

IALA Recommendation R-121

On

the Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 – 325 kHz

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Document Revisions

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

Date	Page / Section Revised	Requirement for Revision
Sept. 2004	5. Integrity, 11. Validation, New Appendix 1 "DGNSS Broadcast Site Settings	Provide better guidance on these important areas to administrations setting up and operating DGNSS services.

IALA Recommendation on the Performance and Monitoring of a DGNSS Service in the frequency band 283.5 - 325 kHz

THE COUNCIL

NOTING the function of the IALA with respect to Safety of Navigation, the efficiency of maritime transport and the protection of the environment,

NOTING ALSO IMO resolutions A.915(22) on Maritime Policy for the Future Global Navigation Satellite System (GNSS), and A.953(23) on World Wide Radionavigation System,

NOTING FURTHER ITU-R Recommendation M.823-2 on the Technical characteristics of differential transmissions for Global Navigation Satellite Systems (GNSS) from maritime radio DGNSS sites in the frequency band 285-325 kHz (283.5-315 kHz in Region 1),

RECOGNISING the need to ensure that Differential GNSS (DGNSS) services in the frequency band 283.5 kHz – 325 kHz are operated in accordance with certain minimum standards that take into account relevant ITU-R Recommendations and IMO Resolutions,

RECOGNISING ALSO that the minimum standards should include the signal format, reference datum, availability, continuity, integrity, accuracy, signal monitoring, range and coverage, status reporting, validation, and the publication of information about the system,

HAVING CONSIDERED the proposals made by the Radionavigation Committee:

ADOPTS the Minimum Standards for the Performance and Monitoring of DGNSS Services in the frequency band 283.5 – 325 kHz set out in the annex of this recommendation; and

RECOMMENDS National Members and other appropriate Authorities providing, or intending to provide, DGNSS services in the frequency band 283.5 – 325 kHz, to use the Minimum Standards set out in the annex to this recommendation.

Annex

Minimum Standards for the Performance and Monitoring of DGNS Services in the frequency band 283.5 – 325 kHz

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1 General

A Global Navigation Satellite System (GNSS), currently GPS and GLONASS, is a space-based positioning, navigation and time distribution system designed for world wide use. Differential GNSS (DGNSS) is a means of improving the accuracy of GNSS and providing integrity monitoring to the civil user. DGNSS involves having, at precisely known locations, reference stations that provide real-time corrections to the GNSS signals and integrity monitoring.

This Recommendation describes the use of transmitters in the 285 – 325 kHz / 283.5 – 315 kHz LF/MF marine frequency band to transmit DGNSS. It must be noted that DGNSS is an augmentation of GNSS and is not a stand-alone radionavigation system.

The removal of Selective Availability (S.A.) from GPS in May 2000 did not remove the requirement for GNSS augmentation. Without augmentation GNSS accuracy may contain significant errors for extended periods of time and no integrity information is provided. Integrity is the ability to provide users with warnings within a specified time when the system should not be used for navigation. Although this may be acceptable for some users, such as fishermen and pleasure boat owners, it is not acceptable for merchant vessels, normally operating with tighter safety margins and higher risks.

System performance is based on the assumptions that the system provider conforms to these guidelines and that the user equipment meets the design and installation standards as specified in Section 9.

2 Signal Format

The data format and transmission characteristics are detailed in ITU-R Recommendation M.823-2 (Ref. 1)¹

Depending on requirements, the following message types should be used:

- Type 1 (GPS Full Correction Set) or 31 (GLONASS Full Correction Set)
- Type 9 (GPS Partial Correction Set) or 34 (GLONASS Partial Correction Set)
- Type 3 (GPS Reference Station Parameters) or Type 32 (GLONASS Reference Station Parameters)
- Type 7 (DGPS Radiobeacon Almanac) or Type 35 (GLONASS Radiobeacon Almanac)
- Type 6 (Null frame, used as transmission fill).

¹ The ITU-R Recommendation incorporates the format developed by RTCM Special Committee 104. (Ref. 3)

Partial Correction Sets messages are preferred because of better performance in impulse noise conditions.

Message Types 3/32, and 7/35 should be broadcast at the minimum time intervals specified in ITU-R Recommendation M.823.

Message Type 5, which deals with GPS constellation health, is included in ITU-R Recommendation M.823, but is not normally used.

Message Type 16/36 may be used to broadcast special messages in text form, but should not normally be used for integrity warnings, which are included in message headers. Type 16/36 messages may be used for status information, or for navigation related information such as hydrographic or meteorological data. Type 16/36 messages should never be broadcast consecutively as this will cause excessive receiver alarms, receiver memory overloads, and/or data link loading.

<p>Type 16 /36 messages should not be broadcast for a period of at least ninety seconds preceding or following a Type 3/32, 5, or 7/35 message and the interval between successive Type 16/36 messages should be no less than three minutes.</p>

Proposed Message Type 27 (DGPS extended radiobeacon almanac) may be required in the future to be broadcast in conjunction with Message Type 7 to fulfil IMO [MSC 114 (73)] automatic radiobeacon selection mode.

3 Reference Datum

The datum used should be stated in the Administration's publications. WGS84 is typically used by most service providers. If a datum is used that is not consistent with WGS84 in the case of GPS or PE90 in the case of GLONASS, Message Type 4 should be broadcast to indicate the datum. It should be noted that use of the incorrect datum could result in errors of up to several hundred metres.

4 Availability and Continuity

IMO resolution A.953(23) provides for three standards on accuracy, availability and continuity from a satellite radionavigation system. They represent the situation when coverage is provided by a system comprising the satellite transmissions alone, when a single additional transmitting station augments the satellite transmissions and when two or more additional transmitting stations augment the satellite transmissions. The standards, in tabular form, are:

Table 1

Area	Absolute Horizontal Accuracy	Signal Availability	Continuity	Augmentation
Ocean	≤100 m	>99.8% over 30 days	N/A	None
Coastal/harbour with low level of risk	≤10m	>99.5% over 2 years	≥99.85% over 3 hours	Single station
Coastal/harbour with high level of risk	≤10 m	>99.8% over 2 years	≥99.97% over 3 hours	2 or more stations

4.1 Availability

The availability standard adopted for a DGNSS service in the band is related to the techniques used in planning and implementing the service. The availability of the GNSS satellite constellation is not taken into account in the availability of the DGNSS service.

Availability is defined in IMO Resolution A.915 (22) (Ref. 4) 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.”

Signal availability is defined as the availability of a radio signal in a specified coverage area.

System availability is defined as the availability of a system to a user, including signal availability and the performance of the user's receiver.

Mathematically this can be written as:

$$\text{Availability (A)*} = \frac{\text{MTBO}}{\text{MTBO} + \text{MTSR}}$$

Where:

MTBO = Mean time between outages; based on a 2 year averaging period (30 days ocean phase)

MTSR = Mean time to service restoration; based on a 2 year averaging period (30 days ocean phase)

This accounts for scheduled and unscheduled service interruptions, i.e. preventative and corrective maintenance.

* Alternatively expressed as UP TIME/TOTAL TIME where TOTAL TIME = 2 years

Worked example (# 1):

Assuming a scheduled maintenance cycle of 6 months, i.e. mean time between scheduled maintenance is 0.5 years – therefore there will be 4 scheduled maintenance breaks in 2 years.

