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**POSITIONING AND NAVIGATION SYSTEMS**

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**1- INTRODUCTION****1.1 DEFINITIONS**

This Technical Specification outlines the requirements for the FPSO (Floating Production Unit) Positioning and Navigation Systems, operating for PETROBRAS in Brazilian offshore basins.

During the hook up and pull in operations, e.g., the SPI (*Sistema de Posicionamento Integrado – Integrated Positioning System*) software, developed by Petrobras Geodesy Department, uses the position and heading sensors and a pair of UHF radios to send FPSO positioning data for all vessels involved, and transmit vessel positions to the FPSO receivers. The same process happens aboard all other vessels. Therefore, SPI software allows all maritime units to be displayed on the same screen of the positioning and navigation software.

After the oil production kick off, PETRONAV (Petrobras Navigation software) run position monitoring from position, heading and attitude sensors. Through the DOF (Diagram of Offset) system, this position monitoring allows faster assessment of possible damage to the mooring system, enabling a faster decision-making. This is an important tool to increase the FPSO operational safety.

The content of this document describe the equipment requirements for FPSO control during critical operations as towing, hook up, riser connection/disconnections (pull in / pull out), mooring lines tensioning and maintenance, supply and offloading operations. The systems described in this Technical specification will also allow monitoring of FPSO displacement in order to calculate riser stresses and alarm in case of mooring line snapping, as well as monitoring all vessels within range.



## 1.2 ABREVIATIONS

AHRS- Attitude And Heading Reference System

DOF- Diagram of Offset

FPSO - Floating Production Unit

DGPS- Differential Global Positioning System

GNSS - Global Navigation Satellite System

GPS- Global Positioning System

GNSS- Global Navigation Satellite System

IP- Internet Protocol

NMEA – National Marine Electronic Association

PETRONAV - Petrobras Navigation software

POS- Positioning

PNS- Positioning Navigation System

RTCM- radio Technical Commission for Maritime Services

SAT - Site Acceptance Test

SPI - Integrated Positioning System

UHF – Ultra High Frequency

VHF- Very High Frequency

UPS- Uninterruptible Power Supply

## 1.3 REFERENCE DOCUMENTS, CODES AND STANDARDS

### a) International Electrotechnical Commission (IEC)

IEC 60945 - Maritime navigation and radiocommunication equipment and systems – General requirements – Methods of testing and required test results, Fourth Edition, 2002

IEC 61108 - GNSS Part 1: Global positioning system (GPS) - Receiver equipment, 2003

IEC 61108 - GNSS Part 2: Global navigation satellite system (GLONASS) - Receiver equipment, 1998

IEC 61108 - GNSS Part 3: Galileo receiver equipment, 2010

IEC 61108 - GNSS Part 4: Shipborne DGPS and DGLONASS maritime radio beacon receiver equipment, 2004

IEC 61162 - Digital interfaces Part 1: Single talker and multiple listeners, 2010

IEC 61993 - AIS Part 2: Class A shipborne equipment of the universal AIS, 2001

### b) International Marine Contractors Association (IMCA)

IMCA S 012 - Guidelines on Installation and Maintenance of DGNSS-Based Positioning Sys, 2011

### c) International Telecommunication Union (ITU)

ITU-R M.1371-4 - Technical characteristics for an AIS using TDMA in the VHF maritime mobile band

### d) National Marine Electronics Association (NMEA)

NMEA 0183 – Standard for Interfacing Marine Electronics Devices

### e) Classification Society



The detailed design shall be submitted to approval by a well-known Classification Society. The design and installation shall take into account their requirements and comments.

## 2 TECHNICAL REQUIREMENTS

### 2.1 GNSS RECEIVER

02 (two) GNSS (Global Navigation Satellite System) independent receivers with the following minimum specifications:

