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| IALA Guideline |

DraFT G1111-2

Producing Requirements for Voice communications

Functions, Performance And radar specifIC AcceptANce

Edition x.x

Date (of approval by Council)

urn:mrn:iala:pub:g1111-3(2’nd draft)

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

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| --- | --- | --- |
| Date | Details | Approval |
|  | Edition 0.1  This document originated from Guideline G1111 which has been subdivided into 13 sub-guidelines, including this document. Excisting text put into new document structure, aligned with other G1111 documents structure  .  (Note - G1111 originated from annex of Recommendation V-128 Ed 3 in May 2015) |  |
| 24-01-2022 | H. Verra edition 0.0 |  |
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# INTRODUCTION

Radio communication equipment is typically integrated into VTS applications to provide the VTSO with a real-time means of disseminating information from the traffic image to VTS participants to support safe navigation of the VTS area.

The intent of this Guideline is

* To be a common source of information on VTS Voice Communication systems.
* To provide detailed information about functional and performance requirements regarding voice communication in VTS systems

## The IALA G1111 guideline series

This Guideline is one of the G1111 series of guideline documents. The purpose of the G1111 series is to assist the VTS Provider in preparing the definition, specification, establishment, operation, and upgrades of a VTS system. The documents address the relationship between the operational requirements and VTS system performance (technical) requirements and how these requirements affect system design and sub system requirements.

The G1111 series of guideline documents present system design, sensors, communications, processing, and acceptance, without inferring priority. The guideline documents are numbered and titled as follows:

* G1111 Establishing Functional & Performance Requirements for VTS Systems
* G1111-1 Producing Requirements for the Core VTS System
* G1111-2 Producing Requirements for Voice Communications
* G1111-3 Producing Requirements for RADAR
* G1111-4 Producing Requirements for AIS and VDES
* G1111-5 Producing Requirements for Environment Monitoring Systems
* G1111-6 Producing Requirements for Electro Optical Systems
* G1111-7 Producing Requirements for Radio Direction Finders
* G1111-8 Producing Requirements for Long Range Sensors
* G1111-9 Framework for Acceptance of VTS Systems

A VTS system primarily comprises three elements: an IT platform, software functionality and a suite of communication devices and sensors. The Communication devices and sensors are each covered by the new Guidelines G.1111-2 to G.1111-8.

# DEFINITIONS

## General Terms

|  |  |  |
| --- | --- | --- |
| **VTS System** | – | within the G.1111 guidelines, the VTS System is the VTS software, hardware, communications and sensors. This excludes personnel and procedures. |
| **VTS Equipment** | – | within the G.1111 guidelines, VTS Equipment refers to the individual items of software, hardware, communications and sensors, which make up the VTS System. |
| **VTS User** | - | within the G.1111 guidelines, VTS User is defined as someone with either an operational, technical, or administrative need to use or access the VTS System. |

## Specific Terms

Specific terms in this document are defined as follows:

* **Simplex ;**  communication is unidirectional,. Only one device on a frequency can transmit, others can only receive during that period. Both transmitter and receiver use the same frequency.
* **Duplex ;** communication is bi-directional**.** two-way communication enables both stations totransmit and receive simultaneously. It is implemented using a different frequency for transmitting and receiving
* **Directional antenna** ; a directional antenna is an antenna which radiates or receives greater power in specific directions
* **Omni-directional antenna ;** an omnidirectional antenna is a class of antenna’s which radiates equal radio power in all directions.  ,
* .
* **Antenna Gain ;** it is a relative measure of an antenna's ability to direct or concentrate radio frequency energy in a particular pattern or direction. This measurement is typically measured in dBi (Decibels relative to an isotropic radiator) or in dBd (Decibels relative to a dipole radiator). However in most marine VHF antenna specifications it is simply stated as dB gain.
* **Digital Selective Calling (DSC);** is a standard for transmitting pre-defined digital messages via the [medium-frequency](https://en.wikipedia.org/wiki/Medium-frequency) (MF), [high-frequency](https://en.wikipedia.org/wiki/High-frequency) (HF) and [very-high-frequency](https://en.wikipedia.org/wiki/Marine_VHF_radio) (VHF) maritime radio systems. It is a core part of the [Global Maritime Distress Safety System](https://en.wikipedia.org/wiki/Global_Maritime_Distress_Safety_System) (GMDSS)