Assuming a MTBF of 2 years. Therefore the average number of failures over 2 years is expected to be approximately 1.

Summing, there will be 5 outages over the two-year period. Therefore the mean time between outages is 2/5 years or approximately 3500 hours.

If the average out of service time for scheduled maintenance is 6 hours. The total out of service time for scheduled maintenance over the two-year period is 24 hours. Similarly, if the unscheduled maintenance period is 12 hours, the total time out of service over the two-year period is 36 hours. This covers 5 maintenance events and, therefore, the mean time to service restoration is 36/5 hours or approximately 7 hours.

The overall availability over the two year period is therefore $(3500/(3500+7)) = 99.8\%$

Worked example (# 2):

Assuming a scheduled maintenance cycle of 6 months, i.e. mean time between scheduled maintenance is 0.5 years – therefore there will be 4 scheduled maintenance breaks in 2 years.

Assuming a MTBO of 2000 hours for unscheduled maintenance. Therefore the average number of failures over 2 years (17520 hours) is expected to be approximately 9. (Actually 8.76 rounded up to 9)

Summing, there will be 13 outages over the two year period (4 scheduled + 9 unscheduled). Therefore the mean time between outages is 17520 hours/13 equals 1348 hours.

If the average out of service time for scheduled maintenance is 6 hours. The total out of service time for scheduled maintenance over the two-year period is 24 hours. Similarly, if the unscheduled maintenance period is 63 hours (an average of approximately 7 hours per outage – some will be more and some will be less) the total time out of service over the two-year period is 87 hours. This covers 13 maintenance events and, therefore, the mean time to service restoration is 87/13 hours or approximately 7 hours.

The overall availability over the two year period is therefore $1348/(1348+7) = 99.5\%$

4.2 Continuity

Continuity, or reliability, is the *ability* of a system to function within specified performance limits without interruption during a specified period (normally short term).

The equation below refers to an availability type calculation, i.e. the average over the continuity time interval (CTI) that the service is available or the probability that the service is available at any instant during the CTI. It is more appropriate to calculate the probability that the service is available throughout the CTI. The suggested approach is given below:

Assuming the service is functioning at the beginning of the operation, then the probability that it is still functioning at a time (t) later is:

$$C = \exp (-t/MTBF)$$

This is the standard expression for reliability and excludes scheduled outages (i.e. uses MTBF) assuming that planned outages will be notified and the operation will not take place. The probability that the service will be available after a time CTI, that is the continuity is then:

$$C = \exp (-CTI/MTBF)$$

If MTBF is very much greater than CTI, this can be approximated to:

$$C = 1 - (CTI/MTBF)$$

Where:

MTBF = Mean time between failures; based on a 2 year averaging period

CTI = Continuity time interval; in the case of maritime continuity, equal to 3 hours

There is no need to include the availability at the beginning of the time period of the operation because if there is no service, then the operation will not commence.

Worked example (# 1):

Using the figures in the previous example for a system with a 2 year MTBF, the continuity over a three hour period is $1-(3/17520) = 99.98\%$

Worked example (# 2):

Using the figures in the previous example for a system with a 2000 hour MTBF, the continuity over a three hour period is $1-(3/2000) = 99.85\%$.

Table 2

IMO A.915 (22) requirements for Continuity in the coastal zone

Category	Interval	Performance	Goal	Failures (Average)
High risk	3 hrs	2 years	99.97%	2
Low risk/Sole DGNSS site coverage	3 hrs	2 years	99.85%	9

5 Integrity

“Integrity is the ability to provide users with warnings within a specified time when the system should not be used for navigation.” (Ref. 4)

Integrity or integrity monitoring can be separated into different domains:

a. Local Integrity Monitoring

The local integrity monitoring is performed at the reference station site within the integrity monitoring (IM) receiver. The IM sends flags (alarms) to the reference station (RS) receiver along with system feedback. The alarms can further be separated into the following categories:

- *Position domain alarms*
Position domain alarms are generated when the radial position error, computed by the IM, exceeds the DGNSS service provider protection limit for more than the pre-set period of time. When the RS receives a position domain flag it sets the *Station Health Field* in the header of each broadcast message to indicate this "unhealthy" condition.
- *Pseudorange domain alarms*
Pseudorange domain alarms are generated when the computed residual for a given pseudorange exceeds the pre-set threshold for more than the pre-set period of time. Upon receipt of a pseudorange alarm the RS will set the PRC and RRC values for the satellite to the "do not use" values, as defined in RTCM SC 104.
- *Integrity Monitor System Feedback*
When a pseudorange and/or position domain alarm threshold is exceeded, the IM sends an immediate system feedback message to the RS. Additionally, this message, a RTCM SC104 RSIM 20, is sent on a pre-set periodic basis, which confirms to the RS that it is actually being monitored. When the RS will not receive IM system feedback within the specified time period it sets the *Station Health Field* in the header of each broadcast message to "unmonitored".
- *MSK Radiobeacon Monitoring*
Further some characteristics of the MSK radiobeacon signal like signal strength, signal to noise ratio, RTCM message throughput (WER) and correction age will be monitored at the IM. This kind of monitoring will be indicated as IM alarm or warnings to the DGNSS system provider and may cause a switch to standby equipment.

b. Far Field Integrity Monitoring

Some nations have also implemented far field monitoring facilities. In this case IM will be installed at remote locations. This kind of monitoring can provide better information of current coverage and availability of a DGNSS site.

The criteria used for identifying an integrity failure should be stated by the Administration in their publications. The time for broadcasting an integrity warning to the user, from the time the integrity problem is identified, should not be greater than 10 seconds.

The recommended thresholds for detecting failures are provided in Table 3 Section 12 – DGNSS STATION SETTINGS.

When it has been determined that the error condition no longer exists, there may be a delay, similar to that used for initially identifying the error, before the error warning is withdrawn.

6 Accuracy

The absolute horizontal accuracy should be better than 10m at the 95% probability level within the published coverage area. The alert level is 2.5 times the accuracy as stated in IMO A915 (22).

The absolute horizontal accuracy of the position solution at the reference station should be about 0.5 to 1 metre. This can be achieved by using a high quality reference receiver with carrier smoothing and to achieve this level of accuracy, reference receiver antennae positions should be surveyed to a 3D accuracy of better than 20cm.

Due to spatial decorrelation, achievable accuracy degrades as the distance from the broadcast site increases (0.4-1 meter per 100nm typically). Accuracy is further degraded by computational and other uncertainties in user equipment and the ability of user equipment to compensate for other error sources such as multipath and propagation distortions. Typically, in moderate atmospheric conditions, achievable accuracies of 0.5-5 metres are possible. Further studies of actual absolute horizontal accuracy are ongoing by several service providers.