- a) To be conform with IEC 61108-1:2003 (GPS) and IEC 61108-2:1998 (GLONASS), with integrated solution;
- b) The firmware shall be able to be upgraded to newer GNSS constellations as Galileo system (IEC 61108-3:2010) or another one;
- c) To comply with IEC 60945:2002 (general requirements for marine equipment);
- d) Operating all available frequencies of GNSS, like L1,L2 and L5 GPS frequencies; L1 and L2 GLONASS; Galileo frequencies E5, E6, L1 and frequencies as well as newer GNSS frequencies that become available.;
- e) The GNSS receivers must be able to get correction RTCM SC104 v2.3 data from DGNSS UHF devices (according to **item 2.2**), PETROBRAS intranet (TCP/IP) and from a commercial service (according to **item 2.3**);
- f) Provide at least GNS, ZDA, GSV and GGA data according to IEC 61162-1:2010 (NMEA 0183);
- g) It shall be provided an Ethernet port to connect to PETROBRAS LAN Network;
- h) The equipment shall be able to access remote data and remote configuration;
- i) At least 2 (two) serial EIA-232 ports.

### 2.2 DGNSS UHF CORRECTIONS RECEIVING SYSTEM

02 (two) UHF radio/modem receiver with the following minimum specifications:

- a) Operate in compatible mode with PETROBRAS DGNSS Network, which works with Pacific Crest PDL HPB or ADL Vantage Pro, with Transparent w/EOT Timeout protocol and modulation type GMSK;
- b) Operate in 450 MHz - 470 MHz range with 12.5 KHz bandwidth per channel;
- c) Have 7dBi gain omnidirectional antenna and impedance compatible with receiver;
- d) Enable, at any time, channel configuration (USB key permanence);
- e) The UHF receiver shall be configured to provide RTCM SC104 v2.3 DGNSS corrections from PETROBRAS stations to GNSS receivers (**item 2.1**);
- f) The Frequency channels plan will be informed during the project detailing.

### 2.3 GNSS SATELLITE CORRECTION SERVICE

01 (one) GNSS satellite correction service (augmentation), throughout the life of the charter, which meets the following minimum specifications:

- a) Having less than 1 meter of horizontal accuracy (95%) through real-time correction;



- b) Have 99.8% availability for periods of 30 days on all area offshore;
- c) Receive multi constellation, GNSS, through at least two different communication satellites;
- d) The service must be configured to correct the signal from GNSS receivers (**item 2.1**) and its hardware may form with the GNSS receiver a single device or not.
- e) The maintenance is according with **item 5**.

#### 2.4 ATTITUDE AND HEADING REFERENCE SYSTEM (AHRS)

01 (one) attitude and heading reference system which meets the following minimum specifications:

- a) True heading accuracy: 0.1° secLat (2 sigma, 95%);
- b) Pitch and roll accuracy: 0.02° (2 sigma, 95%);
- c) Heave accuracy: 5 cm or 10% whichever higher (2 sigma, 95%);
- d) It shall not have moving parts in its basic principle, shall not be based on geomagnetic effects and must be independent of GNSS;
- e) To comply with IEC 60945:2002 (general requirements for marine equipment);
- f) Having two data outputs. One port must provide the HDT message, according to IEC 61162-1:2010 (NMEA 0183) and in other port must provide TSS1 (Teledyne TSS Ltd.);
- g) It shall be provide an Ethernet port to connect to PETROBRAS LAN Network.
- h) The equipment shall be able to remote data access and remote configuration.

2.4.1 As a reference Petrobras uses IX BLUE Quadrans Fiber Optic Guroscope. Similar or a better quality specification will be accepted.

### 3 MONITORING AND NAVIGATION SYSTEMS

#### 3.1 COMPUTER SYSTEM FOR MONITORING AND NAVIGATION

According to Fig.1, 01 (one) information technology system with the following minimum specifications:

- a) 02 (two) computers and peripherals with current Operational System used by PETROBRAS;
- b) 02 (two) multi-serial boards (8 ports) or equivalent devices with original drivers;
- c) 01 (one) serial (8 ports) / ethernet (1-port) converter or equivalent with original drivers;
- d) 02 (two) monitors 19" (at least) LCD or LED with original drivers;
- e) 02 (two) licenses of the current Operational System used by PETROBRAS;
- f) To comply with IEC 60945:2002 (general requirements for marine equipment).

