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SHARING STUDIES BETWEEN MES AND EXISTING TERRESTRIAL SERVICES IN THE BANDS ALREADY ALLOCATED TO THE MSS BELOW 1 GHz

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SHARING STUDIES BETWEEN MES AND EXISTING TERRESTRIAL SERVICES IN THE BANDS ALREADY ALLOCATED TO THE MSS BELOW 1 GHZ

1 INTRODUCTION

This Report addresses the sharing between the mobile-satellite service (MSS) in bands below 1 GHz (S-PCS<1 GHz) and existing terrestrial services in bands already allocated to the MSS below 1 GHz. Based on the studies contained in this Report, operational constraints are proposed for those MSS systems that are implemented in accordance with ERC/DEC(99)06. Table 1 provides a listing of the frequency bands already allocated to the MSS below 1 GHz. This report considers each candidate system operating or planned to operate in one or more bands and the other radio services operating in these bands. The studies take into account certain mitigation techniques to be employed by individual MSS systems to improve the compatibility between Mobile Earth Stations (MESs) and other allocated radio services.

S-PCS<1 GHz systems provide packet switched data communications at low bit rates and provide services including messaging, user data and positioning. These systems fall into two categories:

- Narrow-band FDMA systems using dynamic channel assignment.
- Wide-band, low power density, spread spectrum systems.

In Europe the bands below 1 GHz are extensively used by existing terrestrial and space services. The use is expanding and there are plans to introduce key new pan-European terrestrial services in certain bands.

1.1 MSS Allocations below 1 GHz

The existing Region 1 allocations for MSS below 1 GHz are summarised in Table 1.

FREQUENCY ALLOCATION (MHz)	APPLICABLE FOOTNOTES	ALLOCATION STATUS
137-137.025 (s-E)	S5.209, S5.208A	Primary
137.025-137.175 (s-E)	S5.209, S5.208A	Secondary
137.175-137.825 (s-E)	S5.209, S5.208A	Primary
137.825-138 (s-E)	S5.209, S5.208A	Secondary
148-149.9 (E-s)	S5.209, S5.218, S5.219, S5.221	Primary
149.9 - 150.05 (E-s)	S5.209, S5.224A	Primary
235-322 (E-s) (s-E)	S5.254	S9.21
312-315 (E-s)	S5.254, S5.255	Secondary
335.4-399.9 (E-s) (s-E)	S5.254	S9.21
387-390 (s-E)	S5.254, S5.255, S5.208A	Secondary
399.9 - 400.05 (E-s)	S5.209, S5.220, S5.224A	Primary
400.15-401 (s-E)	S5.209, S5.208A	Primary
406-406.1 (E-s)	S5.266, S5.267	Primary

Table 1: MSS Allocations below 1 GHz

The 406-406.1 MHz band is allocated for EPIRBs use only, therefore to summarise 1.53 MHz (space-to-Earth) and 1.9 MHz (Earth-to-space) is allocated to the MSS on a primary basis and 3.325 MHz (space-to-Earth) and 3 MHz (Earth-to-space) on a secondary basis. An additional 151.5 MHz is allocated by footnote S5.254 on a non interference basis and subject to agreement obtained under S9.21 and 0.3 MHz for MSS (Earth-to-space) on a primary basis, limited to LMSS (Earth-to-space) until January 1, 2015.

1.2 Candidate S-PCS<1 GHz Systems

Based on information provided in response to the CEPT Call for Information for S-PCS<1 GHz systems, the candidate MSS systems currently operating or planned to operate in the bands below 1 GHz, are as follows:

- LEOTELCOM-1
- LEOTELCOM-2
- MLMS
- SAFIR 2

At a later stage ERC received information on an additional satellite system in response to the CEPT Call for Information for S-PCS<1 GHz systems and decided to include this system in the list of candidate systems of ERC/DEC/(99)06:

- LEOTELCOM-5

Due to the inclusion of the new satellite system in the list of candidate systems the ERC Report 87 was revised accordingly.

Technical parameters used in sharing studies for these candidate MSS systems can be found in Annex 1.