7 Range/Coverage

Nominal ranges of stations over seawater paths should be published at a stated field strength (for example 50, 75 or 100 $\mu\text{V/m}$) (Ref. 5). Published coverage diagrams are normally based on software modelling predictions and should be verified by measurements. The modelling process can be quite complex and difficult, especially over mixed land/sea paths. Advice regarding modelling can be sought through IALA. In predicting coverage, each service provider should establish the required field strength by giving consideration to the following factors:

- Ø Radiated power,- Antenna system configuration, including horizontal and vertical polar diagrams.
- Ø Land paths - Additional attenuation over land should be calculated from current ITU-R curves and practice applicable at 300 kHz (Refs. 6 & 7).
- Ø Fading due to skywave propagation of the station's signal - At night the field strength at every point in the coverage should be not less than that specified at the nominal range for at least 95% of the time. Night-time field strengths may be calculated in accordance with references 8, 9 & 10.
- Ø Atmospheric noise - Assumed levels of atmospheric noise should be in accordance with current ITU-R data and practice applicable at 300 kHz. It is recommended that the noise level be that which is not exceeded more than 95% of the time on average throughout the year (Refs. 11 & 12).

- Ø Precipitation static - In those areas where precipitation static is known to be a significant problem, an appropriate factor should be added to the atmospheric noise (Ref. 13).
- Ø Man-made noise - In those situations, such as harbours, where man-made noise is significant in comparison with natural noise sources, the local man-made noise level should be taken into account (Ref. 14).
- Ø Bit rate - Transmission rates of 100 bits per second (bps) are generally used. 200 bps transmissions may be used to achieve a higher message throughput in impulse noise conditions but are more susceptible to Gaussian noise than 100 bps broadcasts, and will generally provide a lesser range.
- Ø Interference - Interference from stations on the proposed channel and on channels up to **1.5 kHz** either side should be taken into account. The protection ratios to be applied are those of the ITU-R (Ref. 1), appropriate to the type of interference and the frequency separation. Both groundwave and skywave propagation should be considered.

8 Transmitter Performance

The performance of the LF/MF transmitter and its antenna can be affected by weather conditions. An automatic Antenna Tuning Unit (ATU) should be used to minimise such effects.

Some administrations provide standby antennas to maintain service in the event of storm damage or outages for maintenance. It is normal practice to duplicate the transmitter, reference station and power supply.

There are well-established methods for the measurement of radiated power, field strength and antenna efficiency (Ref. 15).

9 Receiver Performance

In order to utilise the full DGNSS service capability, users should operate a GPS receiver conforming to the technical specifications set out in *IEC 61108-1*, or a GLONASS receiver conforming to the technical specifications set out in *IEC 61108-2*, combined with a differential GNSS receiver conforming to the technical specifications set out in *IEC 61108-4* (Refs. 16 & 17).

The performance of the LF/MF receiver and its antenna can also be affected by environmental conditions, for example precipitation static in high latitudes and atmospheric noise from electrical storms (Ref. 14). H-field antennas are usually better in this respect, although less sensitive than E-field (whip) antennas. Shipborne noise can also limit performance and it is important to provide good grounding for installations with E-field antennas. Mounting location on the vessel can also be important and local interference and noise sources should be identified and dealt with (Ref. 17).

10 Monitoring

On-site integrity monitors should be provided at each transmitting station, to check the transmitted signal and the data content. Additional signal monitoring is recommended using receivers placed at sites some distance from the reference station (Far Field Monitor) but within the coverage area to validate broadcast site RF and signal performance.

Communication lines to a central control and monitoring site may link integrity monitors. A second control and monitoring site may be provided as a standby. Data may either be logged on station and downloaded periodically or passed directly to the central control site. It is recommended that this data be archived for a period sufficient to meet local litigation requirements. See also section 5.

11 Validation

This validation procedure is provided to ensure the operational status of a DGNSS system.

11.1 Elements of performance

Performance of a radionavigation broadcast service is defined by five basic components: *accuracy, integrity, availability, coverage and continuity*. A.953(23) provides performance standards for three navigation phases: *ocean, coastal/harbour with low risk and coastal/harbour with high risk*. The performance standards are based on definitions of accuracy, availability and continuity as described in this recommendation and IMO Resolution A.915(22) Maritime Policy for future GNSS systems. The calculation of maritime DGNSS system performance parameters should take account only of maritime coverage areas.

11.2 Availability

The entire purpose of a radionavigation service is to provide navigation quality information to enable users in the service coverage area to calculate a more precise position and make safety-of-life decisions based upon this information. While various conditions may disrupt transmitted DGNSS signals, the net result is the same in that users lose their ability to determine their position using this service. Since one of the primary benefits is the significant improvement in positional accuracy, DGNSS can be used in waterways with more stringent navigation tolerances than the previous navigation systems could provide. Inherently, these more stringent applications also create tighter performance standards for the broadcast signal.

Availability in the coverage area can be measured (1) at the broadcast site, (2) by the use of a far-field monitor, or (3) by using a combination of these two methods, as determined by the administration. Availability is calculated based on periods of usable and unusable times during a total period of time. Periods of time are measured to the second. In dual-coverage areas, the combined availability will be higher than the individual availabilities.

The **period of performance**, for calculating DGNSS availability and continuity (as defined by IMO Performance Standard A.953(23)), is two calendar years for the coastal/harbour phase of navigation. A.953(23) recognises the GNSS constellation is not 100% available and discounts the time when the constellation is inadequate to calculate a two-dimensional

position solution. The **adjusted period of performance** is the period of performance decreased by the amount of time that the GNSS constellation is inadequate.

Administrations will have the option of defining, in their operational doctrine when the GNSS constellation is deemed inadequate. Typically this measurement incorporates some consideration of the GNSS constellation's dilution of precision as seen by the reference station.

The adjusted period of performance should be calculated, using a variety of sources including for GPS, the USCG Navigation Centre website: www.navcen.uscg.gov/gpsnotices, the recorded data at the reference station site and sites recording and monitoring GPS performance. For GLONASS, the website: www.glonass-center.ru. Extraordinary non routine site reconfigurations such as MF antenna replacement should be excluded from the adjusted period of performance. Administrations should give adequate advanced notice to users prior to such an event.

Example: During a two-year period of 1999-2000, the GPS constellation did not support two-dimensional navigation for 137 minutes. The adjusted period of performance is the total period of performance (262800 minutes) minus the unusable GPS constellation period (137 minutes), which equals 262663 minutes.

Unusable conditions: The DGNSS broadcast is unusable in the following conditions (or any continuous combination of conditions):

- 1) **Signal outage:** When the differential broadcast is not transmitted for a period greater than the momentary unusable period².
- 2) **Signal unmonitored:** When the differential broadcast health condition is unmonitored for a period greater than the momentary unusable period. Periods of control network outage will not be counted as “signal unmonitored” as long as the system is adequately engineered to respond to anomalies autonomously *or can be proven using post analyses*.
- 3) **Signal low power:** When the broadcast signal falls below the prescribed levels set by the administration, e.g. by 4 dB³ for a period greater than the momentary unusable period described below. A signal is to be considered underpowered when the low-power conditions create a gap in the prescribed coverage.
- 4) **Signal unhealthy:** The broadcast health bit is sometimes set to “unhealthy” *when the position threshold of the Integrity Monitor is exceeded*.
- 5) **Combinations of momentary unusable conditions:** When any continuous combination of unusable conditions occur for a period greater than the momentary unusable period.

Example: 12:15:10 Signal low powered
 12:15:25 Signal outage
 12:15:40 Signal on air but low power

2 For an explanation of momentary unusable period, please see page 14

3 Administrations typically set power levels to provide greater coverage than prescribed minima, thus providing some safety margin in power output.

