REPORT 1166

TECHNICAL CHARACTERISTICS OF GPS DIFFERENTIAL TRANSMISSIONS FROM MARITIME RADIOBEACONS

(Question 58/8)

(1990)

1. Introduction

1.1 The Global Positioning System (GPS) is a satellite navigation system being established by the United States. The navigational accuracy expected to be available to many users will be about 100 metres (with a 95% probability). This accuracy will be adequate for most general navigation requirements but not for some specific applications, such as harbour approach, Vessel Traffic Services (VTS), navigational surveying, dredging, cable and pipe-laying, the positioning of buoys and other off-shore structures and position sensors for electronic chart systems.

1.2 The navigational accuracy of GPS can be improved considerably by the transmission of differential corrections obtained from suitably located reference stations. Consideration of the technical, administrative and economic factors which influence the choice of the means of transmitting differential corrections has indicated that the use of maritime radiobeacons operating in the band 285 - 315 kHz would be one feasible solution because:

- propagation of transmissions in this frequency band is predominantly ground wave with a usable range of the same order of magnitude as the range of applicability of the reference station;
- footnote 466 of the Radio Regulations permits radiobeacon stations in the maritime radionavigation service to transmit supplementary navigational information;
- maritime radiobeacons currently provide coverage of coastal waters in many parts of the world. This would enable a world-wide standard of differential GPS transmissions to be introduced efficiently and economically.

1.3 Although the present studies addressed specifically the GPS system, the same principles apply to other radionavigational, or satellite navigational systems, such as Glonass or Loran-C.

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* The Director of the CCIR is requested to bring this Report to the attention of IMO and IALA.

2. Other requirements for a differential GPS system

2.1 A differential GPS system should be suitable for the purposes of high accuracy radionavigation up to 100 nautical miles from shore and for radiolocation up to 200 nautical miles from shore. The form of transmission should be standardized internationally for global use and user equipment should be of low cost.

2.2 If practicable, and with an update time of less than 10 seconds, the differential GPS corrections, when used in conjunction with information from the GPS satellites, should provide the following navigational accuracies (with 95% probability):

	Offshore	Inshore	Inland waterways
radionavigation	$\simeq$ 20 m	$\simeq$ 10 m	$\leq$ 5 m
radiolocation	$\simeq$ 10 m	$\simeq$ 5 m	1 - 2 m

2.3 The system should be available for radionavigation for at least 99% of the time, averaged over one year, and for radiolocation for at least 90% of the time, averaged over the same period. However, lower availability may be acceptable in areas of minor importance.

2.4 If a satellite system providing navigational accuracies approaching those given in § 2.2 becomes available for general use, the development and implementation of a differential GPS system is unlikely to be justified.

3. Factors concerning differential GPS reference stations

3.1 The location of differential GPS reference stations depends primarily upon the distance at which the corrections will provide the necessary navigational accuracy and the size of the area to be covered. In some circumstances one differential GPS reference station could be used to provide correction information to several transmitting stations.

3.2 In considering the optimum number of differential GPS stations for any given area, a number of factors need to be taken into account. Assuming that a choice exists between medium range stations, with an effective range of about 250 kilometres, and long range stations, with an effective range of about 500 kilometres, the following should be borne in mind:

Option	Advantages	Disadvantages
Medium range stations	Low sky-wave interference High availability High accuracy Standard medium power equipment suitable	Smaller coverage Larger number of stations needed for area coverage Probably more frequency channels needed
Long range stations	Fewer stations needed for area coverage Possibly fewer frequency channels needed	Sky-wave interference limits system availability at extremity of range Navigational accuracy may be degraded at long ranges No standard high power equipment available

4. System concept

4.1 A system concept which is under study by IALA is based on the following parameters and characteristics:

- the data and message format should follow the recommendations of RTCM Special Committee 104 (version 2.0);
- the information rate should be 100 bit/s;
- the transmission of differential GPS corrections should be continuous because this would provide high accuracy with low user equipment complexity;
- an error detecting and error correcting code with a rate of 1/4 should be used to ensure high availability at maximum range in areas of high atmospheric noise. This would result in a transmission rate of 400 bit/s;
- MSK modulation should be used for bandwidth economy. At a transmission rate of 400 bit/s, the bandwidth requirements would be 472 Hz for 99% of transmitted power;
- 500 Hz channel spacing would be adequate to ensure a minimum of adjacent channel interference and would be compatible with the channel spacing of radiobeacons in all regions including the European Maritime Area (EMA);
- assuming a co-channel interference protection ratio of 12 dB, complete coverage could be achieved using a maximum of 12 channels, each of 500 Hz bandwidth.

4.2 Other systems concepts are under study in some countries for long-distance operations of differential GPS. They could also be reported. If required, the differential corrections of these szstems could also be reported.

5. Differential GPS transmitting stations

5.1 A differential GPS transmitting station may be combined with a radiobeacon (RB) station by off-setting the differential modulation by 500 Hz from the modulation of the radiobeacon. However, a differential GPS station may also be an independent transmitter.

5.2 A comparison of the two options showed the following:

Option	Advantages	Disadvantages
Combined radio-beacon/differ-ential GPS station	Low-cost solution full use of radio-beacon infrastructure Minor regulatory changes necessary to EMA plan In most cases it would be simple to super-impose some differ-ential GPS channels over the radiobeacon pattern	No flexibility regarding range, coverage or protection ratio of differential GPS system Probably slight increase in receiver complexity Coordination of frequency allocations to RB and RB/differ-ential GPS stations necessary Mutual interference between radiobeacons and differential GPS stations possible Full exploitation of differ-ential GPS potential may not be possible
Dedicated differential GPS station	Maximum system flexibility Probably reduced receiver complexity	No common use of radiobeacon infrastructure possible Regulatory changes necessary to the Radio Regulations

5.3 If dedicated GPS stations were to be introduced and 12 differential GPS channels were required, then a 6 kHz bandwidth is required within the radiobeacon band. This could be made either as a block or by designating certain specific channels spread evenly across the band. A comparison of these options showed the following:

Option	Advantages	Disadvantages
Block allocation of 6 kHz (12 x 500 Hz)	No interference between RB and differential GPS services Maximum flexibility to develop potential of differential GPS system	No combination of RB and differential GPS transmitters possible
Designated differential GPS channels spread over the radiobeacon band	Combination of RB and differential transmitters possible where necessary Risk of interference between radiobeacon and differential GPS services low	Re-allocation of RB frequencies necessary

6. Further studies

Further studies are needed into the operational and technical aspects of using maritime radiobeacons for the transmission of differential GPS corrections, including:

- the optimum effective operational range of the transmissions;
- the protection ratio and sky-wave effects;
- frequency arrangements within the band 285 - 315 kHz and the required number of channels for differential GPS transmissions;
- the type of error detection and correction coding;
- the system costs and user requirements.