging devices, such as daylight CCTV, day/night CCTV, Infrared- and laser-illuminated cameras.

Imaging devices (or sensors) provide visual situational awareness and can be used as primary VTS sensors, as additional sensors to Radar, AIS and other sensors and for perimeter and building surveillance.

When used as a VTS sensor, EOS data may be integrated into VTS applications to provide the operator real-time situational awareness within the range of the EOS equipment.

### EOS Components

An EOS is made up of the following components:

* The imaging device that produces the actual electronic image
* The lens that creates the field of view and focuses the incoming light onto the image device
* The sensor housing
* For Pan, Tilt, Zoom (PTZ) EOS, the electromechanical system that moves the camera and allows the lens to zoom in and out.

## References

|  |  |
| --- | --- |
| Electronics Industry Association (EIA) | Recommended Standard RS-170 |
| IMO | SOLAS Chapter V (Safety of Navigation) – Regulation 12 |
| IEC 61162-1 | Digital Interfaces for Navigational Equipment within a Ship (also known as NMEA 0183) |
| IEC 529 | Degrees of protection provided by enclosures (IP Code) |
| IEC 721-3-6 | Classification of environmental conditions, Part 3: Classification of groups of environmental parameters and their severities; Ship environment |
| IEC 60945 | Maritime navigation and radio communication equipment and systems - General requirements, methods of testing and required test results |
| IEC 60825-1 | Safety of laser products |
| ISO/IEC 13818-2 | Generic coding of moving pictures and associated audio information: Video |
| ITU-T Recommendation H.263 | Video coding for low bit rate communication |
| ITU-T Recommendation H.264 | Advanced video coding for generic audiovisual services |

## Characteristics

### Definitions

The following definitions are used within the context of an imaging system:

**Detection**: The VTSO can observe an object on the water surface.

**Recognition:** The VTSO can recognize an object and classify it according to its shape (such as a container ship or a ferry boat)

**Identification:** The VTSO can positively identify the object (e.g. ship name or MMSI)

### Electro-Optical Systems

In most cases, EOSs are used in limited areas, not necessarily covered by other sensors, or are used to provide supplementary information, such as visual identification. In some cases, EOSs are used as the primary surveillance system, for example, within a port, harbour or locks.

Within the context of EOS, there is an extensive range of technology and characteristics available. These characteristics range from simple, short range, day light only surveillance capability up to very sophisticated long range thermal and day/ ­night capable technology.

Additional characteristics to be considered with regard to EOS include, the use of fixed cameras versus the benefits of pan, tilt, zoom (PTZ) cameras, as well as width and depth of field of view, image sensor resolution, and light sensitivity.

The level of sophistication of the EOS determines whether the sensor continues to operate in less than optimum conditions, i.e. in fog and rain and during night time. This aspect should be taken in to account when considering the use of EOS for VTS surveillance.

The output of an EOS can be displayed on a dedicated display or be integrated within the VTS traffic situation display, including the control of the EOS system itself.

In order to support high definition video with useable frame rates, data bandwidth requirements for remote high-definition EOS sensors can be very demanding. Care should be taken in analysing the bandwidth requirements when planning the implementation of high-definition EOS sensors.

Where more than one camera is installed to cover a VTS area, it may be desirable for the output from multiple cameras to be provided in one composite picture.

In addition to the sensors themselves there is also a wide range of image processing capability available. These capabilities range from simple video presentation to sophisticated image processing including image recognition and analysis, automated tracking and alerting/alarm capabilities.

VTS authorities should carefully consider the requirements for EOS systems, based on operating hours, cost/benefit and maintenance cost.

