RECOMMENDATION ITU-R SA.1627

Telecommunication requirements and characteristics of EESS and MetSat service systems for data collection and platform location

(Question ITU-R 142/7)

(2003)

The ITU Radiocommunication Assembly,

considering

a) that satellite data collection systems and (DCS) platform location of the Earth exploration- and meteorological-satellite (EESS and MetSat service) services have unique telecommunication requirements;

b) that the allocation to the EESS in the band 401-403 MHz had been raised to primary status at WRC-97;

c) that information concerning the characteristics of present and future DCS is useful for carrying out studies based on Recommendations ITU-R SA.1162, ITU-R SA.1163 and ITU-R SA.1164,

recommends

1 that the requirements and characteristics described in Annex 1 should be taken into account in planning satellite DCS and platform location of the EESS and MetSat service.

Annex 1

Telecommunication requirements and characteristics of EESS and MetSat service DCS and platform location

1 Principle and applications

This Recommendation applies to EESS and MetSat service DCS and platform location. The purpose of a satellite DCS is to provide a telecommunication network for users needing information from a variety of sources, which may be located anywhere in the world, including oceans, deserts or other not easily accessible regions.

The concept of a satellite DCS is the following:

– automatic, autonomous platforms installed on land or mounted on a support (boat, aircraft, balloon, anchored or drifting buoy, land vehicle) for the transmission of meteorological (pressure, temperature, humidity, etc.) or geophysical (tsunami warnings, seismic, oceanographic and geodetic data, etc.) parameters. These platforms should, as far as possible, be light and compact, use little power and be inexpensive;

– the information compiled and transmitted by the platforms is received on board a satellite and forwarded through one or more data acquisition earth stations to a system management centre;

– once centralized, the information is carried to users by conventional means of telecommunication;

– if necessary, provision may also be made to distribute information from the management centre to the platforms through the same system.

Such a system differs from conventional telecommunications in that it cannot be conceived without the use of satellites and is intended for a special category of customers whose needs cannot be met by other means. In general, it favours one direction of transmission and essentially serves to centralize information. It may, however, be backed up by a facility for the distribution of information to the data collection platforms (DCPs). Finally, a requirement that is very important for many users is that the data collection function may easily be coupled with a location system which determines the coordinates of the transmitting platforms.

A DCS has many fields of application: meteorology, Earth resources, hydrography, seismic observation, vulcanology, geodesy and geodynamics, anchored or drifting oceanographic buoys, oil prospecting, wild animal tracking, etc.

2 Satellite system design

Two types of orbit may be used: the geostationary-satellite orbit (GSO) or low-Earth orbits (LEO).

2.1 LEO satellite systems

The LEO satellites are generally placed in circular orbits at altitudes of between 600 and 1 800 km, with a period of revolution of approximately 2 h. The whole of the Earth, including the poles, can be scanned with a single satellite, but the number of passes is relatively low (about three or four per day over the equator). It may be increased by using several satellites, e.g. a twelve passes per day over the equator may be obtained with three satellites. Passes are far more frequent near the poles.

A single equatorial satellite could cover the Earth tropical region with a dozen passes per day. A satellite constellation with low inclination could considerably extend the Earth covered area, as a complementary system to the polar one.

The platforms of the LEO satellite systems are generally simple due to the better radio link budget compared with the GSO satellites. The location function is easier to provide using the Doppler-Fizeau effect.

However they have a limited instantaneous coverage area; typically the geocentric half-angle of the field of view is of the order of 30°, and the duration of the mutual visibility between the satellite and a given beacon is limited to a range generally from 10 to 15 min. Furthermore, it is necessary to store information on board the satellite to provide the worldwide coverage.

A typical example of a LEO satellite system is the one of the National Oceanographic and Atmospheric Administration (NOAA) in the United States of America with two meteorological satellites in sun-synchronous orbits. The planes of the two circular orbits are orthogonal, the inclination about 98°, the altitudes are 830 and 870 km and the orbital period about 102 min. Another example of a LEO satellite system is the Brazilian DCS based on low inclination orbit satellites (25º) and an altitude of 750 km, acting as a complementary system to the NOAA satellites.

The METOP series of satellites from EUMETSAT, the first launch of which is scheduled in 2003, constitute another example of a LEO satellite system. Those satellites are sun-synchronous having an altitude of 820 km.

2.2 GSO satellite systems

The geometric coverage area of a geostationary satellite is a spherical cap with a geocentric half-angle of approximately 81°.

The GSO satellite provides a permanent visibility over a vast area, quasi of the scale of an hemisphere. The information is transmitted continuously and reaches the user very rapidly. However, at least four satellites are required for world coverage, excluding the polar regions. The platforms must be equipped with directional antennas and/or higher powered transmitters than for the LEO case. Finally, the location function is difficult to provide.

