Document Revisions (Title style)

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**On**

**Marine beacon coverage prediction**

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The Maritime use of SBAS

# Introduction

Many maritime administrations provide marine beacon differential GNSS correction services. This Guideline outlines how to calculate the expected signal strength for any given station under varying conditions and outlines how the coverage area of any station, or group of stations, may be calculated.

# SCOPE [Scope / Purpose (may be called Objectives)]

This document aims to assist marine beacon DGNSS service providers when calculating the expected range of any transmitting station, or groups of stations. IALA R-121 invites all service providers to inform users of the coverage area of their systems.

# [Definitions / Acronyms, as required]

1. Acronyms

|  |  |
| --- | --- |
| EDAS | EGNOS Data Access Service |
|  |  |
|  |  |
|  |  |
|  |  |

# Background

A marine radiobeacon transmits omni-directionally. Its signal reaches the receiver by two main paths: groundwave and skywave. The groundwave-propagated component travels over the surface of the Earth. The skywave-propagated one is refracted by the ionosphere and is more prevalent at night.

## Groundwave propagation

As a groundwave signal propagates, its field strength is progressively attenuated. The rate of this attenuation depends on the frequency of the signal and the type of ground it travels across. The ITU provide a series of propagation curves within ITU P.XXX which can be used to predict the expected signal strength given the type of ground and its electrical conductivity.

The conductivity of the ground for the propagation path being considered can be identified via the ITU World Atlas of Ground Conductivities [69], from which it’s possible to identify the different conductivities affecting the propagation path.

Where a propagation path crosses ground of more than one conductivity type, the ITU recommend the use of Millington’s method to calculate the total path attenuation.

### Millington’s Method

Millington’s method works on the assumption that the direction of propagation is irrelevant to the total attenuation, so the total attenuation measured in each direction is calculated and then the average taken.

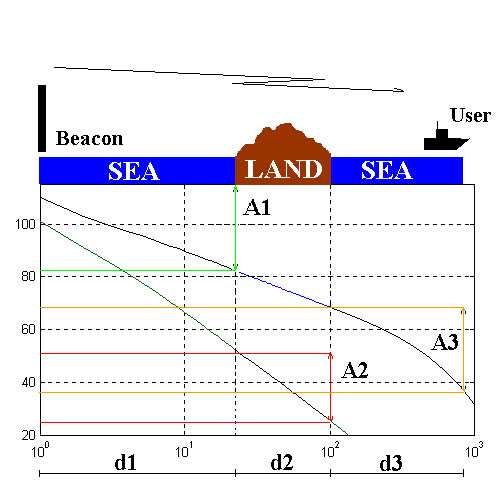


Figure 1: An example of a groundwave signal propagating over a mixed ground conductivity.

Fig 1 gives an example of transmission to the user. The signal propagates over three ground conductivity areas, propagating across seawater, land and seawater once more. The attenuation experienced between the transmitter and the edge of land results in the attenuation *A1,* shown in green. Then across the land, the signal is further attenuated by the amount *A2,* shown in red. Then, when it propagates over seawater once again, it is attenuated by *A3*, (shown in orange), until it reaches the receiver.

The total attenuation on the signal across the full propagation path is the sum of all three, A1+A2+A3. This is then repeated from the other direction and the two attenuation figures averaged, resulting in the total attenuation. (why are they different?)

## Skywave Propagation

At night, signal components propagating as skywaves reach the receiver by refracting in ionospheric layers of the Earth’s atmosphere [70]. While the data transmitted in the skywave signal is valid, it does have a detrimental effect on coverage since it can cancel the groundwave signal and so cause “self‑fading”. The effect of self‑fading on coverage depends critically on the strengths of the groundwave and skywave signals, and is therefore a function of distance from the transmitter, rather than transmitter power.

The ITU has developed a method of estimating the median field strengths [70] of radiobeacon signals (*SkydB* (dB)) over propagation paths (of range d(km) as:

,

where *A* = 106.6 – sin (Φ), with Φ being the geomagnetic latitude; *k* the basic loss factor; *p* is the slant propagation distance in km; *Gs* is the sea gain; *Gv* is the antenna gain factor; and *Δp* is the beacon’s power with respect to 1kW.

The value at the mid-point of the propagation path is used the geomagnetic latitude Φ. Geomagnetic latitude is latitude with respect to the poles of Earth’s magnetic field. The co-ordinates of the north geomagnetic pole (GNPLAT and GNPLON) can be found from several sources, including the British Geological Society [ref]. The geomagnetic latitude of a point at geographic latitude *α* and geographic longitude *β* is given by:

The slant propagation distance, *p*, is the total path length travelled by the skywave signal component (Fig. 3.6). With a typical E-layer height of 100km this distance would be:

.