12:15:55 Signal usable

Each of the individual unusable events qualify as momentary failure events. However, since the combination of events was continuous, the entire 45 second period (from 12:15:10 to 12:15:55) is considered unusable.

- 6) **Intermittent signals:** An intermittently usable signal (one that is not usable for at least 20 continuous seconds) implies unusable periods precede and follow the momentarily usable period. Such time is not accountable as usable and shall be included in the aggregate unusable period, beginning with the initial disruption of the usable period and ending with the resumption of usable time. *If the aggregate period is greater than the momentary unusable time defined below, then this period is unusable.*

Example: 12:15:10 Signal low powered
12:15:25 Signal usable
12:15:40 Signal low power
12:15:55 Signal usable

Each of the unusable low power events qualify as momentary events. But the short interval of usable time is not enough to qualify as usable, so the combination of unusable and momentary usable times are combined (from 12.15.10 12.15.55), creating a 45 second period of unusable time

Usable time is a contiguous period of healthy differential corrections and associated messages of sufficient signal strength to cover the intended service area. A period of usable time is a minimum of 20 seconds.

Momentary unusable period is that period when the signal is unusable for short durations and does not disrupt the user receiver's ability to calculate "corrected" position solutions. A momentary unusable period is any period that does not exceed 21 seconds. *The specified values of momentary unusable time and usable time are independent of each other.* Momentary unusable time is based upon the following:

- 1) **Accuracy tolerance** – When selective availability was applied to GPS signals, the maximum period a receiver could use a set of corrections was 30 seconds before statistically exceeding 10-meter position tolerance threshold. Some receivers still have this 30-second threshold programmed into their logic and the threshold is unchangeable. While pseudorange corrections in a non-SA environment are usable for much longer periods, the 30-second tolerance remains as a maximum momentary period for legacy equipment. *The receiver should revert to GPS-only operation when an "unhealthy" state is received.* Such conditions preclude the concept of a 30 second float capability by the receiver through a momentary unusable period.
- 2) **Message transmission time:** At 100 bps baud rate, the maximum transmission time of RTCM type 9-3, one of three sets is 2.1s. Therefore, 6.3s is required to clear the message buffer and transmit three Type 9-3 messages.

- 3) **Missed messages** – Presuming at least one of the three messages mentioned above is not received clearly, the user has to wait until another message of 2.1 seconds is received to provide the necessary corrections.

Conclusion – The driving forces are #2 and #3, accounting for a total of 8.4 seconds against a maximum period of 30 seconds (from #1). Thus a momentary of < 21.6 seconds (30-8.4) would not disrupt the receiver's ability to provide accurate position solutions. For practical purposes, a maximum momentary unusable time is defined as 21 seconds, anything greater than that constitutes unusable time.

Time to alarm – The user can expect to be notified within 10 seconds when an out-of-tolerance position is seen by the integrity monitor. When the signal broadcast is interrupted, users are notified of the signal loss by the receiver and should not expect further integrity messages.

11.3 Coverage:

DGNSS augmentations are designed to provide improved accuracy and integrity as required for more stringent coastal/harbour phases of navigation. There are two categories within that phase of navigation: high risk and low risk. Two or more DGNSS sites, providing overlapping coverage, typically serve high risk waterways. Low risk waterways are typically served by coverage from a single DGNSS site.

Overlapping coverage: Where the coverage from two or more DGNSS sites provide overlapping coverage, as long as at least one signal is available in all parts of the waterway, the requirement for signal coverage along the waterway is met. Thus from a coverage perspective, unusable time for a waterway can be calculated as the time when any portion of the waterway is without usable signals. DGNSS sites whose complete specified coverage area is also completely covered by one or several adjacent DGNSS sites are considered to be **dual coverage DGNSS sites**. The DGNSS coverage provided by adjacent countries may, if agreed, be taken into account when calculating the performance of a maritime DGNSS system.

Single coverage: Unless dual coverage is provided throughout the whole coverage area, some DGNSS sites provide a mix of overlapping and single coverage. DGNSS sites that provide single coverage to at least some portion of a waterway are considered to be **single coverage DGNSS sites**,

Calculation

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

- 1) by waterway model, or
- 2) by DGNSS site/DGNSS site combination model

Waterway availability model: In this model administrations need to define which waterways are high risk and which waterways are low risk. 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.

DGNSS site availability model: In this model, administrations must define which DGNSS sites serve low risk waterways and which serve high risk waterways. The overall availability is calculated by averaging the availability of the associated individual DGNSS sites as illustrated in the examples below.

Example 1: A high risk waterway receives complete DGNSS coverage from each of two DGNSS sites. DGNSS site A's availability was 99%, DGNSS site B's availability was 99,7%, but both DGNSS sites suffered coincidental outages during 0,2% of the period. Although neither DGNSS site individually met the availability target the combined availability was 99.8% and met the performance goal achieved.

Example 2: DGNSS site A (from above) also provides coverage to a low risk waterway. DGNSS site C, adjacent to DGNSS site A, provides completely overlapping coverage to the low risk waterway portion served by DGNSS site A. DGNSS site C's performance was 99%, but neither unusable period (of DGNSS sites A and C) coincided. The low risk waterway covered by DGNSS site A received usable signals for 100% of the time.

High risk/low risk availability calculations (see Table 1 in Section 4): When designing DGNSS networks, administrations should consider establishing such aids as the volume of traffic and the degree of risk require. If a waterway has a high degree of risk, the administration may choose to install more than one DGNSS site to increase the availability of the DGNSS service.

IALA calculations presume the presence of at least two signals to meet the prescribed DGNSS availability goals for high risk waterways. In areas of low navigational risk, administrations may choose to provide service just from one DGNSS site. The provision of dual coverage to low risk waterways does not change the service availability requirement for that coverage area to the high risk category.

While these two distinctly different situations have different availability requirements based upon the level of risk, the concept of availability remains consistent – the availability of at least one signal (meeting the minimum signal strength as specified by the administration) in all parts of the coverage area.

11.4 Continuity

Inherent in a radionavigation service is the capability to provide accurate position fixing and integrity information without interruption. Interruptions to DGNSS deny vital information to the users and, if frequent, erodes user confidence in the ability of the service to provide that information. The numbers of unusable events, not the length of the usable periods, determines continuity performance.

Additionally, in the event a healthy and monitored DGNSS site begins to experience intermittent failures (i.e. failures separated in time by a period less than one continuity time interval (CTI)), the period of intermittent operation would be counted as a single failure event for continuity purposes.

Continuity in the coverage area can be measured (1) at the broadcast site, (2) by the use of a far field monitor, or (3) by using a combination of these methods. Continuity is based upon the mean time between failures as measured over a two year period and a 3 hour continuity

time interval. The period of performance is not adjusted for inadequate GPS constellation, nor do GPS constellation deficiencies count as failures against continuity.

Continuity events: All unscheduled non-momentary unusable events described in the availability section are considered failures. Unlike availability, continuity does not count scheduled maintenance events as failures. Since public notices are provided for all scheduled maintenance events, user should be aware of such planned outages and plan the voyage accordingly.

11.5 Control Station

A **Control Station** is a station to which unmanned reference stations/integrity monitors report by data communications lines. The control station is normally manned at all times. Control station personnel take the actions required when initiated by error reports from the reference stations/integrity monitors. No standards or recommendations apply to the control station at this time.