## REQUIREMENTS

### Operational Requirements

#### Sensor Site Selection

Factors to be taken into account, when deciding on where to place an EOS sensor, include:

* The desired line of sight, field of view and the required operational range for the sensor.
* The availability of existing infrastructure, such as power, data commun­ications and physical security. Where possible, consideration should be given to co-locating a new EOS sensor with existing or planned sensors, e.g. radar.
* Maintenance should be considered in view of access to the camera location, the replenishment of consumables (e.g. wiper liquid) and installation of replacement parts as well as vehicle access.
* The presence of strong and/or intermittent light sources that can adversely affect the performance of the EOS sensor, in particular for low-light and infrared cameras.
* The presence of man-made structures, such as cranes, cooling towers and chimneys, all of which can either block the field of view or significantly affect local environmental conditions – consider, for instance, emissions from cooling towers

#### Sensor Selection

Operational requirements to be considered, when selecting a particular type of EOS, include:

* VTS night time operation – extended night operations in a particular area will typically require use of low-light, day/night, IR- or even laser-illuminated capable imaging sensors
* The intended use of the EOS as either primary sensor for the area or the anticipated use as a supporting sensor
* The typical environmental conditions in the operational area. Prevailing dust conditions, the proximity to salt sprays, the occurrence of heavy rains and high ambient temperatures and so on, will dictate the minimum technical capabilities of the imaging sensor.

#### Detection, Recognition and Identification

Detection needs should be carefully considered when specifying the functional requirements for an EOS sensor. The operational requirement should specify at what maximum range a VTSO should be able to detect a target. Table 5‑1 provides the recommended minimum performance requirements for various focal lengths (35 mm equivalent Field of View).

**Table 5‑1** EOS Recommended Minimum Performance Requirements

|  |  |  |  |
| --- | --- | --- | --- |
| **Lens Focal Length**  **(35 mm equivalent)** | **Detection** | **Recognition** | **Identification** |
| 140 mm | 5.8km | 1.6km | 800m |
| 50 mm (50° FoV) | 2.2km | 580m | 290m |
| 19 mm | 880m | 230m | 110m |

#### Recording and Replay

EOS sensor data should be recorded automatically. VTS Authorities should be able to replay this data synchronised with other sensor recordings. Replay of EOS data should not interfere with the on-going VTS operation and may require separate display systems.

The impact of storage requirements for high-resolution video data, especially if several EOSs are used, can be quite significant. The VTS Authority should carefully consider the quality of recording as well as meeting the legal requirements for the storage of historical data.

### Functional Requirements

#### Pan, Tilt and Zoom

EOSs can be fitted on a fixed platform or mounted on an electromechanical Pan, Tilt, Zoom (PTZ) frame. The latter allows a considerable amount freedom in pointing the EOS to a target or a particular area of interest.

Fixed sensors are typically placed so as to provide general surveillance of a fixed area of interest, such as fairways and approaches to bridges and locks.

PTZ sensors can be controlled directly by the VTSO, typically using a joystick or keyboard. PTZ sensors can be a shared resource between, for example, a Harbour Master and VTS, therefore the VTS authority may need to publish a code of practice to govern EOS sensor operation.

Depending upon the level of integration with the VTS system, the PTZ could also be controlled through the VTS application.

The VTS application could:

* control the sensor via automated tracking of a target, observed by the VTS,
* configure the sensors to react to various events, such as:
  + anchor watch violations,
  + traffic separation violations.
* allow the VTSO to direct a PTZ sensor to survey a specific area, zone or activity, for instance, pilot boarding and disembarking operations
* allow the VTSO to set up automated scan sequences to cover selected areas in turn

#### Precision and Repeatability

Precision refers the ability to set the pan, tilt and zoom to the requested position within a certain tolerance. Repeatability refers to the ability to reliably recreate a certain setting.

The required degree of precision will depend on the application of the EOS. For example, a long range surveillance sensor, at maximum zoom will have a narrow field of view. Therefore, in this case, the PTZ should have a high degree of precision. Conversely, an EOS sensor with a wider field of view will not require such a precise PTZ. In both cases, the repeatability should be more or less the same.

#### Auto Focus

Focus should be an intrinsic and automated function within the EOS and should be specified accordingly.

#### Image Processing

EOS systems are susceptible to vibrations, due to wind or nearby equipment, such as a rotating radar antenna. VTS authorities should consider specifying anti-vibration capabilities in the EOS, such as image stabilizers.

There are many processing techniques available which enhance images or derive information from images and these continue to evolve. For example, objects within the field of view of the EOS can be tracked by the EOS, allowing the EOS to automatically follow a designated target.

VTS authorities should work with equipment suppliers to determine which of these techniques and the resulting capabilities are appropriate for the VTS in question.