## Specific IALA Definitions

# References

1. Convention on Safety of Life at Sea (SOLAS) Chapter IV (Radio Communications).
2. Convention on Safety of Life at Sea (SOLAS) Chapter V (Safety of Navigation) – Regulation 12.
3. Convention on Safety of Life at Sea (SOLAS) Chapter V (Safety of Navigation) – Regulation 19.
4. IMO Resolution A.686(17) - Code on Alarms and Indicators (and MSC.39(63) Adoption of amendments to the Code on Alarms and Indicators.
5. 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.
6. IALA World Maritime Radio Communications Plan.
7. IEC 60945 - Maritime navigation and radio communication equipment and systems - General requirements, methods of testing and required test results.
8. IEC 61162 - Digital Interfaces for Navigation Equipment within a Ship.
9. 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.
10. ITU-R M.493-11 - Digital selective-calling system for use in the maritime mobile service.
11. ITU-R M.541-9 - Operational procedures for the use of Digital Selective Calling equipment in the Maritime Mobile Service.
12. ITU-R M.689-2 - International maritime VHF radiotelephone system with automatic facilities based on DSC signalling format.
13. ITU-R M.1082-1 - International maritime MF/HF radiotelephone system with automatic facilities based on DSC signalling format.
14. ITU-R M.1084-5 – Interim solutions for improved efficiency in the use of the band 156-174 MHz by stations in the maritime mobile service.
15. 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.
16. [*"Recommendation M.541: Operational procedures for the use of digital selective-calling equipment in the maritime mobile service"*](https://www.itu.int/rec/R-REC-M.541/en). [*International Telecommunication Union*](https://en.wikipedia.org/wiki/International_Telecommunication_Union). 2015.
17. [Very high frequency - Wikipedia](https://nl.wikipedia.org/wiki/Very_high_frequency)
18. IMO Resolution A.801(19) – Provision of Radio Services for the GMDSS.

# Abbreviations

Please refer to IALA G.1111 Establishing Functional and Performance Requirements for VTS systems for an extensive list of abbreviations and acronyms covering the entire G1111 series

GMDSS General Maritime Distress and Safety System

MMSI Maritime Mobile System Identifier

# Operational considirations

## Coverage

Typically voice communication for VTS operations can be achieved using the Maritime VHF-band and VHF DSC. However VTS Providers may choose to implement extended coverage based on the sea area’s defined by the GMDSS

* Area A1 - Within range of VHF coast stations with continuous DSC (digital selection calling) alerting available (about 20-30 nautical miles);
* Area A2 - Beyond area A1, but within range of MF coastal stations with continuous DSC alerting available (about 100 nautical miles);
* Area A3 - Beyond the first two areas, but within coverage of communication satellites (in practice this means INMARSAT and Iridium)

Inmarsat covers the area between roughly 70°North and 70°South and Iridium is global.

* 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 consistent with the GMDSS Sea Areas indicated above.

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

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

### 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 should comply with national and international regulations, particularly with the Master Plan of shore-based facilities for GMDSS. The use of simplex and 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 [14].

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. The VTSO should be provided with a clear and easy to use display that enables the monitoring of all channels, easy selection of incoming calls and easy channel selection for outgoing calls. An indication of signal strength should be provided where multiple radio sites and monitoring the same voice channel.

DSC provides additional facilities that can improve the effectiveness of VHF voice communication. DSC calls (on VHF Channel 70) can be addressed to a ship by using its MMSI which means that the VTSO can be certain that the call can only be answered by the correct vessel. In addition, a DSC call can make the radio equipment on the bridge of a ship will produce an acoustic alarm. In certain situations, this can be useful for alerting an unresponsive crew. Other DSC facilities, including receipt of GMDSS DSC emergency calls can be managed through an effective DSC interface. .

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 [15]. 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 Provider may require specific channels to be designated by the National Radio Authority for specific types of operations. The equipment should comply with national and international regulations.