12 Publication of Information

Individual Administrations are encouraged to publish service descriptions, including coverage predictions and system performance statistics; examples are given in references 18 to 23.

In addition to the information contained in the standard message types, described in Section 1, notice of current or planned signal unavailability should be provided to users through the appropriate service (e.g. coastal radio station, VTS, Navtex, Safetynet etc.)

Wherever practicable, information on scheduled and unscheduled off-air periods should be promulgated to users as follows:

Table 4

Scheduled maintenance	Date and expected downtime	One month in advance is recommended, but at least 1 week in advance is mandatory
Unscheduled outages	Expected downtime	As soon as practicable and not more than 1 hour after the occurrence

IALA Guidelines on Bilateral Agreements and Inter-Agency MOU's on the Provision of DGNSS services in the frequency band 283.5 kHz– 325 kHz contains examples of such documents. The examples include guidance on the information that should be exchanged between co-operating agencies and, where appropriate, the circumstances and timing for it to be exchanged.

IALA will continue to maintain the master list of radiobeacon DGNSS stations on the Internet. Input to the master list will be prepared by each Administration. IALA will provide an electronic template that should be used for initial entry of station data and assembly of the complete Administration submission. After initial submission, Administrations will be responsible for updating their own sections of the IALA master list. The process to

incorporate changes will require each Administration to provide a complete, updated section of the list for all the DGNSS sites that they operate. Each complete submission will appear exactly as submitted.

Tables 5.1 and 5.2 contain the information to be provided by administrations who plan to implement the Type 7 or Type 27 message respectively.

The file contains the following information:

Header information:

Country, Organisation, File Name, Date last updated, and Total number of sites in the file.

Site Information:

Each site will have the following fields of information with commas to separate each field.

Table 5.1
 Template for administrations using Type 7 Message

Field	Attribute
Site name	Max. 32 ASCII characters (including white space)
Transmitter ID	Integer, 0-999
RS1 ID	Integer, 0-999
RS2 ID	Integer, 0-999
Latitude	DD MM
North/South	N/S
Longitude	DDD MM
East/West	E/W
Radio frequency	Float, 283.5-325.0
Datum	ASCII, WGS-84 for GPS, PE90 for GLONASS, or Local Datum
Official operational status	Integer 0 = fully operational 1 = test/preliminary 2 = not in operation
Bit rate	Integer, 25, 50, 100, 200 bps
Synchronisation type	(Reserved)
Broadcast coding	Integer 0 = no added coding 1 = FEC coding

Example submission:

Field	Entry Data
Site name	ISLE OF NAVIGATIONAL EXCELLENCE
Transmitter ID	000
RS1 ID	000
RS2 ID	999
Latitude	90 00
North/South	N
Longitude	180 00
East/West	W
Radio frequency	283.5
Datum	WGS-84
Official operational status	2
Bit rate	200
Synchronisation type	(Reserved)
Broadcast coding	0

Table 5.2
 Template for administrations using Type 27 Message

Field	Attribute
Short name (Max. 9 characters)	Same format as for the type 16 message. The name should conform to the IALA list, Short Form.
Reference Station (RS)1 ID	Integer, 0-1023
Reference Station (RS)2 ID	Integer, 0-1023
Latitude (Degrees / Minutes)	DD MM ; North / South
Longitude (Degrees / Minutes)	DDD MM ; East / West
Operational Status	00-Fully Operational 01-Test Mode 10-No Information available 11-Not in operation (Planned)
Radio frequency (kHz)	283.5 kHz to 325 kHz
Bit rate	000- 25 bits/s 001- 50 bits/s 010- 100 bits/s 011- 200 bits/s
Datum	0 - WGS-84 1 – Local
Synchronisation type	(Reserved)

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APPENDIX 1

DGNSS BROADCAST SITE SETTINGS

It is recognised that certain reference station and integrity monitor threshold settings are vital to the proper performance of the DGNSS station. Table 3 contains the list of parameters and recommended range of settings that affect the DGNSS service and/or the service provider. In order to gain some insight into the functions of the reference station and integrity monitor, service providers should consult the RTCM Recommended Standards for Differential NAVSTAR GPS Reference stations and Integrity monitors (RSIM) version 1.1.

Table 3 – DGNSS Broadcast Site Settings

Parameter	Setting/ Threshold	Interval	System Impact	
			To system provider	To user
a) REFERENCE STATION				
Minimum satellites	4		- Cause a reference station alarm - if available switch to standby RS receiver	position could be bad caused by too few corrected SV (poor HDOP)
Pseudorange Correction	90 – 600m		- Cause a reference station alarm - Will set PRC and RRC values for a specific SV to "do not use" as described within RTCM SC104	Will drop "do not use" marked SV from position solution
Range rate correction	0.5 – 10 m/s		See above	See above
Integrity Monitor feedback	3 – 12 s		- Causes station health (header) to be set "unmonitored" - if available switch to standby IM receiver	- Use selected station with caution - Switch to another DGNSS site if available
Elevation angle	5 – 10 degs.		- improved availability at lower elevation angle setting	- slight degradation of user position accuracy when operating at lower elevation angle setting
b) INTEGRITY MONITOR				
RTCM correction age	10 - 30 s	1 – 30 s	- Cause a IM station warning or alarm - if available switch to standby RS receiver	- If correction age is higher than 10 sec this may affect TTA requirements. - Switch to another DGNSS site if available
Message error ratio	0.1 (10%)	10 - 60 s	See above	See above
Beacon SNR	> 7 db	> 7 s	See above	Will reduce coverage area
Beacon signal strength	4 to 7db from nominal	10 – 60 s	See above	Will reduce coverage area
Minimum satellites	3-4		- Cause a IM station alarm - Cause station health (header) to be set "unmonitored" only if no position fix can be performed due to low number of SV	- Use selected station with caution - Switch to another DGNSS site if available

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Parameter	Setting/ Threshold	Interval	System Impact	
			To system provider	To user
SV Interval (Difference of used satellites)		0 to 10 s	<ul style="list-style-type: none"> - Cause an IM station alarm - Cause station health (header) to be set "unmonitored" - if available switch to standby IM receiver - if available switch to standby RS receiver 	<ul style="list-style-type: none"> - Use selected station with caution - Switch to another DGNSS site if available
HDOP	< 7.5	10 – 30 s	<ul style="list-style-type: none"> - Cause an IM station alarm - Cause station health (header) to be set "unmonitored" - if available switch to standby IM receiver 	<ul style="list-style-type: none"> - Use selected station with caution - Switch to another DGNSS site if available
Absolute Horizontal Position	1.5 – 10m	10 – 30 s	<ul style="list-style-type: none"> - Cause an IM station alarm - Cause station health (header) to be set "unmonitored" - if available switch to standby IM/RS receiver 	<ul style="list-style-type: none"> - Don't use this station - Switch to another DGNSS site if available
Pseudorange residual (PRR)	< 12m	10 – 30 s	<ul style="list-style-type: none"> - Cause a IM station alarm - Will set PRC and RRC values for a specific SV to "do not use" as described 	Will drop "do not use" marked SV from position solution
Range rate residual	< 10 m/s	10 – 60 s	See above	See above
Low UDRE	1 – 100m	Please consult manufacturer for settings	<ul style="list-style-type: none"> - Cause a IM station alarm - Cause station health (header) to be set "unmonitored" - if available switch to standby IM/RS receiver 	Switch to another DGNSS site if available
Elevation angle	0 – 10 deg.		<ul style="list-style-type: none"> - optimal monitoring of the broadcast when setting is identical to the RS's 	<ul style="list-style-type: none"> - optimal broadcast service

Notes on Table 3

A - Reference Station

A-1. Minimum satellites

Pseudorange corrections of three satellites are sufficient to generate a 2D horizontal position solution and correct the clock bias, assuming a fixed height input. Generating the pseudorange corrections of four satellites will allow a user to solve for the height and derive a 3D position. Since the user does not always know the correct input height, a 3D position solution using four satellites is preferred.