A GSO satellite system is essential where instantaneous transmission is required either continuously or at set times. Because a large number of platforms are visible from a GSO satellite, the DCP transmissions must occupy up to several hundred channels in the band 401-403 MHz, the exact number being different for different systems.

3 Platform location

Mobile platforms (balloons, drifting buoys, wild animals, etc.) are used for a great many applications and their movements, which are unpredictable, need to be tracked in order to carry out the mission (wind determination, study of marine currents, study of migratory movements, etc.). In such cases, the location and collection functions are performed simultaneously.

Either the distance or the radial velocity (Doppler effect), or both, may be measured. A number of measurements are taken and processed in order to locate the transmitting platform with an accuracy ranging from a few metres to a few kilometres.

The Doppler method of location is not applicable to GSO satellites. Location from GSO satellites may be theoretically achieved by interferometry from a single satellite or by ranging within the overlap area of two satellites.

4 Platform modes of operation

4.1 Interrogated platforms

4.1.1 Interrogated platforms in GSO satellite systems

Each platform contains both a transmitter and a receiver. The system management centre transmits to the satellite a work programme containing the addresses of the platforms to be interrogated and the time at which this operation must be carried out. The platforms cannot transmit unless they are interrogated. However, they can be designed to request interrogation, e.g. geophysical warning systems. This mode of operation is very reliable and there is no risk of mutual interference. However, the platform must be equipped with a receiver which increases its cost.

4.1.2 Interrogated platforms in LEO satellite systems

A service link is currently being implemented in LEO satellite systems to allow a communication from management centres to DCPs. The purpose of this service link is multiple. It can be simply to turn on or off the main power consumption components of a DCP, or more sophisticated actions like a reconfiguration of the DCP sensors. It will also improve the throughput of data collection by acknowledging the correct reception of messages and thus avoiding a useless repetition. This new link is currently being implemented on the satellite ADEOS-II, and will be implemented on the METOP and NPOESS series of satellites.

4.2 Platforms operating in a random access mode

In GSO DCSs, random access platforms are used for transmitting warnings. The platform normally reports only when a fixed threshold of the phenomenon being measured is met or exceeded. An example is a platform which in monitoring seismic activity only reports if the seismic activity is greater than normal. In practice, separate channels in the allocated band are reserved for random-access platforms in order to reduce the probability of interference with the other types of platform.

In LEO DCSs, each platform repeats its message separately from the others and at given intervals. Interference may therefore occur between platforms which are in line-of-sight of the satellite at the same time. Consequently, the satellite can work with only a limited number of platforms in line-of-sight at the same time.

4.3 Self-timed platforms

Self-timed platforms are used principally with GSO DCSs. Each platform transmits its messages automatically within preset times. The reporting intervals are determined at preset times by a clock internal to the platform. Each platform is identified by its address and the frequency (assigned channel) on which it transmits its report. In practice, satellite operators manage the assignment of the time slots and the broadcast channels of the platforms.

5 Typical platform transmitter characteristics

5.1 Platforms of LEO systems

The typical characteristics of LEO data collection and location platforms indicated hereafter are those of the ARGOS, Brazilian and MOS DCSs.

Each platform transmits sporadically. Each emission consists of two successive parts: during the first part a pure carrier is transmitted; during the second part the signal is modulated by the message to be transmitted. Here are the three kinds of platforms of the ARGOS DCS: PSK/PM, mixed QPSK, Gaussian filtered minimum shift keying (GMSK). The PSK/PM platforms are also used by the Brazilian DCS and MOS DCS. In addition to those three kinds of platforms, each ARGOS platform can be equipped with a downlink receiver.

5.1.1 PSK/PM platforms

- Unmodulated part:
  - duration of the order of 160 ms.
- Modulated part:
  - includes 48 service bits followed by the data from the sensors. Depending on the number of sensors the total duration of the modulated part ranges between 200 and 760 ms.
- Period of repetition:
  - platforms to be located: chosen between 60 and 100 s;
  - platforms to be used only for data collection: chosen above 200 s.
- Data encoding:
  - biphase-level coding at a bit rate of 400 bit/s.
- Carrier and modulator:
  - present MOS platforms = 401.50 MHz;
  - ARGOS platforms = 401.65 MHz ± 30 kHz;
  - Brazilian DCS platforms = 401.635 MHz ± 30 kHz;
  - modulation: PSK/PM with a modulation index of 1.1 ± 0.1 rad.
- Emitted power:
  - less than or near 3 W.
- Frequency stability (to obtain a location accuracy of better than 1 km):
  - medium-term drift (15 min) not to exceed 0.5×10^{-9}/min;
  - short-term stability (100 ms): 1×10^{-9}.

The location accuracy depends to some extent on the stability of the platform oscillator; this specification may vary according to the objective sought.