MF is also used for the distribution of DGNSS correction signals.

### Satellite Communications

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

#### Diversity

Is used in systems with multiple transmitters, separated from each other, on the same frequency. The audio signal from the receiver which gives the best signal strength, is switched to the speakers. When replying the receiver with best signal strength is selected for transmission. This implies that the VTS will receive all transmissions in the area being covered by all receivers, but when answering, the VTS will not be heard by ships out of range from the selected transmitter.

Since only 1 transmitter is selected for transmitting no issues will occur in ‘overlap’ area’s.

This set-up may be appropriate for Inland Waterways.

Broadcasting is transmission from multiple transmitters at the same time. In area’s of overlapping coverage, VTS providers should consider that clear communication needs to be achieved and that interference should be avoided.

#### DSC (Digital selective calling)

DSC senders are programmed with the ship's [Maritime Mobile Service Identity](https://en.wikipedia.org/wiki/Maritime_Mobile_Service_Identity) (MMSI) and may be connected to the ship's [Global Positioning System](https://en.wikipedia.org/wiki/Global_Positioning_System) (GPS), which allows the apparatus to know who it is, what time it is and where it is.

When sending a distress signal, the DSC device will at minimum include the ship's [MMSI](https://en.wikipedia.org/wiki/MMSI) number. It may also include the [coordinates](https://en.wikipedia.org/wiki/Geographic_coordinate_system) if radio is connected to GPS system and, if necessary, the channel for the following [radiotelephony](https://en.wikipedia.org/wiki/Radiotelephony) or [radiotelex](https://en.wikipedia.org/wiki/Radiotelex) messages.[[3]](https://en.wikipedia.org/wiki/Digital_selective_calling#cite_note-b37-3) The distress can be sent either as a single-frequency or multi-frequency attempt.

DSC Frequencies are defined in ITU M.541

# Producing Functional and Performance requirements

Different suppliers are likely to have different solutions to the same functional and performance requirements. Therefore, the VTS Provider should avoid prescribing specific technical solutions. As a general principle, when specifying requirements for a voice communication system, the VTS Provider should clearly state the coverage area requirements and the voice communication channels and functions that will be used and sites where it is possible to install equipment should also be identified.

## Coverage

Clearly defining the area where voice communication coverage is required is the first step in establishing the performance requirements of the voice communication system. In addition, it is also necessary to understand the types of vessel that will be involved in communication with the VTS at various ranges. Large vessels such as VLCCs normally have their communication antenna on a mast on the roof of the bridge. In such cases, the antenna may be at a height of 30m above sea level whereas a fishing vessel may have communication antenna at heights of 10m above sea level and therefore communication would be possible with the VLCC at a greater range than for a fishing vessel. Therefore, the voice communication coverage area should be determined based on the maximum communication range required for communication with the smallest size of participating vessel.

Setting up a voice communication usually starts with determining the area(‘s) to be covered for a each frequency / channel. In addition to range, the upossibility of overlapping coverage should be taken into account. Local legislation/regulations considering antenna height and transmission power, as well as practical considerations like availability of set-up points will lead to an antenna plan. Use of omni-directional antenna’s vs. directional antenna’s may be part of this process.

## VHF Sites

Appropriate and available sites for the installation of Voice Communication equipment need to be specified. A voice communication site will need facilities for the installation of antenna equipment in an elevated position. This may be achieved through the provision of a communications tower or a multi sensor tower that also hosts other equipment. It should be noted that where multiple antenna installations are required at a single location, there must be vertical separation between each antenna. The site should also provide space to house rack mounted equipment, preferably in a temperature controlled environment.

It should be noted that multiple radios can be combined and operate through the same antenna. The result of this action is that the output power of connected radio equipment will be reduced. Therefore the use of a combiner will compromise transmission coverage performance. For example, the use of two radios transmitting through a single antenna will result in a 50% reduction in output power.