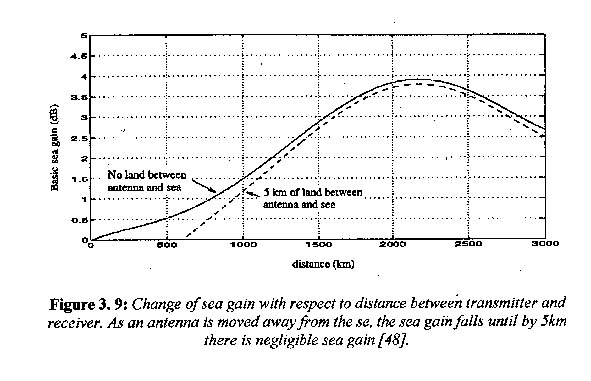
The basic loss factor attenuation due to the ionosphere, *k*, is calculated using:

,

where *fkHz* is the frequency in kHz.

Sea gain, *Gs*, takes into accountthe small increase in skywave field strength experienced when either the transmitter or the receiver is located close to the sea. Fig. 3.8 shows that there is a sea gain of 1.5dB over a 1000km path, for each end close to the sea. Sea gain falls with distance from the sea, becoming negligible by 5km [72].

*Gv*, the antenna gain factor, depends on the vertical polar diagram of the antenna. Almost all radiobeacon antennas are vertical monopoles, with or without capacity hats, and short in terms of wavelength.



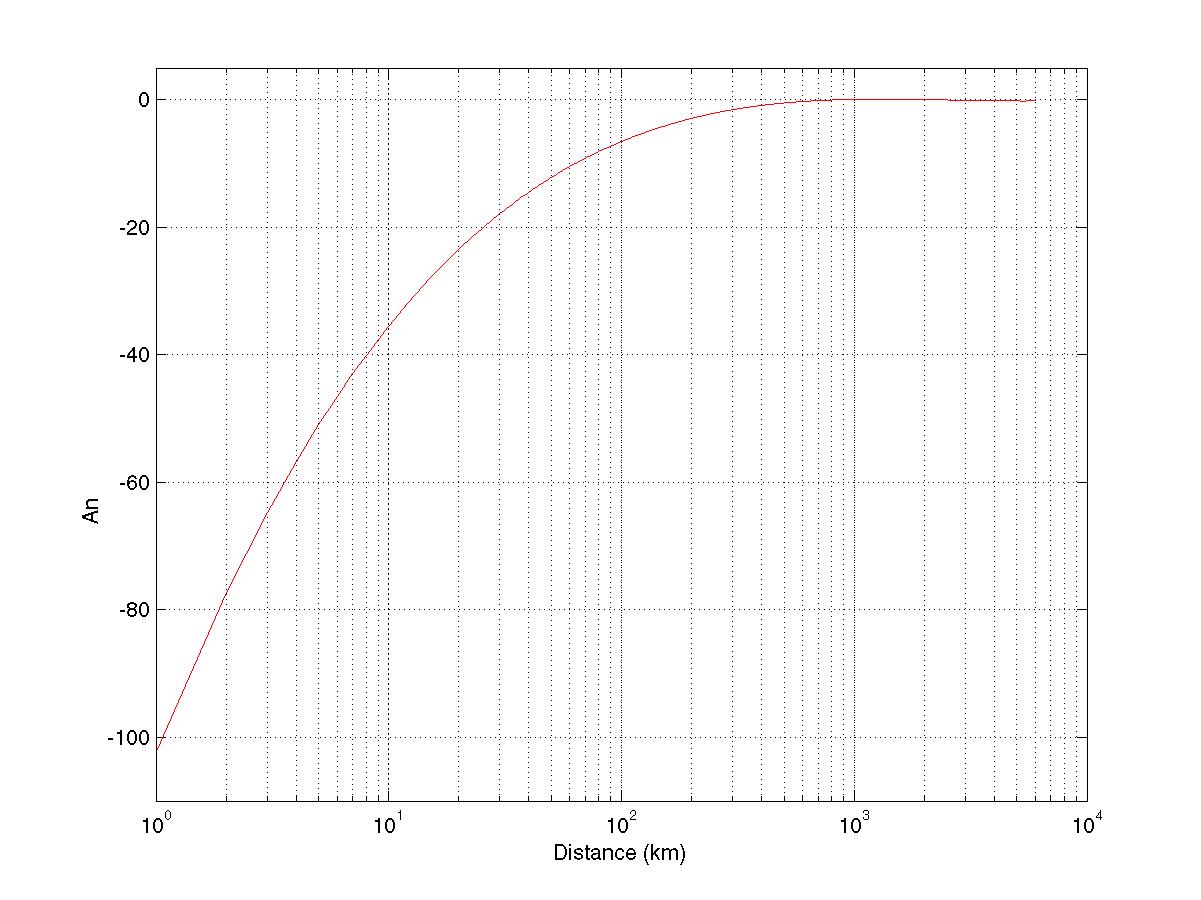
*Figure2: Sea gain occurs when either the transmitter or the receiver is located within 5km of the sea. Its magnitude depends on the separation of the transmitter and the user. [72].*

Thus the E‑field polar diagram has a maximum in the horizontal plane and a null vertically above. Equation 3.5 shows a polynomial fit to this radiation pattern [14]:

,

where *ld* = log10 (distance in km).