Accordingly, the minimum satellite setting should be four to indicate the presence of four broadcast pseudorange corrections. When the visible satellite constellation goes below this threshold, an internal alarm may be sent to the service provider. This setting does not affect the issuance of Type 9 Message since for example, three pseudorange corrections of three satellites will be broadcast.

A-2. Pseudorange Correction

Pseudorange corrections are generated by the Reference Station to compensate for the delay that signals encounter as they pass through the ionosphere and troposphere, as well as clock and satellite ephemeris errors observed at the Reference Station. The Reference Station computes a pseudorange to the satellite and compares it with an absolute range based on its known surveyed antenna position. The Reference Station measures the difference between the pseudorange and the absolute range and generates differential corrections. Pseudorange corrections do not compensate for local errors caused by multipath or receiver noise.

This alarm threshold value is set for 100-600m. If the pseudorange correction exceeds this value, it may indicate a satellite problem. Smaller threshold values may cause the Reference Station to halt corrections for a satellite. Larger threshold values may result in slightly greater system inaccuracies reaching the user.

Note: When the Integrity Monitor flags the pseudorange bad for a particular SV, the Reference Station may actually set the PRC to the RTCM defined "do not use this SV" value that is greater than +/- 655.344 m or 1 +/- 10485.44m. So if an alarm occurs, it could be caused by the "do not use" value, and the effect on the User will be to drop that SV while the PRC is set at "do not use."

A-3. Range Rate Correction

Range rate is determined by measuring the Doppler shift of the satellite carrier. The Reference Station calculates the rate of change for the pseudorange of all the satellites it is tracking. Range Rate correction was a very effective way of mitigating Selective Availability (SA) dither.

This alarm threshold value is set for 1-10m/s. If the pseudorange correction exceeds this value, it may indicate that the satellite is actually moving erratically or has a clock problem. Smaller threshold values may result in the Reference Station halting satellite corrections

unnecessarily. Larger threshold values may result in slightly greater system inaccuracies transmitted to the user.

Range rate corrections may be set to zero to eliminate the effects of random noise error generation as long as DGPS corrections are broadcast within 30 to 60 seconds.

Note:

When the Integrity Monitor flags the RRC bad for a particular SV, the Reference Station may actually set the RRC to the RTCM defined "do not use this SV" value that is greater than +/- .254 m/s or +/- 4.064m/s. So if an alarm occurs, it could be caused by the "do not use" value, and the effect on the User will be to drop that SV while the RRC is set at "do not use."

A-4. Integrity Monitor Feedback

Integrity Monitor feedback provides the Reference Station with information on the accuracy of the DGPS broadcast. The threshold setting determines the maximum amount of time the Reference Station will continue to transmit corrections based on the last time it was monitored by the Integrity Monitor.

The Integrity Monitor ensures the accuracy of the broadcast by determining its own position with its internal GPS receiver and monitoring the MSK broadcast from the DGPS transmitter. The Integrity Monitor applies corrections to the raw GPS data and determines the computed position of its receiving antenna. If the computed position drifts outside of an allowable window based on the surveyed antenna position, the Integrity Monitor sends an RSIM#20 message to both the Reference Station and the control station if appropriate. The RSIM #20 tells the Reference Station about bad pseudorange values for 1 SV at time as well as in/out of tolerance on position. When the Integrity Monitor flags a SV PRR (pseudorange residual) bad, the Reference Station reacts on just that 1 SV according to REF(3). If the Integrity Monitor reports a position out of tolerance, then the Reference Station will set the header of all RTCM messages to "unhealthy". If the RSIM #20 is not received within the Threshold Value, then the Reference Station will set the header of all messages to "unmonitored." The Reference Station will then flag the RTCM type data as unhealthy and the standby Reference Station / Integrity Monitor may be brought on-line, if appropriate.

This alarm threshold value is set for 3s-12s. If the Reference Station doesn't receive a feedback message from the Integrity Monitor for the period of time specified by this threshold, it will begin to flag its message headers with "unmonitored".

Smaller threshold values may result in excessive unavailability times at the site. Larger threshold values may result in unmonitored or poor quality corrections transmitted to the user.

A-5. Elevation Angle (Mask Angle)

The purpose of the mask angle is to screen all satellites below a predetermined angle above the horizon. The Reference Station will not use satellites below this level in its position and/or clock solutions. Most Reference Stations do track satellites below the mask angle if an open channel is available and can pass observables via an open communication port.

The mask angle is set at between 5 to 10 degrees. Operating at the lower end of the range will benefit the service provider as more useable satellites will improve availability, especially

when some satellite(s) are unavailable. However, multipath, tropospheric and satellite observables errors tend to become more significant in degrading the user position solution as the mask angle is lowered (i.e. low elevation angle satellites are included in the solution). At the user end, some of these effects are not currently being mitigated by the service provider.

B. Integrity Monitor

B-1. RTCM correction age

RTCM correction age (measured in seconds) is the time difference between the time when a set of corrections is computed at the reference receiver and the time when the corrections are received within the Integrity Monitor's DGPS receiver.

The correction age is directly related to the data rate used at the reference station. In normal operation the correction age is as follows:

(using a set of 9 SV and Message type 9-3)

- 50 Bit/s: this baud rate is not typically used
- 100 Bit/s: 6-7 sec
- 200 Bit/s: 3-4 sec.

Since S/A was set to zero, the resulting position accuracy at a user GPS receiver is no longer affected by correction ages less than a few minutes. The remaining errors within the GPS signal like ionosphere and troposphere change slowly in time.

Thus in an environment where S/A is set to zero, correction ages above the given threshold will have an impact on the integrity functionality of a reference station. Taking into account the integrity requirement with a TTA of 10 seconds to inform the user, the correction age should not exceed this value significantly.

Due to the method used to calculate the correction age, high settings (>10s) may need to be used in some applications to avoid frequent alarms.

Correction Age Interval

This interval is a time period over which correction data is observed and averaged. The Integrity Monitor is continuously monitoring the correction age interval so there should be little or no processing overhead change. If the value is out of tolerance an alarm is generated.

This value is set at between 1–30 seconds. Longer intervals result in slower detection of excessive pseudorange correction age. Shorter intervals add processing overhead to the Integrity Monitor

B-2. Message error ratio

During data link reception, message error ratio is calculated as the number of bad bits divided by the total number of bits.

The value is set at 0.1. A higher ratio is an indication that there may be a problem with the data link. Lower threshold values hold the transmitter to a higher standard of modulation.