#### 3.2 INTEGRATED POSITIONING SYSTEM (SPI)

3.2.1 02 (two) radio/modem UHF transceiver to coordinate integrated operations of mobilization and demobilization with other vessels, with the following minimum specifications:

- a) Operate in compatible mode with the PETROBRAS SPI system, which uses Pacific Crest PDL HPB or ADL Vantage Pro;
- b) Operate in 450 MHz - 470 MHz range with 12.5 KHz bandwidth per channel;
- c) Have an omnidirectional antenna, with power of 250 W / VSWR <1.5:1, 7dBi gain and impedance compatible with UHF transceiver;



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- d) Enable, at any time, channel configuration (USB key permanence);
- e) Transmitting power with 25 W or more with possibility to reduce power to 5W or less if it's necessary.

3.2.2 01 (one) ethernet-serial converter with minimum of four serial ports.

#### 4 INSTALLATION AND INTEGRATION

##### 4.1 INSTALLATION AND INTEGRATION OF EQUIPMENT, ANTENNA AND SENSORS

The equipment, antennas, sensors and positioning systems shall be installed according to the following criteria:

- a) The CONTRACTOR shall provide, in addition to installation, all cables and suitable connectors;
- b) The choice of cables and connectors must ensure the integrity of positioning data on the computer, monitor, peripherals and PETROBRAS LAN Network;
- c) The installation of GNSS system shall follow the guidelines of the IMCA S 012 publication. The distance between the GNSS antennas (baseline) shall be larger than 30 meters;
- d) For GNSS and UHF installation, the maximum accepted signal attenuation due to cable and connector losses is 10 dB;
- e) The installation and calibration of the FPSO sensors must be made by manufacturers or their representatives. The manufacturer or their representatives shall make a report informing the deviation values obtained in the facility;
- f) Stern device (UHF Transceiver A) shall be connected to the positioning computer;
- g) The UHF Transceiver A antenna shall be installed on the top of the antennas mast or in the highest place in the stern area;  
These devices shall be close to the monitoring and navigation rack, if possible;
- h) PETROBRAS strongly recommends that all antennas should be installed over wing deck or Telecom Tower. Installation project shall be previously submitted to PETROBRAS;
- i) The installation of PNS shall follow the PNS Block Diagram (FIGURE 1).