Antenna can be configured as Transmit / Receive Antenna or as single function antenna. A single function (Receive) antenna can be split to the receive connection on all voice communication base station equipment. Where there are multiple radios on a single site, a single function (receive) antenna should be installed at the highest location so that it has the best chance to receive weaker signals from small vessels at long range. Transmit antenna would then be installed at lower positions on the tower (to maintain the appropriate vertical separation). Whilst they will be lower and potentially suffer a loss of range performance, a single transmitter transmitting through a single antenna will transit at its full power output.

Separate transmit and receive antennas can result in the transmitted signal being detected by the receive antenna at the same site. In such circumstances, it is necessary to mute the receiver while the VTSO is transmitting so that the feedback does not confuse the operator into believing that another incoming vessel has called the station. For VTS Areas with multiple VHF sites, it is also possible that a transmission by the VTSO from one station can be received by an adjacent radio site and would appear like an incoming call. It is preferable that, when transmitting on a particular channel, that the Receivers at local and adjacent radio sites should be muted on the transmitting channel to avoid such confusion.

For systems involving multiple radio sites, the signal strength of Incoming calls should be monitored by the voice communication system. A signal strength indicator should be presented to the VTSO so that he can select the radio site that has the best signal strength as this will provide the clearest audio. Ideally , the voice communication system should automatically route the audio from the radio site with the best signal strength, directly to the VTSO speaker or headset.

## Operator Functions

The VTSO should be provided with a simple and easy to use interface to the voice communication system. As a minimum, the VTSO should be provided with the following:

* Channel selection facilities
* Status display
* Microphone
* Loudspeaker
* PTT switch (hand or foot activated)
* Headset

It is common for modern Voice Communication Systems to use a touch screen display for presenting the status of all radio equipment and to enable channel and radio selection. The VTSO should be able to select to use a Microphone and Loudspeaker or a Headset while taking measures to ensure that the use of the voice communication system by a VTSO does not disturb another VTSO at an adjacent workstation position. Wherever possible acoustic barriers should be used between VTSO workstations.

The voice communication functional requirements for the VTSO should provide ease of use of the radio equipment to ensure that the necessary information can be communicated to visiting vessels. A status display should clearly present the current operational status of each item of radio equipment with clear indication of incomin calls and when transmitting. The Operator Display should also be able to provide facilities for the handling and transmission of DSC messages.

## Recording and Replay

The Voice Communication System shall record all conversations time synchronised with the traffic image recording. At least 90 days (G1111.1 ?)of recordings shall be maintained on the system and available for playback.

The replay of a recorded conversation shall be possible at any time in synchronisation with the recorded traffic image, however, an on screen message shall alert the VTSO that the system is in the Replay mode and that the conversations being replayed are not live.

## Emergency Situations

GMDSS is a suite of communication services that are intended to enable any vessel in distress to call for assistance. As identified in section 5 above, it includes VHF, HF and MF voice communication frequencies as well as DSC frequencies across these bands. VTS Providers should consider whether to include additional frequency bands in order to assist in emergency situations. In addition, consideration should be given to the inclusion of facilities for voice communication in the VHF Air Band (108MHz – 137MHz) in order to coordinate with Search & Rescue Assets such as helicopters.

## Installation and maintenance considerations

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 [7], 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.

Special attention should be given during the design stage to ensure electromagnetic compatibility (EMC) of radio communication equipment used. Frequency spectrum (i.e. VHF working channels), used for VTS radio communication, must be agreed with the national radio licensing authority.

### 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 .

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) [4], the siting and installation of radio communication equipment should make provision for accessibility, maintenance and repair. Also provisions regarding logging and monitoring should be taken into account.

### Interfacing

Although there are internationally agreed interface standards for interfacing electronic equipment on board ships (IEC-61162-1 and IEC-61162-3 [8]), 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.

However, work within the IALA e-NAV committee and other organisations aim for open systems architecture with associated international standards, which may be adopted as developed.

VTS authorities are currently making use of Internet Protocol (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. VoIP technology (especially when applied for VTS radio communications) is very sensitive to delays in the IP network. Excessive delays may cause significant degradation of VHF communication quality. Additional challenges include the need to use the IP packet 'Quality of Service' functionality by the IP network to minimize negative effects such as latency and jitter.