#### Configuration

VTSOs should only need to have access to an agreed set of operational functions. Configuration, tuning, maintenance and advanced set-up functions should be restricted to designated support personnel.

## Design, Installation and Maintenance Considerations

### Durability and Resistance to Environmental Conditions

#### Vibration

EOS systems may be susceptible to performance degradation due to excessive vibration of the installation. This is particularly relevant in strong wind conditions.

VTS authorities should ensure that the supporting infrastructure for the EOS is able to handle the expected environmental conditions and meets any appropriate building regulations.

#### Specific Environmental Safeguards

VTS authorities should require EOS systems to have the following external and internal environmental safe guards where appropriate:

* Lens wash/wipers
* Replaceable clear lens filters to protect exposed optics
* Internal heaters and anti-condensation capabilities
* Mechanical lens protection – e.g. for thermal cameras

### Data Communications

EOS data has significant demands on available bandwidth and due consideration should be given to ensure that sufficient bandwidth is available. Bandwidth requirements can be reduced by using video data compression techniques. It is recommended that VTS authorities consider using standard video data compression for EOS data, such as MPEG-2 (IEC 13818-2), H.263 or H.264. An added benefit of data compression is reduced storage requirements for recordings. Depending on the EOS system, proprietary compression techniques could be considered, however these may not necessarily improve the bandwidth efficiency.

It should be noted that when using a particular video data compression technique, image quality may be reduced as compared to uncompressed data.

Modern Cameras are typically supplied with direct digital output. Where cameras are selected that do not have digital output, it is recommended that digital encoders are included in the overall design and installed at the sensor head. The reason for this is that analogue signalling will require a separate infrastructure, whereas encoded video can be distributed across existing networks.

### Maintenance

The routine maintenance effort for EOS sensors can be quite considerable. In particular, high-end, thermal and laser-gated sensors may include features, such as cooling, housing wash and wipe and PTZ units that require maintenance of the mechanical parts. This has significant impact upon EOS MTBF figures. VTS authorities should consider these issues when selecting such devices.

Given that EOS sensors are often installed high on towers or on dedicated poles, care should be taken to ensure that access for cleaning, maintenance and replacement is taken in to account.

### Laser Safety Precautions

Some types of EOS sensors use laser devices to illuminate the area of interest. Such equipment should conform to IEC 60825-1- “Safety of laser products” and relevant national standards.

# Radio Direction Finders

## Introduction

RDF is a sensor system that supports VTS and SAR operation by indicating the direction/bearing to a VHF transmitting station. Since a RDF only indicates bearing, two or more appropriately located RDFs are needed to estimate the position of the transmitting station.

RDF can be used to correlate a VHF transmission with a particular target thereby identifying the target in question. This is particularly useful if the target does not have AIS and cannot be identified otherwise.

Another use of RDF is to estimate the position of a transmitting station that is not detected otherwise, e.g. because of its small size.

RDF is not suitable for continuous tracking since it can only estimate a position while the target is actually transmitting.

## Operational Requirements

VTS authorities should consider the need for an RDF system based on the type of traffic in the VTS area, such as the presence of non-SOLAS class vessels and recreational vessels that do not carry an AIS transponder (assuming the VTS is able to receive AIS data). The VTS authority should assess the requirement for a RDF system based on a risk assessment of these and other relevant factors.

When a RDF system is assessed as being necessary, the VTS authorities should, at least, consider the following:

1. The required RDF coverage area, based on
   1. possible RDF location(s),
   2. waterway structure and navigational hazards,
   3. the types of ships to be detected,
   4. expected meteorological conditions.
2. The declared VTS level of capability and possible responsibilities for SAR
3. Required bearing accuracy
4. The required frequency range of the RDF equipment (this may e.g. include frequencies used for SAR)
5. The number of simultaneously monitored VHF channels
6. Other influencing factors, such as obstructions in the line of sight and the presence of potential reflective surfaces, which may reduce the performance of an RDF system.

### RDF Coverage Area

The RDF coverage area needs to be consistent with the declared VTS level of capability, the results of risk assessment and possible VTS responsibilities for SAR.

The detection performance of a RDF across the coverage area should be sufficient to detect 95% of the traffic that cannot be identified by others means, such as AIS.