PNS Block Diagram – General vision

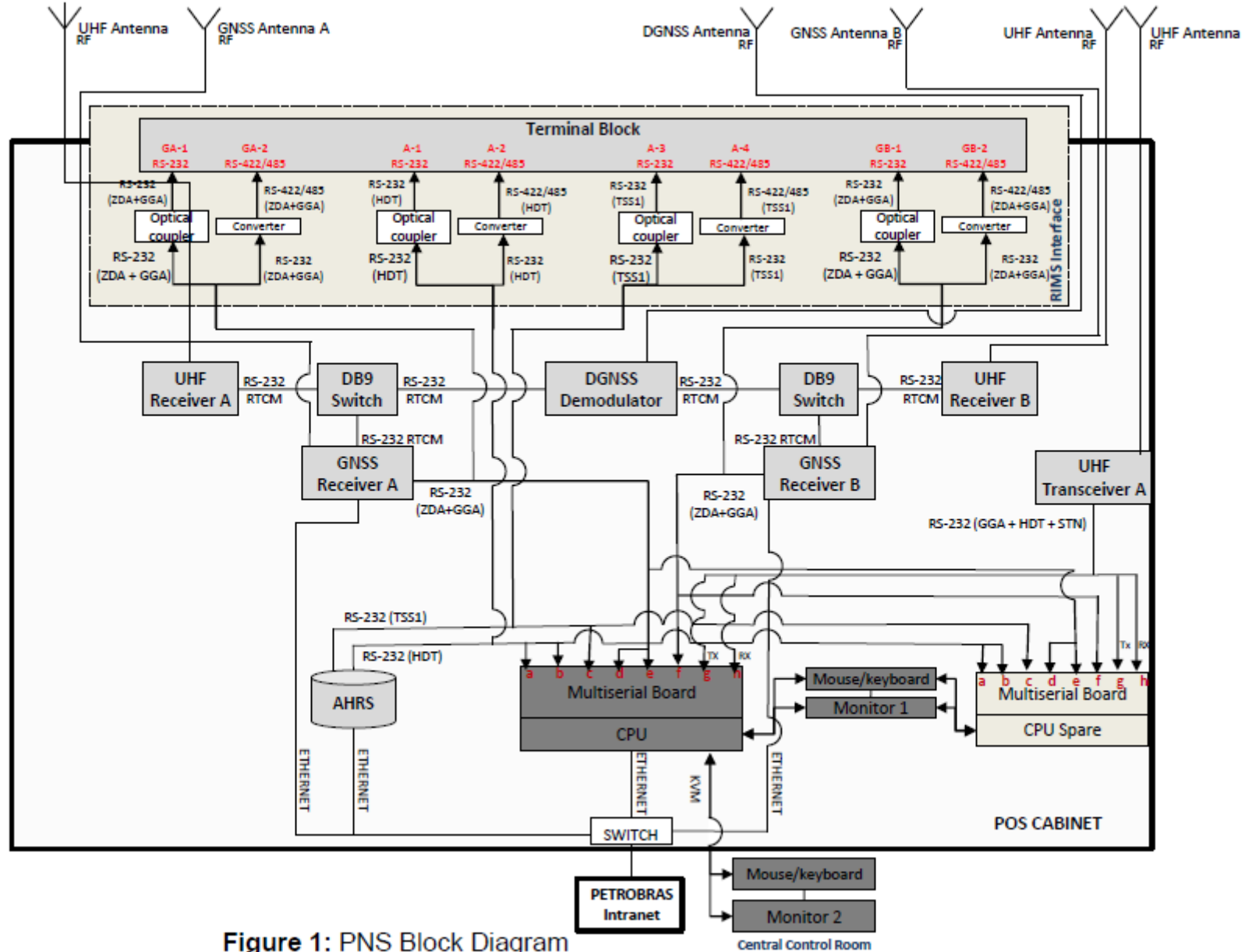


Figure 1: PNS Block Diagram





#### 4.2 POSITIONING AND NAVIGATION SYSTEM INSTALLATION AND INTEGRATION

The information technology system for positioning and navigation system shall be installed according the following criteria:

- a) Both computers shall be mounted into a rack and shall remain turned on;
- b) The rack shall be installed in the TER (Telecommunications Equipment Room). One monitor (Monitor 1) shall be installed in the POS rack and the other (monitor 2) in the Central Control Room.;
- c) The softwares shall be installed and computers shall receive the data from all sensors with integrity;
- d) FPSO CONTRACTOR shall provide a PETROBRAS LAN Network port (Ethernet) to POS computer;
- e) The positioning system shall be fed by UPS with at least 30 (thirty) minutes autonomy and adequate power supply;
- h) It shall have 01 (one) VHF marine radio and 01 (one) phone (PETROBRAS) near the positioning desk for intercom surveyor during mooring operations, at bridge;
- f) Prior to the commencement of operations, the computers of the POS rack shall be sent to PETROBRAS for systems installation and approval. After approval, the FPSO's technician shall reposition it and reconnect it on the site;
- g) All computers involved on this system shall be sent to PETROBRAS for intranet installation and configuration. It usually takes 60 days, and shall be configured according to Geodesy Department Software Kit and recommendations;
- h) Eight fixed IPs shall be requested to PETROBRAS and configured on both GNSS receivers, AHRS sensor, Ethernet serial converter (if necessary) and any equipment with Ethernet interface that PETROBRAS deems necessary to connect them to the PETROBRAS LAN Network;
- i) External interface system (RHMS, Riser & Hybrid Riser Monitoring System, or another external system): each GNSS Receiver must have its own one serial output (NMEA 0183 – ZDA and GGA messages) and AHRS must have one output for heading (NMEA 0183 – HDT message) and another one for attitude (TSS1 protocol), according to the following minimum criteria:
  - One optical coupler for each GNSS Receiver;
  - Two optical coupler for AHRS;
  - Each serial output must be available as one DB-9F optically coupled RS-232 and as one terminal block four wire, full duplex, RS422/485;
  - All serial output must be integrated in a terminal block. Figure 1 above shows this scheme and additional details.