Fig. 3.7 shows that the *Gv* term causes high attenuation to the skywave components reflected at high angles that would return to earth close to the station. It decreases with range, having negligible effect beyond 3000km [72].



*Figure 3: Antenna gain of a short monopole against distance at which skywave component returns to earth*

## Nominal range

The nominal range is the distance at which the transmitter signal strength will fall to a set level if it was propagating over a sea path. The reference level depends on the latitude of the transmitter, as shown in Table X.

|  |  |  |
| --- | --- | --- |
| Units | Nominal range reference level | |
| V/m | N of 43oN | 50 |
| S of 43oN | 75 |
| dBV/m | N of 43oN | 34 |
| S of 43oN | 37.5 |

Therefore a station with a nominal range of 177km located above 43oN will have a signal strength of 34dBV/m at 177km over a seawater path.

## Interference

The 283.5 - 325kHz frequency band is shared with non-directional beacons, aeronautical beacons and marine DGNSS beacons, all of which can interfere with the reception of the wanted signal.

Marine beacon receivers are designed to mitigate interference where possible and will employ rejection ratios at least as good as those identified in ITU-R M.823.

When calculating or predicting coverage, interference must be taken into account, especially at distance from the transmitting station. Atmospheric noise can also add to this interference level.

# Calculating expected signal strengths

## Calculating the expected signal strength under day-time conditions

It is possible to calculate the expected signal strength expected under day-time conditions through knowledge of the transmitter location, station nominal range, attenuation and the receiver location.

The process is made more simple if the measurement site is between 20-100km from the transmitter and over a (predominately) sea path.

Using the 300kHz ITU-R groundwave propagation curves, it is possible to read the expected signal strength for a 1kW transmitter over the propagation path, from which the wanted transmitter power in respect to the 1kW transmitter can be calculated.

Then, for the known spatial separation of the transmitter and measurement location, one can read the expected signal strength for the 1kW curve by reading the appropriate attenuation curve. Having read the field strength expected for the 1kW transmitter, the figure is then adjusted with respect to the actual transmitted power.

For example:

## Calculating the expected signal strength under night-time conditions

## Calculating the level if interference

## Calculating antenna efficiency

# Coverage prediction

A marine DGPS beacon is deemed to provide coverage when its signal exceeds minima set by the International Telecommunications Union (ITU), as shown in Table 3.1. Calculating these signal parameters at different locations is a complex task involving many factors.

## Performance requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Units | Marine (MB) | | Aero (NDB) | DGNSS |
| Minimum Field Strength | V/m | N of 43oN | 50 | 70 | 10 |
| S of 43oN | 75 |
| dBV/m | N of 43oN | 34 | 37 | 20 |
| S of 43oN | 37.5 |
| Minimum Signal-to-Noise ratio (SNR) | dB | 15 | | 15 | 7 |

*Table 3.1 Minimum field strengths and signal-to-noise ratios for marine, aeronautical and DGNSS beacons in the European Maritime Area [57,60,64].*

The coverage of a radiobeacon depends on the signal strength of its own, wanted, signal. It also depends on the signal-to-noise ratio. In this case “noise” includes atmospheric noise, ship’s noise, or signals from other “interfering” beacons. Calculating the strengths of these various components is a complex process, often stochastic, and with results that change with location.

## Self-fading

## Interference

## Atmospheric noise

# In-field measurements

## Equipment

The following equipment will be needed to accurately measure marine beacon field strengths:

* field strength meter or spectrum analyser (calibrated)
* Appropriate loop antenna (calibrated, if required) and tripod
* Marine beacon receiver
* Compass
* Map with general location of transmitter and measurement location.

## Process

At the selected measurement site, connect the field strength meter or spectrum analyser and configure to the correct frequency, bandwidth and attenuation, as required, to give a calibrated reading of the transmission of interest.

Then rotate the loop antenna so that the loop is aligned with the direction of the transmitter, using the compass if required to get the correct bearing. Check that when the loop antenna is then moved through 90 degrees the signal strength drops. Find the point where the signal strength falls to the lowers point (null) and then turn the antenna back through 90 degrees. It should now be correctly aligned with the incoming signal.

The reported signal strength is that measured at that location for the signal of interest. If data is to be recorded over a longer period of time, the marine beacon receiver can be configured to log the data via the NMEA $GPMSS string, however care should be taken to note the offset in reported signal strength between the receiver and the calibrated loop antenna.

# references

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