5.1.2 Mixed QPSK platforms

- Unmodulated part:
  - duration of the order of 80 ms.
- Modulated part:
  - includes 48 service bits followed by the data from the sensors. Depending on the number of sensors the total duration of the modulated part ranges between 200 and 760 ms.
- Period of repetition:
  - platforms to be located: chosen between 60 and 100 s;
  - platforms to be used only for data collection: chosen above 200 s.
- Channel coding:
  - the input bit stream, having a bit rate of 400 bit/s, is convolutionally encoded using a (7, 1/2) code.
  - modulator
  - modulation: QPSK.

– Data encoding:

  – the channel coded bit stream has a bit rate of 800 bit/s. As the QPSK modulation is expressed in terms of I and Q, the bit stream is split into an I and Q axis. On the I axis, the symbols are non return to zero (NRZ) level encoded, and on the Q axis, the symbols are biphase-level encoded.

– Carrier:

  – ARGOS platforms = 401.65 MHz ± 30 kHz.

– Emitted power:

  – less than or near 3 W.

– Frequency stability (to obtain a location accuracy of better than 1 km):

  – medium-term drift (15 min) not to exceed 0.5×10^{-9}/min;

  – short-term stability (100 ms): 1×10^{-9}.

The location accuracy depends to some extent on the stability of the platform oscillator; this specification may vary according to the objective sought.

5.1.3 GMSK platforms

– Unmodulated part:

  – duration of the order of 80 ms.

– Modulated part:

  – includes 48 service bits followed by the data from the sensors. Depending on the number of sensors the total duration of the modulated part ranges between 120 ms and 1.1 s.

– Period of repetition:

  – platforms to be used for data collection only: chosen about 200 s.

– Modulator:

  – modulation: GMSK.

– Channel coding:

  – the input bit stream, having a bit rate of 4 800 bit/s, is convolutionally encoded using a (7, 3/4) code.

– Data encoding:

  – the channel coded bit stream has bit rate of 6 400 bit/s, and the bits are NRZ-level encoded.

– Carrier:

  – ARGOS GMSK platforms = 401.595 MHz ± 3 kHz.

– Emitted power:

  – about 5 W.

5.1.4 Receiver downlink

Some of the above LEO satellite system platforms will incorporate a receiver in the band 460-470 MHz. They will receive, from a satellite flying over, a continuous data stream at low bit rate containing flags and messages. The received pfd will be low therefore the receivers have to be very sensitive, but not expensive and so not too sophisticated. The receive DCS antenna will be of a simple low cost/low gain type.

5.2 Platforms of GSO systems

In the meteorological GSO systems, the DCP transmissions are called "reports" and the details of these reports vary between regional and international services.

5.2.1 International Data Collection System (IDCS)

The IDCS is coordinated amongst GSO meteorological satellite operators within the framework of the Coordination Group of Meteorological Satellites (CGMS) to provide almost worldwide coverage via 33 international DCP channels.

The DCP international format reports consist of the following contiguous elements:

- unmodulated carrier for 5 s;
- a 250 bits alternate "0" and "1" preamble;
- a 15 bits maximal linear sequence code synchronization word;
- the DCP address which is a 31 bits BCH coded word;
- the environmental data which are a maximum of 649 words, each word being 8 bits long;
- the 31 bits end-of-transmission sequence;
- bit rate of 100 bit/s;
- encoding: NRZ split-phase Manchester.
- Carrier:
  - the International DCP includes 33 channels, of 3 kHz each, filling the band 402.001-402.100 MHz;
  - through coordination, satellite operators share other regional DCP frequencies in the band 401-403 MHz;
  - modulation: the carrier is phase modulated, the modulation index being 60°.
- Transmitted power:
  - approximately 10 W for a platform with high-gain antenna; about 40 W for a semi-isotropic (full horizon to zenith) antenna. The antenna polarization is right-hand circular.
- Frequency stability:
  - 1.5×10^{-6}/year; phase jitter on the unmodulated carrier shall not exceed 3° r.m.s.

5.2.2 Regional data collection service

In complement to the IDCS, each GSO meteorological satellite provides a regional data collection service in its area of coverage via regional DCP channels. Bandwidth and data rate characteristics of regional DCP channels depend upon the respective GSO meteorological satellites.

As an example, platforms designed for transmission via regional DCP channels of GOES satellites operate at data rates of 100, 300, and 1 200 bit/s. Current 100 bit/s systems use Manchester encoded BPSK. The platforms have e.i.r.p.s averaging 15 dBW, but which can typically range from 5 to 19 dBW depending on operating conditions. The 300 and 1 200 bit/s platforms use trellis coded 8-PSK modulation. Because the GOES satellite does not demodulate the platform uplinks, but simply transponds them down to the command and data acquisition (CDA) station in the band 1 670-1 700 MHz, the satellite is transparent to the type of modulation used. The 1 200 bit/s platforms generally have 3 or 4 dB higher e.i.r.p. than the other platforms.