Factors affecting the detection performance of RDF systems, including potential interference and propagation characteristics, shall be taken into account as well as special local conditions, such as heavy rainfall.

In order to allow accurate identification in the main area of operation with two or more RDF stations, the bearing angles on target should cross close to 90º (the position accuracy with two or more RDF stations degrades very rapidly when the bearing angles do not cross at 90º; in the extreme cases of 0º and 180º crossing angles no position estimation is possible). This may pose significant restrictions on the potential locations of the RDF stations.

The recommended method for determination of RDF coverage and range performance is a combination of site inspections and RDF system performance calculations. Figure 18 provides an example of such a calculation.



Figure 18 Estimated Position Accuracy of a RDF Configuration

The evaluation should include:

* Calculation of VHF Radio Range based on RDF antenna height and minimal VHF antenna height on the target of interest
* Calculation of all applicable losses (target’s VHF transceiver power, required RDF sensitivity, losses in VHF cable etc.)
* Evaluation of the effects from propagation conditions and obstructions
* Influence of meteorological conditions

The calculations may be supplemented by comparison and/or validation test.

### Declared VTS Level of Capability

The need for RDF stations??? Is RDF needed for a VTS area of level “Basic”?

### Bearing Accuracy

One of the most important performance parameters of the Radio Direction Finder system is the bearing accuracy. Besides the technical characteristics of the RDF equipment, many other factors may significantly reduce the bearing accuracy in real conditions. Therefore, the following aspects should be taken in account when assessing bearing accuracy:

* The specified RDF equipment bearing accuracy - typically specified for “near to ideal” conditions.
* The environment of the RDF antenna. Multipath signal propagation, caused by reflections from surrounding objects, can significantly deteriorate the bearing accuracy.
* The received signal strength. Low received signal levels may significantly reduce the bearing accuracy. Major factors affecting received signal strength are:
* Distance to the target
* RDF receiver(s) sensitivity, antenna gain and feed losses
* Weather conditions
* Output power and duration of transmitted signal
* The delay between signal detection and output for presentation should be no more than 3 seconds. The main cause of this delay is the internal processing of the received signal within the RDF system to achieve declared accuracy.

In order to achieve the best possible performance, proper calibration is essential and will mitigate against the adverse effects of some of the factors listed above.

The recommended bearing accuracy for different levels of capability is provided in **table 6‑1**.

**Table 6‑1** Recommended Standard Deviation of the RDF Bearing Accuracy

|  |  |  |
| --- | --- | --- |
| **Level of Capability** | | |
| **Basic** | **Standard** | **Advanced** |
| ≤ ± 5º | ≤ ± 3º | ≤ ± 2º |

### Frequency Range

Since the main purpose of RDF is detection of VHF communication devices, the frequency range of RDF should, at least, correspond to the frequencies used for marine VHF communications. Additionally, support for standard SAR frequencies (121.5 MHz, 243 MHz and 406 MHz) may be required if the VTS authority has a responsibility for SAR operations.

### Number of Simultaneously Monitored VHF Channels

RDF may support simultaneous or almost simultaneous reception on multiple VHF frequencies. This can be achieved using one or several VHF receivers (typically 4-8).

The single-receiver RDF can be switched to any VHF channel at any time. This can be done manually or automatically (when the RDF receiver scans a pre-defined list of VHF channels).

There may also be a need to monitor several VHF channels at the same time. For example, SAR channels and VHF channel 16 may be required to be monitored simultaneously, while all other VHF working channels are monitored selectively. In such a situation, the use of a multiple-receiver RDF is required.

## Functional Requirements

### VHF Channel Management

There are two types of RDF systems available on the market:

* RDF systems with a single-channel receiver
* RDF systems with a multi-channel receiver

RDF systems with a multi-channel receiver may simultaneously receive and process multiple frequencies. Which RDF system is appropriate for the VTS authority should be determined from the operational requirements.