### Back-Up and Fall-Back Arrangements

Backup facilities can be provided by duplicated radio communication equipment based on an availability assessment.

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

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

The requirements should be based on a Business Case and a Feasibility study (risk assessment, operational feasibility, legality, technical capability, available budget, and time) as described in IALA Guideline G1150. The risk assessment should address the specific risks within areas of interest and the way to handle or mitigate the risks.

# Development and Innovations

dPMR or digital [private mobile radio](https://en.wikipedia.org/wiki/Private_mobile_radio), is a [common air interface](https://en.wikipedia.org/wiki/Common_Air_Interface) for digital mobile communications. dPMR is an open, non-proprietary standard that was developed by the [European Telecommunications Standards Institute](https://en.wikipedia.org/wiki/European_Telecommunications_Standards_Institute) (ETSI) and published under the reference ETSI TS 102 658.

A simplified version of the dPMR protocol intended for licence-free applications was also published by ETSI under the reference TS 102 490.

The major advantage is the ability to use 4 voice channels in the same spectrum that currently allows only one. This was the initial driving criteria as the implementation of VDES means that the number of channels available for voice is reduced.

There are extra features within dPMR and the question is which one will be implemented. Depending on decisions made by IMO, ITU and proposals by IALA there could be some features added now done within the GMDSS branch. Two good features will be a full identification number (MMSI) embedded in the signal and a position report. These data with the data on shore and ship from radar and AIS could give a fuller 'situational awareness' picture



#### Specifications

* Access method: [FDMA](https://en.wikipedia.org/wiki/FDMA)
* Transmission rate: 4,800 bit/s
* Modulation: four-level [FSK](https://en.wikipedia.org/wiki/Frequency-shift_keying)

What is significant is that dPMR achieves all this in a 6.25 kHz channel.

Because the emission mask is so tight, two 6.25 kHz dPMR signals can be used next to each other within a 12.5 kHz channel without causing interference to each other or adjacent channels. Compliance with EN301 166 at 6.25 kHz for current equipment provides some measure of guarantee that interference issues will be no different with either 12.5 kHz or 25 kHz. Frequency co-coordinators in the USA have even made recommendations to the FCC about setting up new 6.25 kHz systems adjacent to existing systems, outlining parameters to avoid harmful interference.

dPMR equipment complies with the relevant European standard ETSI EN 301 166 as well as the FCC emission mask applicable for operation in the US.

dPMR supports several voice coding algorithms. Class A equipment is based on [AMBE+2](https://en.wikipedia.org/wiki/AMBE%2B2) vocoder, Class R uses [RALCWI](https://en.wikipedia.org/wiki/RALCWI) (Robust Advanced Low Complexity Waveform Interpolation) vocoder, and Class M equipment uses manufacturer specific algorithm. Equipment from these different classes is not interoperable in digital mode and therefore, must revert to analog FM mode.

#### dPMR functionality

dPMR446 radios comply with the ETSI TS 102 490[[1]](https://en.wikipedia.org/wiki/Digital_private_mobile_radio#cite_note-1) open standard and are limited to 500 mW RF power with fixed antennas per [ECC Decision](https://en.wikipedia.org/wiki/Electronic_Communications_Committee) (05)12.[[2]](https://en.wikipedia.org/wiki/Digital_private_mobile_radio#cite_note-2) They are ideally suited to recreational and professional users who do not need wide area coverage with base stations and repeaters.

dPMR446 equipment is capable of voice, data and voice+data modes of operation.

This means that dPMR446 can provide voice calls, text messaging ([SMS](https://en.wikipedia.org/wiki/SMS)), status and embedded data such as GPS position etc.

#### dPMR Mode 1

This is the peer to peer mode of dPMR (without repeaters or infrastructure) but without the limitations of the licence-free counterpart. It can operate all typical licensed PMR frequency bands and without the RF power limits of dPMR446. As well as offering voice and data, dPMR446 Mode 1 also supports combined voice+data so it is possible to embed data into a voice call or automatically append it at the end of a call.