When one of the 30-bit words in a message frame fails the parity test the bits for the entire message are considered bad.

Message error ratio interval

This interval is a time period over which data is observed to use for calculating the message error ratio. There should be little or no extra processing overhead in the Integrity Monitor based on this interval because the MSK receiver is continuously monitoring the message error ratio. If the value is out of tolerance an alarm is generated.

This value is set at between 10–60 seconds. Longer intervals result in slower detection of data link problems. Shorter intervals add processing overhead to the Integrity Monitor.

B-3. Beacon SNR

The signal-to-noise ratio (SNR) is the minimum acceptable ratio of the amplitude of the data link signal to the amplitude of the ambient noise expressed in dB.

This value is set at >7 db. If the near-field SNR falls below this value, the data link signal may not be of sufficient quality that the user's receiver can properly decode the broadcast.

Beacon SNR interval

This interval is basically a time period over which data is observed. The Integrity Monitor is continuously monitoring the SNR so there should be little or no processing overhead change. If the value is out of tolerance an alarm is generated.

This value is set at between 10–30 seconds. Longer intervals result in slower detection of data link problems. Shorter intervals add processing overhead to the Integrity Monitor.

B-4. Beacon signal strength

The beacon signal strength is a measure of the near field signal strength expressed in dB(μ V/m).

This alarm threshold value is set 4dB-7dB down from nominal. If beacon signal strength falls below the threshold, the data link signal may not be at a level sufficient for the user's receiver to properly decode the broadcast.

Nominal alarm threshold value is set by the service provider according to site specific measurements.

Note: The Message Error Ratio, Beacon SNR and Signal Strength intervals are similar to moving window averages - you are making calculations every second no matter what the Interval is, but if during, or for an entire Interval the value goes beyond the Threshold, an alarm is generated. Shorter Intervals show changes more quickly, and Longer Intervals show changes more slowly (because it takes a greater number of changes to raise the "average").

Beacon signal strength interval

This interval is basically a time period over which data is observed. The Integrity Monitor is continuously monitoring the Beacon signal strength so there should be little or no processing overhead change. If the value is out of tolerance an alarm is generated.

This value is set at between 10–30 seconds. Longer intervals result in slower detection of data link problems. Shorter intervals add processing overhead to the Integrity Monitor.

B-5. Minimum satellites

This setting specifies the minimum number of satellites with accompanying pseudorange corrections required to generate a valid 3D differential position solution. The integrity monitor should be set to detect the PRCs of at least 4 satellites. *When the visible satellite constellation goes below this threshold, an internal alarm may be sent to the service provider. Setting the last computed fixed height as a value in order to derive a 2D position, should be avoided as the assumed height will introduce a position error.*

This value is set to alarm when less than 4 satellites are visible.

B-6. SV interval (Difference of used satellites)

This parameter is not described in REF (3). Some manufacturers, however, have implemented this setting. This interval is basically a time period over which data is observed, specifying the maximum time delta between correctors for use in a solution computation. The Integrity Monitor is continuously monitoring the SV interval so there should be little or no change in processing overhead. If the value is out of tolerance an alarm is generated.

Service providers that employ this parameter typically set this value from 0-10s

B-7. HDOP

The Integrity Monitor uses horizontal dilution of precision (HDOP) to measure the current quality of the constellation geometry as it relates to triangulation of the pseudoranges.

This value is set at <7.5. Low HDOP numbers indicate good constellation geometry. High HDOP values indicate poor constellation geometry. If the HDOP is higher than the threshold, the validity of the corrections becomes uncertain and the site's pseudorange generation must be suspended.

HDOP interval

This interval is basically a time period over which data is observed. The Integrity Monitor is continuously monitoring the HDOP so there should be little or no processing overhead change. If the value is out of tolerance an alarm is generated.

This value is set at between 10–30 seconds. Longer intervals result in slower detection of HDOP data problems. Shorter intervals add processing overhead to the Integrity Monitor.

B-8. Absolute Horizontal Position

Also referred to as Horizontal Position Error. The Integrity Monitor applies pseudorange corrections received over the data link to the pseudoranges generated by its internal GPS receiver. It uses these corrected pseudo ranges to generate a DGPS corrected position. The radial error in that position in relation to the surveyed monument is the 2D position Error.

This value is set at between 5-10 meters. Smaller threshold values may result in greater site unavailability time – more time out of tolerance. Larger threshold values may result in greater system inaccuracies transmitted to the user.

2D position interval

This interval is basically a time period over which data is observed. The Integrity Monitor is continuously monitoring the 2D position interval so there should be little or no processing overhead change. If the value is out of tolerance an alarm is generated.

This value is set at between 10–30 seconds. Longer intervals result in slower detection of system position accuracy problems that may originate from a variety of sources. Shorter intervals add processing overhead to the Integrity Monitor.

B-9. Pseudorange residual

The Integrity Monitor applies pseudorange corrections received over the data link to individual pseudoranges generated by its internal GPS receiver, and then compares them to its known surveyed monument's position. The resulting value is the Pseudorange residual.

This value is set at <12 meters. Smaller threshold values may result in the Integrity Monitor telling the Reference Station to stop correcting satellites unnecessarily. Larger threshold values may result in greater system inaccuracies transmitted to the user.

Pseudorange residual interval

This interval is basically a time period over which data is observed. The Integrity Monitor is continuously monitoring the Pseudorange residual interval so there should be little or no processing overhead change. If the value is out of tolerance an alarm is generated.

This value is set at between 10–30 seconds. Longer intervals result in slower detection of pseudorange accuracy problems. Shorter intervals add processing overhead to the Integrity Monitor.

B-10 Range rate residual

The difference between the most recent range rate correction received and the current pseudorange rate measured at the Integrity Monitor.

This value is set at <10m/s. Motion faster than the threshold value may indicate a problem with the satellite actually moving erratically or may indicate a satellite clock problem. Smaller threshold values may result in the Integrity Monitor telling the Reference Station to stop correcting satellites unnecessarily. Larger threshold values may result in greater system inaccuracies transmitted to the user.

Range rate residual interval

This interval is basically a time period over which data is observed. The Integrity Monitor is continuously monitoring the Range rate residual interval so there should be little or no processing overhead change. If the value is out of tolerance an alarm is generated.

This value is set at between 10–60 seconds. Longer intervals result in slower detection of excessive Reference Station Range Rate correction values. Shorter intervals add processing overhead to the Integrity Monitor.

B-11. Low User Differential Range Error (UDRE)

UDRE is a one-sigma estimate of the pseudorange correction error due to ambient noise and residual multipath. Basically, every PRC generated by the Reference Station has a "reported" UDRE value in it and when the Integrity Monitor uses the PRC it tries to determine if the "reported" UDRE is correct. If the Integrity Monitor determines that the reported UDRE is set to a value "LOWER" than it should be, then we have a "Low UDRE" condition.

This value is set at 1m-100m. Using higher UDRE threshold values may allow multipath and receiver noise errors to impact the user. Lower values may result in excessive site unavailable time.

Low UDRE interval

This interval is basically a time period over which data is observed. The Integrity Monitor is continuously monitoring the Range rate residual interval so there should be little or no processing overhead change. If the value is out of tolerance an alarm is generated.