Single-channel receiver RDF systems should, as a minimum, include:

* Remotely controlled selection of VHF channel
* Automatic channel scan function from a pre-defined list of working channels
* If relevant, prioritization of SAR channels in scanning mode

Multi-channel receiver RDF systems should, as a minimum, include

* Remotely controlled selection of VHF channels for each receiver
* Automatic channel scan function from a pre-defined list of working channels for one or more receivers
* Simultaneous output of detected bearings for all receivers

### SAR Functionality

Where VTS authorities have SAR responsibilities, additional functionality of RDF equipment may be required, such as:

* Detection of devices transmitting on SAR frequencies
* Automatic filtering of Emergency Location Transponder (ELT) tones of Man-Overboard EPIRB devices
* Receiving and decoding of COSPAS/SARSAT signals

### Man Overboard EPIRB Detection Capabilities

This capability ensures detection of specific standardized ELT codes transmitted by EPIRB devices. It minimizes the probability of false alarms, caused by spurious transmissions on SAR frequencies.

### COSPAS/SARSAT Detection and Decoding

This capability ensures reception and decoding of digital data transmitted by COSPAS/SARSAT radio beacons. Received data contains the identification number and the measured geographic coordinates of the radio beacon, which can be used for SAR planning.

### Built-In Test and Diagnostics

Built-in test features should include monitoring of functions and performance and should be accessible remotely.

## Design, Installation and Maintenance Consider­ations

### Antenna Installation

RDF antenna installation requires careful consideration, especially with regard to the site. The following aspects should be considered:

* The RDF antenna should be placed on a very stable support to avoid any rotation or torque as this directly affects RDF bearing accuracy
* The antenna height should be sufficient for detection of VHF transmissions from the targets of interest across the coverage area
* The presence of objects and geographic features that might cause reflections or the blocking of signals
* Rotating or moving objects (like radar antennas and PTZ CCTV) should be a safe distance from the RDF antenna (see manufacturer’s instructions)

### Lightning Protection

Typically, a RDF antenna is placed on the very top of a mast, so special attention should be paid to lightning protection of the structure. It should provide adequate lightning protection without causing reflections and/or obstruction of the incoming VHF signals.

### Calibration

Calibration should be performed according to the manufacturer’s instructions and should be revisited if there are significant changes to the equipment and/or environment.

# Long Range sensors

## Introduction

VTS equipment provides the VTS Authority with real-time data from short range line-of-sight sensors, such as radar, CCTV and AIS. On occasions, the use of information, derived from long-range sensors (typically long range radar, satellite communications systems and satellite AIS), can provide supplementary information. It may assist in locating vessels that have not arrived on schedule or detect vessels that arrive unannounced. It allows authorities to assess potential security risks or, should the need arise, provide input data for search planning in case of a SAR incident.

Typical long range sensors include:

* LRIT (Long Range Identification & Tracking)
* Satellite AIS
* HF Radar
* Satellite-based Synthetic Aperture Radar (SARSAT)

This annex provides an overview of each of the above and identifies the applicability, benefits and limitations of these sensors to VTS and Coastal Authorities.

## Long Range Identification and Tracking (LRIT)

LRIT is a mandatory carriage requirement for SOLAS vessels. It provides a ship position report at regular intervals based upon the area of operation. The normal reporting interval is every 6 hours. LRIT data is received by International Data Centres (IDC) and is available to the flag authority and to the maritime authorities of transit and destination countries.

In circumstances where a vessel has arrived unexpectedly or gone missing, the historical LRIT information may provide the additional information needed for a security assessment or the planning of search activities.

### Specific Design, Configuration, Installation and Maint­enance Considerations

LRIT is an established service and, subject to approval by the national maritime authority, the VTS Authority can access the International Data Centre and integrate appropriate LRIT data with relative ease.

It should be noted that LRIT data normally carries an airtime cost per position report and that the IDC may charge for the provision of the data.

As the applications for LRIT data continue to evolve, other uses and benefits may be determined and implemented.

## Satellite AIS

An AIS satellite listens to AIS transmissions within its footprint area and stores the data on-board until it passes over a ground station, to which the data can be downloaded. Satellite AIS has a potentially global coverage, particularly now that dedicated VHF channels are allocated to satellite AIS.

The AIS satellite may receive several AIS transmissions in the same time slot, particularly in dense traffic areas. Such data collisions may make it impossible to properly decode the individual AIS messages again, resulting in inaccurate or completely wrong positions, despite the use of advanced de-collision algorithms.