## 5 POSITIONING AND NAVIGATION SYSTEM MAINTENANCE

Throughout the term of the charter, contractor must maintain positioning system according to the following criteria:


- a) The responsibility for the installation, calibration, maintenance or replacement of all equipment is responsibility of the FPSO CONTRACTOR;
- b) In case of diverging signals from any device, PETROBRAS will request its calibration or repair;
- c) The FPSO CONTRACTOR shall update the firmware of the systems every 5 years, or when manufacturers inform it is necessary;
- d) Preventive and corrective maintenance plan for all PNS, with 6 (six) months intervals, containing at least following items:
  - d.1) Inspection of all PNS, e.g., equipment, antennas, cables and connectors;
  - d.2) A Report containing:
    - i) Description of inspection, regarding sub item d.1;
    - ii) Sample digital files (at least one minute duration) for each message sensor. For example, for GNSS receivers, a file containing NMEA 0183 protocol. The purpose of this item is to follow up the operability of each sensor;
    - ii) A photo showing POS cabinet and all sensor installed inside it;
- e) During the life of the charter, the FPSO CONTRACTOR shall ensure the operability of all items of this document in full-time and the non-compliance will result in partial unavailability of positioning conditions.

## 6 DOCUMENTATION AND ACCEPTANCE

### 6.1 DOCUMENTATION

The FPSO CONTRACTOR shall have the following documentation:

- a) Manual of all equipment, positioning systems and softwares available to PETROBRAS ;
- b) Installation, configuration and calibration report of the FPSO sensors;
- c) General Report:
  - c.1) Stating the model of all equipment, antennas and sensors;
  - c.2) Describing technique, methodology and equipment used for linear and angular offsets survey, as well as indices/calculations that requested accuracy has been achieved;
  - c.3) Containing a drawing with vertical and horizontal offsets with decimetric tolerance between all antennas and sensors, and a diagram containing angular offsets with decimal degree tolerance, the boards, forward, stern, helideck, riser supporters and fear leaders and the geometric center designed of the FPSO;
  - c.4) Containing calculations for linear and angular offsets; general arrangement and layout antennas;
  - c.5) Containing measurements of linear and angular offsets in technical drawings in scale and in top, front, back and lateral (right and left) views;
  - c.6) A diagram with outside cables and connector types and a device power supply scheme;
  - c.7) A diagram of devices in POS rack and/or inside the telecommunication room.

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- d) A vector CAD file in format \*.dgn, \*.dwg or \*.dxf. with all pertinent and required drawings, e.g., general arrangement and layout antennas;
- e) Digital files (raw and processed) with observations in the survey activity.
- f) Photographs of the installations before the Unit leaves the shipyard.
- g) Homologation Certified emitted by Brazilian National Telecommunications Agency (ANATEL) .

## 6.2 DGNSS UHF SETUP AND ACCEPTANCE

After all installations, CONTRACTOR shall meet the following steps for acceptance:

- a) After positioning systems installation, the FPU CONTRACTOR shall contact PETROBRAS via e-mail to “Suporte de Posicionamento da Geodésia” (suporte\_pos@PETROBRAS.com.br) and “Operação Geodésia” ([operacao\\_geode@PETROBRAS.com.br](mailto:operacao_geode@PETROBRAS.com.br)), following PETROBRAS contracting party with the text "ACCEPTANCE FPSO" followed by the unit name in the title message requesting DGNSS UHF channels and frequencies, sending calibration and offsets reports and stating be ready for pre-acceptance;
- b) After receiving the data channels and DGNSS UHF frequencies, the FPSO CONTRACTOR shall configure them in UHF receivers (item 2.2);
- c) PETROBRAS will schedule a date for the PNS SAT (Site Acceptance Test);
- d) After SAT, the FPSO CONTRACTOR shall make the adjustments indicated by PETROBRAS. PETROBRAS will approve the FPSO before the navigation to the final location.

APPENDIX

Acceptable GPS reallocating

The installation GNSS location must:

- Be on the highest place, with no structure blocking the receiver's view of sky;
- Can not be close to stays, electrical cables, metal masts, CB radio antennas, cellular phone antennas, air-conditioning units, transmitting antennas, radar array, satellite communication equipment;
- Can not be in areas that experience high vibration, excessive heat, electrical interference or strong magnetic fields;

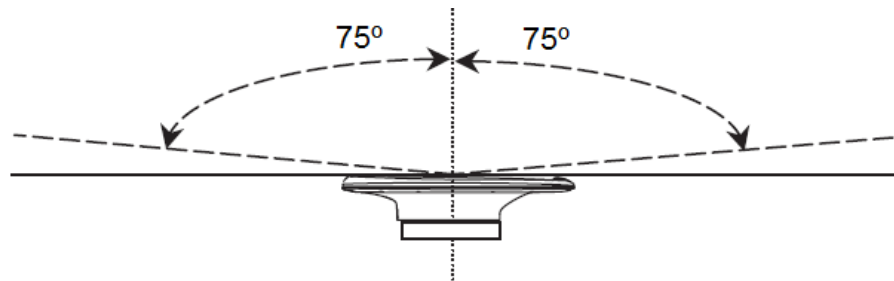


Fig A1 – Antenna shall be installed where the field of view against zenith is at least  $\pm 75^\circ$ .