This value is set at between 10–30 seconds. Longer intervals result in slower detection of excessive receiver noise and multipath problems. Shorter intervals add processing overhead to the Integrity Monitor.

B.12 Elevation Angle (Mask Angle)

The mask angle screens all satellites below a predetermined angle above the horizon. The Integrity Monitor will not use satellites below this level in its position and/or clock solutions.

The mask angle is set at between 5 to 10 degrees at the same value as the reference station. It should never be set higher than that of the same Reference Station. Operating at the lower end of the range will benefit the service provider as more useable satellites will improve availability, especially when there are limited visible satellites. The same comments in A.5 with regard to users operating at the lower range of the mask angle applies for Satellites observed at elevation angles lower than 10 degrees may be adversely impacted by multipath.

APPENDIX 2

Definitions and Glossary of Terms used in GNSS

Accuracy. The degree of conformance between the estimated or measured parameter of a craft at a given time and its true parameter at that time. (Parameters in this context may be position coordinates, velocity, time, angle, etc.)

- *Absolute accuracy (Geodetic or Geographic accuracy).* The accuracy of a position estimate with respect to the geographic or geodetic coordinates of the Earth.
- *Geodetic or Geographic accuracy.* See Absolute accuracy.
- *Predictable accuracy.* The accuracy of the estimated position solution with respect to the charted solution.
- *Relative accuracy.* The accuracy with which a user can determine position relative to that of another user of the same navigation system at the same time.
- *Repeatable accuracy.* The accuracy with which a user can return to a position whose coordinates have been measured at a previous time using uncorrelated measurements from the same navigation system.

Augmentation. Any technique of providing enhancement to the GNSS in order to provide improved navigation performance to the user.

- *Satellite-based augmentation system (SBAS).* A system providing additional satellite signals in order to enhance the performance of the GNSS service.
- *Ground-based augmentation system (GBAS).* A system providing additional signals from a ground-based station in order to enhance the performance of the GNSS service.

Availability. 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

- *Signal availability.* The availability of a radio signal in a specified coverage area.
- *System availability.* The availability of a system to a user, including signal availability and the performance of the user's receiver.

Broadcast Site. The entire DGNSS installation comprising of Reference Stations, Integrity Monitors, LF/MF Transmitter/Antennae, etc. May also be referred to as Broadcast Station.

Continuity. The probability that, assuming a fault free receiver, a user will be able to determine position with specified accuracy and is able to monitor the integrity of the determined position over the (short) time interval applicable for a particular operation within a limited part of the coverage area.

Continuity Time Interval. The period of time that it normally takes to complete a manoeuvre or seek safe anchorage. When determining Continuity, this time period is 3 hours.

Correction. The numerical value of a correction is the best estimate that can be made of the difference between the true and the measured value of a parameter. The sign is such that a correction that is to be added to an observed reading is taken as positive.

Coverage. The coverage provided by a radionavigation system is that surface area or space volume in which the signals are adequate to permit the user to determine position to a specified level of performance.

Differential system. An augmentation system whereby radionavigation signals are monitored at a known position and the corrections so determined are transmitted to users in the coverage area.

Dilution of precision. The factor by which the accuracy of the GNSS position and time coordinates are degraded by geometrical considerations of the constellation of GNSS satellites used by the receiver.

- *Geometric dilution of precision (GDOP).* The factor for the combined 3D-position and time accuracy.
- *Position dilution of precision (PDOP).* The factor for the 3D-position accuracy.
- *Horizontal dilution of precision (HDOP).* The factor for the horizontal position accuracy.
- *Vertical dilution of precision (VDOP).* The factor for the vertical accuracy.
- *Time dilution of precision (TDOP).* The factor for the time accuracy.

Distance root mean square (dRMS). The root mean square of the radial distances from the true position to the observed positions obtained from a number of trials.

Failure. The unintended termination of the ability of a system, or part of a system, to perform its required function.

Fix. A position determined by processing information from a number of navigation observations.

Fix rate. The number of fixes per unit time.

GLONASS. (Globalnaya Navigatsionnaya Sputnikovaya Sistema) - This is a space-based, radio positioning, navigation and time-transfer system operated by the Government of the Russian Federation.

GNSS - Global Navigation Satellite System. A worldwide position, time and velocity radio determination system comprising space, ground and user segments. The system relates to the properties of the GNSS service plus the receiver.

GPS - Global Positioning System. This is a space-based, radio positioning, navigation and time-transfer system operated by the United States Government.

GNSS service. The service relates to the properties of the signal in space provided by the space and ground segments of the GNSS.

Integrated navigation system. A system in which the information from two or more navigation aids is combined in a symbiotic manner to provide an output that is superior to any one of the component aids.

Integrity. The ability to provide users with warnings within a specified time when the system should not be used for navigation.

Integrity monitoring. The process of the determination whether the system performance (or individual observations) allow use for navigation purposes. Overall GNSS system integrity is described by three parameters: *the threshold value or alert limit, the time to alarm and the integrity risk.* The output of integrity monitoring is, that individual (erroneous) observations or the overall GNSS system cannot be used for navigation.

- *Internal integrity monitoring* is performed aboard a craft
- *External integrity monitoring* is provided by external stations

IMO - International Maritime Organization

ITU - International Telecommunication Union

ITU-R - ITU Radiocommunication Sector

IEC - International Electrotechnical Commission

Latency. The time lag between the navigation observations and the presented navigation solution.

MTBF - Mean time between failures. The average time between two successive failures of a system or part of a system.

MTBO - Mean time between outages.

MTRS - Mean time to restore system to full operation.

Navigation. The process of planning, recording and controlling the movement of a craft from one place to another.

PE-90 geodetic system. A consistent set of parameters used in GLONASS describing the size and shape of the Earth, positions of a network of points with respect to the centre of mass of the Earth, transformations from major geodetic datum's and the potential of the Earth, developed in 1990.

Radionavigation. The use of radio signals to support navigation for the determination of position or direction, or for obstruction warning.

Receiver autonomous integrity monitoring (RAIM). A technique whereby the redundant information available at a GNSS receiver is autonomously processed to monitor the integrity of the navigation signals. (See also craft autonomous integrity monitoring.)

Redundancy. The existence of multiple equipment or means for accomplishing a given function in order to increase the reliability of the total system.

Repeatability. The accuracy of a positioning system, taking into account only the random errors. The repeatability is normally expressed in a 95% probability circle.

Root mean square error (RMS). RMS error refers to the variability of a measurement in one dimension. In this one-dimensional case, the RMS error is also an estimate of the standard deviation of the errors.

RTCM - Radio Technical Commission for Maritime services

Threshold value (or alert limit) is the maximum allowable error in the measured position – during integrity monitoring - before an alarm is triggered.

Time to alarm. The time elapsed between the occurrence of a failure in the system and its presentation on the bridge.

True position (2D). The error-free latitude and longitude co-ordinates in a specified geodetic datum.

True position (3D). The error-free latitude, longitude and height co-ordinates in a specified geodetic datum.

VTS - Vessel Traffic Services

World geodetic system (WGS). A consistent set of parameters describing the size and shape of the Earth, positions of a network of points with respect to the centre of mass of the Earth, transformations from major geodetic datums and the potential of the Earth.

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