An AIS satellite will only be able to download data when it is in range of a ground station. This means that the data received by the VTS Authority will not be real time and may be up to 2 hours old (or possibly more).

AIS satellite systems comprise several satellites in different constellations, i.e. a polar-orbiting constellation or a mix of equatorial and polar orbiting satellites. The effect of different orbiting constellations will impact when and for how long ground stations can be accessed to download AIS data. The more frequently the satellite can download the data, the less latency between the received data and the real time position of the actual vessels.

Satellite AIS data is provided through a Service Provider to which the VTS Authority will need to subscribe and is now becoming increasingly available via commercial as well as national government-sponsored satellite AIS operators.

### Specific Design, Configuration, Installation and Maintenance Considerations

The main difference between the terrestrial and satellite AIS data, besides the geographic coverage, is the data latency, i.e. the age of the AIS message when it is actually received by the VTS system. This is generally not a problem, because long range data is used for strategic purposes, where accuracy is less relevant than coverage.

Satellite AIS is an established service that does not require any special design, configuration or installation on the part of the VTS Authority as these are handled by the satellite AIS Service Providers. Once the VTS Authority has subscribed to the AIS satellite service, it will be able to integrate the satellite AIS data as appropriate for his operational requirements.

As the applications for satellite AIS data continue to evolve, other uses and benefits may be determined and implemented.

## HF Radar

One rarely used technology that can offer long range detection of vessels is HF radar. HF radar has one major advantage over other long range detection technologies in that it does not require cooperation from the vessels to be detected.

There are generally two types of HF radars, those that use the low level earth surface “hugging” refraction duct and those that use reflection from the layer to layer boundaries in the ionosphere above the earth (sky wave). Both system types suffer from unpredictable propagation path characteristics, which can support medium and large object detection (metal ships) to hundreds of nautical miles in some conditions, but often offers very little detection performance. This makes specification of achievable performance and detection “availability” a challenge to both radar customers and radar suppliers. The vagaries of the propagation paths can also introduce unpredictable positional measurement errors affecting both angle and range even when an object is clearly detected.

HF radar installation requires some careful selection of suitable coastal terrain which may not suit all potential VTS locations. Similarly, suitable sites will rarely support the necessary infrastructure (power, communications, access for installation and maintenance) and these need to be factored into the installation and operational costs.

Finally, optimising the nature of HF radar may impose high workload on specialised, highly trained operators.

If the limitations are acceptable, this technology offers valuable passive detection in open waters, expensive to obtain by other means (airborne sensors and satellite). Realistically, however, HF radar systems are not used for VTS purposes.

## Synthetic Aperture Radar (SARSAT)

Satellite-based Synthetic Aperture Radar (SARSAT) can provide vessel target information at ranges beyond that of shore-based sensors, including HF Radar. However, such services will probably only provide a single image of a specific area once per day through a few orbiting satellites. Images are stored on-board the satellite until they can be downloaded as the satellite passes over a ground station. The image is processed, following download from the satellite, to detect ships within the area and radar information (without identity) can be derived that can be used to recognise the type of vessel. This type of service is for analysis of vessel movement and not for any form of near real time monitoring. In addition to the latency between the required image capture and the download when passing over a ground station, there is also a further latency related to the processing of the received data.

SARSAT may, for example, be useful for detecting illegal fishing activity in remote areas of a country’s Exclusive Economic Zone and for detecting oil spills and pollution.

### Specific Design, Configuration, Installation and Maintenance Considerations

SARSAT is available from a variety of established service providers and does not require any special design, configuration or installation on the part of the VTS Authority. The VTS Authority will need to subscribe to a SARSAT image service and costs are involved on a per image basis. Once access to such a service has been established, the VTS Authority will be able to integrate the SARSAT target data as appropriate for his operational requirements.

# Radio Communications in VTS

## Introduction

Radio communication equipment is typically integrated into VTS applications to provide the operator with a real-time assessment of the situation in the VTS area of responsibility as well as a means to deliver timely services to VTS participants. Information collected and disseminated via this equipment can assist in assembling the traffic image and in supporting safe navigation of the VTS area.