#### dPMR Mode 2

dPMR Mode 2 operations include repeaters and other infrastructure. This brings extra functionality such as analogue or digital network interfaces which can be IP based. Inclusion of repeaters and base stations means that wide area coverage is possible even more so when multiple repeaters are used. Such multiple repeaters can be managed by dynamic channel selection or they can be part of a co-channel wide area network.

#### dPMR Mode 3

dPMR Mode 3 can offer multichannel, multisite trunked radio networks. This ensures optimum use of spectrum and optimum density of radio traffic.

Management of the radio network starts from the authentication of radios that wish to connect. Calls are set up by the infrastructure when both parties have responded to the call request ensuring optimum use of the radio resource. Calls may be diverted to other radios, landline numbers or even IP addresses. The infrastructure managing these beacon channels would be capable of placing a call to another radio whether that radio is using the same site or another site within the network.

# Acceptance of VTS communication Systems

IALA Guideline 1111-9 Acceptance Framework of VTS System provide general acceptance steps and key area of considerations related to acceptance of VTS System and VTS Equipment.

The VHF voice communication systems could be tested to evaluate the fulfilment to the specific requirement in the agreed requirement according to Test Plan and Test Procedure.

It might also be desirable to verify the availability and include (part off) an annual cycle in the acceptance process to ensure good long-term operation.

## Test Metodology

### VHF Functions and other features

The verification of Operator Functions, Operational outputs can normally be made as functional tests, whereas verification of Transmitting power, SWR, phase measurements etc. can be performed as technical measurements.

#### VHF Coverage

The continuous coverage of the VTS can be checked utilising of targets of opportunity which aligns to the requirement. This may be complemented by use of controlled targets (handhelds of shore as well as ships) determining the maximum range of transmitting/receiving for specific frequencies.

1. VHF Considerations

This annex is descriptive and intended to supplement previous sections in this document and introduce the reader to common radar topics and knowledge specific to VTS radar as well as guidance on what is possible to achieve from radar configurations typical for VTS.

* 1. Antennas

The selection of antenna parameters (height, gain, side lobes, rotation rate, polarisation etc.) for a given installation is key to the resulting radar performance. VTS authorities are, however, advised to avoid specifying detailed antenna characteristics, in favour of identifying and should preferably specify operational requirements such as:

* coverage area and range performance based on need and risk assessments
* track update rates and typical target manoeuvres in high density areas
* need for overlapping and redundant coverage.

The identified operational requirements will allow the radar vendor some flexibility to achieve the best solution within the given constraints and considering cost and location options.

* + 1. Antenna Principles
       1. Maximum detection range

VHF signals propagate in a direct line .The reach of VHF signals basically limited to the line of sight. Due to the curving of the earth surface it is limited, and its limitation is highly determined by the height of the antenna’s (sending and receiving antenna). The formula below can be used for a calculation of the antenna reach , or vice versa calculating which antenna height should be used to achieve a certain reach



h1

h2

S(h1,h2) = 3,57 \* (√h1 +  √ h2 )

In which :

S = maximum line of sight in kilometers

h1 = antenna height station 1 in meters

h2 = antenna height station 1 in meters

Source [Very high frequency - Wikipedia](https://nl.wikipedia.org/wiki/Very_high_frequency)

Figure xx illustrates the basic geometry in target detection associated with antenna height above sea level (ASL) and the effect of the earth curvature, determined by the following formula:

* + - 1. Antenna gain



Figure xx illustrates the effect of antenna gain in association to coverage.

A typical marine VHF antenna is designed with vertical polarization. This means that the best performance from your antenna will be had when your antenna is mounted perfectly vertical. Any angle beyond vertical will lessen the performance of the radio signal.

* 1. Environmental Influence

Obstructions, e.g., topography, buildings and other man-made structures may block or reflect radio signals. Other transmitters 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 should be taken to assess and mitigate effects caused by natural and man-made structures such as bridges, buildings, riverbanks, sheet metal pilings, and steep bends.

Also meteorological and hydrological conditions may impact VHF performance. Area’s of high air pressure may have an influence on the coverage (increased) of the VHF signals .

Sun bursts may also have an effect on the transmission of radio signals and this effect may be more significant during night time them day time.