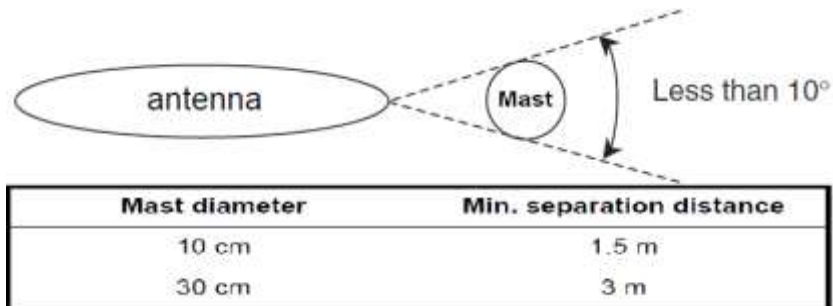


Fig A2 – Minimum separation of antennas to nearby structures, the horizontal angle to the interfering object shall be less than  $10^\circ$ .

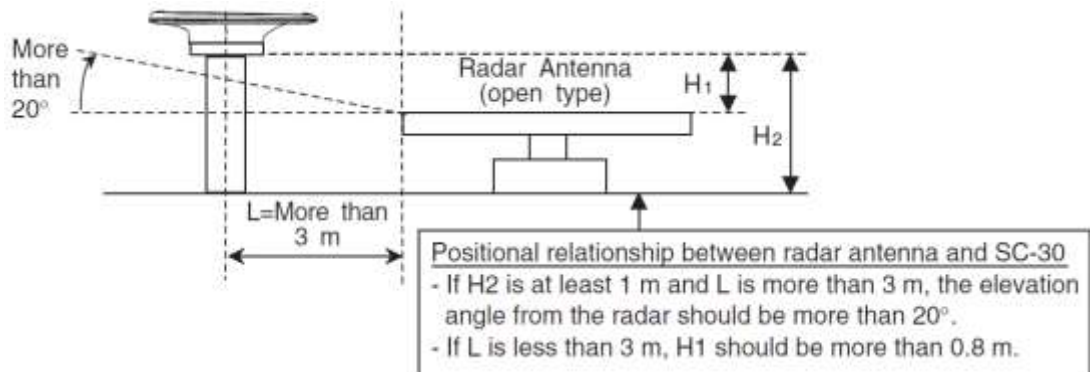


Fig A3 – Minimum separation distances from radar antenna.

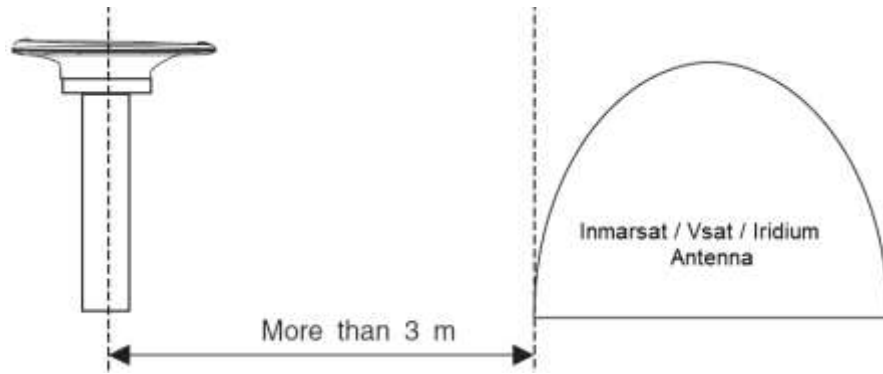


Fig A4 – Minimum separation distances from Inmarsat / Vsat / Iridium antenna.