## References

|  |  |
| --- | --- |
| IMO SOLAS | Relevant SOLAS requirements;   * SOLAS Chapter IV (Radio Communications) * SOLAS Chapter V (Safety of Navigation) – Regulation 12 * SOLAS Chapter V (Safety of Navigation) – Regulation 19 |
| IMO Resolution A.694(17) | General Requirements for Shipborne Radio Equipment forming Part of the Global Maritime Distress and Safety System (GMDSS) and for Electronic Navigational Aids |
| IALA | IALA World Maritime Radio Communications Plan, Edition 1 |
| IEC 60945 | Maritime navigation and radio communication equipment and systems - General requirements, methods of testing and required test results |
| ETSI EN301 929-2 v1.2.1 | Electromagnetic compatibility and radio spectrum matters (ERM): VHF transmitters and receivers as Coast Stations for GMDSS and other applications in the maritime mobile service |
| ITU-R M.493-11 | Digital selective-calling system for use in the maritime mobile service |
| ITU-R M.541-9 | Operational procedures for the use of Digital Selective Calling equipment in the Maritime Mobile Service |
| ITU-R M.689-2 | International maritime VHF radiotelephone system with automatic facilities based on DSC signalling format |
| ITU-R M.1082-1 | International maritime MF/HF radiotelephone system with automatic facilities based on DSC signalling format |
| ITU-R M.1842-1 | Characteristics of VHF radio systems and equipment for the exchange of data and electronic mail in the maritime mobile service |

## Characteristics of Radio Communication Equipment

Radio communication is the central ingredient in the operation of VTS. Radio communications links are used to collect position, safety, and general information from shipboard personnel and remote sensing devices. These links are also the primary means through which services are delivered to VTS participants.

### Coverage

Radio communication equipment are adapted to guarantee the coverage of the GMDSS ( www.imo.org):

* Area A1 - Within range of VHF coast stations with continuous DSC (digital selection calling) alerting available (about 20-30 miles)
* Area A2 - Beyond area A1, but within range of MF coastal stations with continuous DSC alerting available (about 100 miles)
* Area A3 - Beyond the first two areas, but within coverage of geostationary maritime communication satellites (in practice this means Inmarsat). This covers the area between roughly 70° N and 70° S.
* Area A4 - The remaining sea areas. The most important of these is the sea around the North Pole (the area around the South Pole is mostly land). Geostationary satellites, which are positioned above the equator, cannot reach this far.

### VTS Radio Communication

VTS radio communication comprises both voice and data services and potentially video applications using equipment within the frequency bands indicated above for the relevant GMDSS area.

#### Very High Frequency (VHF)

The Maritime VHF band comprises a number of channels within the frequency range of 156 MHz to 162.025 MHz. These are mainly used for voice communication except channel 70 (DSC) and the channels allocated specifically for AIS. The VTS Authority may require VHF Channels to be designated / licensed by the National Radio Authority for specific types of operations (e.g. Coast Station Radio License). Specific channels are determined to provide safety watch, DSC and VTS information.

The VHF equipment shall comply with national and international regulations, particularly with the Master Plan of shore-based facilities for GMDSS. The use of simplex, duplex and semi-duplex channels as well as 25 kHz channels can be used in accordance with the appropriate ITU-R and national regulations. Additionally 12.5 kHz channels are also allowed under Appendix 18 of the Radio Regulations in accordance with ITU-R M.1084.

VTS Centres require a means of clear and easy to use voice communication for interacting with ships. Within the VHF band, the VTS Centre will require the availability of a number of radio channels relative to the number of ship movements and the size of the VTS area. In addition to distress calling, DSC provides a means of direct calling to vessels through the use of the MMSI and other routine call functions.

As it evolves, e-Navigation will rely more and more on data communication between ship and shore. Such data communication between ship and shore or ship to ship can be implemented within the VHF Marine Band in accordance with ITU-R M.1842-1. Following the introduction of this regulation, it is anticipated that a digital infrastructure over Maritime VHF will become available.

#### Medium and High Frequency (MF and HF)

MF and HF may be used on a regional basis where medium and long range communication is required. The VTS Authority may require specific channels to be designated by the National Radio Authority for specific types of operations. The equipment shall comply with national and international regulations. Also, MF is used for the distribution of D-GNNS correction signals.