Studies indicate that performance margins of the 300 and 1 200 bit/s systems in Gaussian channels equal or exceed those of the older 100 bit/s system. As a result, according to the methodology in Recommendation ITU-R SA.1022 for computing interference criteria, the newer systems will tolerate the permissible interference levels provided in Recommendations ITU-R SA.1163 and ITU-R SA.1164, even though the "typical system" in these Recommendations is a 100 bit/s system.

6 Typical satellite receiver characteristics

6.1 LEO satellite receiver characteristics

6.1.1 ARGOS DCS satellite receiver characteristics

– Range of the power received from the DCP:
  – from –167 to –138 dBW, for an antenna gain varying from –6 dBi at the nadir to +2 dBi at the satellite horizon.
– Typical noise power density level:
  – –201 dB(W/Hz), (equivalent receiving noise temperature = 600 K).
– BER (for interference free messages):
  – $< 1 \times 10^{-5}$.
– Receiving bandwidth:
  – 80 kHz, centred at 401.65 MHz, and 110 kHz from 2003 onwards, centred at 401.635 MHz.
– Number of processing channels:
  – 8 and 12 from 2003 onwards.

6.1.2 MOS DCS satellite receiver characteristics

– Range of the pfd received from a DCP:
  – from –145 to –120 dB(W/m^2).
– Typical noise power density level:
  – –201 dB(W/Hz).
– BER (for interference free messages):
  – $< 1 \times 10^{-5}$.
– Receiving bandwidth:
  – 80 kHz centred at 401.5 MHz.

6.1.3 Brazilian DCS satellite receiver characteristics

– Range of the power received from the DCP:
  – from –160 to –130 dBW, for a satellite antenna gain varying from –1 dBi at the nadir to +1 dBi at the satellite horizon.
– Typical noise power density level:
  – –201 dB(W/Hz), (equivalent receiving noise temperature = 600 K).
– BER (for interference free messages):
  – $< 1 \times 10^{-5}$.
– Receiving bandwidth:
  – 60 kHz (and 120 kHz from 2005 onwards), centred at 401.635 MHz.
– All channel processing is done at the receiving ground station.

6.2 GSO satellite receiver characteristics

– Range of the pfd received from a DCP:
  – from –150 to –140 dB(W/m^2).
– Range of receiver sensitivities:
  – $G/T = -28.5$ to -18 dB(K^{-1}) .
– Data relay receiving bandwidth:
  – 0.2 MHz or more depending on the type of satellite.

6.3 LEO satellite-to-platform transmitter characteristics

The RF characteristics of the LEO satellite downlink transmitters are the following:

– Continuous bit stream transmitted by the satellite.
– Modulator:
  – modulation: PSK/PM with a modulation index of 0.8 rad.
– Data encoding:
  – the bit stream has a bit rate of 400 bit/s: the bits are biphase-level encoded.
– Carrier:
  – ARGOS downlink LEO satellite transmitter = 465.9875 MHz.
– Emitted power:
  – about 5 W.
– Antenna gain: variable from nadir to the horizon seen by the satellite to compensate for the space attenuation.

6.4 LEO satellite-to-station transmitter characteristics for transparent transponder

The RF characteristics of the LEO satellite downlink transmitters when a transparent type transponder is used to retransmit received platform messages to the ground station are:

– Modulator:
  – modulation: PM with a modulation index of 1.4 to 1.8 rad.

– Carrier:
  – Brazilian downlink LEO satellite transmitter = 2 267.52 MHz or 462.5 MHz.
– Emitted power:
  – about 200 mW (2 267.52 MHz);
  – about 1 W (462.5 MHz).
– Antenna gain: variable from nadir to the horizon seen by the satellite.

6.5 GSO satellite transmitter characteristics

GSO satellites relay BPSK modulated interrogations from the CDA station in the 2 025-2 110 MHz band to platforms in the 460-470 MHz band. The satellite transponder is a hard-limiter that maintains the downlink e.i.r.p. constant. The satellite e.i.r.p. is 15 dBW, and the data rate is 100 bit/s. The satellite transmit antenna has an Earth-coverage beam.

7 Conclusions

The satellite systems for data collection and platform location of the EESS and MetSat service provide data for users needing information from a variety of sources, which may be located anywhere in the world, including oceans, deserts or other not easily accessible regions. The GSO systems provide data with a delay of typically 5 min but do not cover the polar regions. The LEO systems offer a worldwide coverage as well as the platform location, if needed, with a delay of up to 1 to 3 h. These DCS and location system using very sensitive satellite and DCP receivers have unique telecommunication requirements.