#### Satellite Communications

Exceptionally, communication via satellite may be required, depending on geographic terrain, shoreline of country and service provided by the VTS.

## Requirements

Shipborne equipment should meet the functional requirements of the relevant IMO performance standards and the ITU-R Radio Regulations (see 8.2 References above). Shore based equipment should also conform to the appropriate technical standards, such as ETSI for EU Member states.

### Radio Communications Coverage

The VTS authority should ensure that the VTS radio infrastructure provides adequate coverage for the VTS area.

VHF radio reception is generally dependent upon the line-of-sight distance between VTS receive site and the ship antenna heights. As a minimum requirement, the radio communications range should facilitate VTS ship communications before the ship enters a VTS area of responsibility.

### Digital Selective Calling

Routine calls using DSC can be initiated by the VTS (where fitted) in order to direct a VHF call to a specific vessel through MMSI-based addressing.

The use of DSC makes more efficient use of the available bandwidth. In addition, DSC is also used for distress calling. Further details are provided in ITU-R M.541-9 and ITU-R M.689-2.

### Development and Innovations

VTS authorities are currently making use of IP technology such as VoIP solutions on radio sites and internal communications. This allows for a more efficient use of infrastructure, more flexibility and optimised system design.

### Recording and Playback of Data

The VTS authority shall have the facility to automatically record radio communications and play back these recordings in synchronisation with the recorded traffic situation.

### Malfunctions, Warnings, Alarms and Indications

Please refer to the relevant requirements of IMO Resolution A.686(17) and IMO Resolution MSC.39(63).

### Availability

The requirements for the availability of radio communication equipment are dependent on the mandate of the VTS Authority and the national Administration. . Section **Error! Reference source not found.** provides recommendations for availability.

## Specific Design, Installation and Maintenance Consid­er­ations

### Durability and Resistance to Environmental Conditions

Externally installed electronic equipment should be in an appropriate environmental enclosure. IEC requirements should be applied as far as relevant.

### Interference

Radio communications equipment complies with applicable international standards and regulations - see IEC 60945 which covers the general requirements for navigation and radio equipment and includes interference. The avoidance of interference is essential, therefore equipment should be installed in accordance with manufacturer’s instructions and monitored to ensure that instances of interference are investigated and rectified.

### Power Supply

IEC requirements should be applied as far as relevant. In remote locations, authorities should consider the use of renewable power sources (e.g., solar panels or wind turbines, in combination with batteries) as an alternative to diesel generators. In addition, uninterruptible power supplies could be considered as a backup to the primary power supply.

### Site Selection and Installation

Operational requirements will determine where radio communication transceivers and antennas are to be located and how many are required.

Consideration should be given to the power output of the radio system at the antenna instead of the power output at the radio equipment. Note that, where multiple transceivers are combined and/or filtered through to a single antenna, the effective radiated power could be reduced significantly.

Care must also be taken that proper separation is maintained when co-locating antenna sites (see also section 8.5.2).

To avoid channel saturation, consideration should be given to subdividing the VTS area into communications sectors based upon channel use with adjacent sectors using separate channels.

Sites for radio communication equipment should be selected based upon optimizing the coverage of the VTS area and the ability to provide the required services e.g. telecommunication links and access. Considerations include availability of electrical power, physical security of the site, housing and possible co-location with existing infrastructure.

### Maintenance

In addition to the requirements of IMO Resolution A.694(17), the siting and installation of radio communication equipment should make provision for accessibility, maintenance and repair.

## Interfacing

Although there are internationally agreed interface standards for interfacing electronic equipment on board ships (IEC-61162-1 and IEC-61162-3), VTS radio communication interfaces ashore are mostly vendor-specific. An exception is VoIP, which is standardised by industry and the Internet Engineering Task Force (IETF). Interface standards will thus be dependent on the requirements of the VTS authority and the equipment being installed.

### Back-Up and Fall-Back Arrangements

Backup facilities can be provided by duplicated radio communication equipment in accordance with the requirements in section **Error! Reference source not found.**.

Fall-back arrangements, via a business continuity plan, should be considered such as handing over operations to another VTS.