2 ETSI STANDARDS FOR MES BELOW 1 GHZ

At the time of writing, the ETSI standards developed for Mobile Earth Stations (MESs) operating in MSS bands below 1 GHz are shown in Table 2.

STANDARD	TITLE	VERSION & DATE
EN 301 721	MES providing Low Bit Rate Data Communications (LBRDC) using LEO satellites operating below 1 GHz under Article 3.2 of the R&TTE Directive.	V.1.1.1 (2000-05)
EN 300 721	MES providing Low Bit Rate Data Communications (LBRDC) using LEO satellites operating below 1 GHz.	V1.1.2 (1999-7)
ETS 300 722	Network Control Facility (NCF) for MES providing Low Bit Rate Data Communications (LBRDC) using LEO satellites operating below 1 GHz	Ed.1 (1997-06)
EN 301 489-20	Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 20: Specific conditions for Mobile Earth Stations (MES) used in the Mobile Satellite Services (MSS)	V1.1.1 (2000-12)

Table 2: Current ETSI Standards for MSS MES below 1 GHz.

3 SHARING ISSUES FOR MSS IN BANDS BELOW 1 GHZ

The frequency bands below 1 GHz are heavily used by a number of terrestrial services including the radio astronomy service. To facilitate sharing with these radio services, S-PCS<1 GHz systems may employ mitigation techniques including MES transmission burst duration and duty cycle limitations. One candidate S-PCS<1 GHz system has implemented a dynamic channel assignment system, which is described in detail in Annex 2. Low power density spread spectrum transmission has also been proposed as an alternative interference avoidance measure by two other S-PCS<1 GHz system proponents.

The following ITU-R Recommendations may be considered for sharing between terrestrial services and the MSS:

- **ITU-R M.1039** METHODS FOR EVALUATING SHARING BETWEEN SYSTEMS IN THE MOBILE SERVICE BELOW 1 GHz AND FDMA NON-GEOSTATIONARY-SATELLITE ORBIT (NON-GSO) MOBILE EARTH STATIONS

- **ITU-R M.1087** METHODS FOR EVALUATING SHARING BETWEEN SYSTEMS IN THE LAND MOBILE SERVICE AND SPREAD-SPECTRUM LOW-EARTH ORBIT (LEO) SYSTEMS IN THE MOBILE-SATELLITE SERVICES (MSS) BELOW 1 GHz

- **ITU-R M.1185** METHOD FOR DETERMINING COORDINATION DISTANCE BETWEEN GROUND BASED MOBILE EARTH STATIONS AND TERRESTRIAL STATIONS OPERATING IN THE 148.0 -149.9 MHz BAND

A number of studies have been undertaken to take account of particular inter-service sharing conditions in Europe. These studies have been conducted on a system-specific basis with a view towards determining the sharing feasibility for particular S-PCS<1 GHz systems.

Compatibility of S-PCS<1 GHz with the Radio Astronomy Service. The operation of MSS within the bands 137.0 - 138.0 MHz and 400.15-401 MHz must ensure appropriate measures are used to protect the Radio Astronomy Service (RAS) allocation in the bands 150.05-153 MHz, 322-328.6 MHz and 406.1-410 MHz from unwanted emissions arising from MSS downlinks. Techniques to facilitate the protection of the RAS from MSS systems have been studied within ITU-R WP 8D and a preliminary draft new recommendation on this subject can be found in document –8D/61, Att. 19 (2000). Administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference (S5.208A).

4 CEPT STUDIES

The following subsections are organised by candidate S-PCS<1 GHz systems, with uplink and downlink sharing issues for each system addressed separately. The results and conclusions from CEPT-approved studies are listed for each S-PCS<1 GHz candidate system intending to provide commercial service. Section 5 addresses sharing issues between S-PCS<1 GHz systems.

4.1 LEOTELCOM-1

4.1.1 General System Description

The LEOTELCOM-1 system is a narrow band FDMA constellation comprised of 48 satellites. The system is designed to operate in the frequency bands 137 - 138 MHz (space-to-Earth) and 148 - 149.9 MHz (Earth-to space). With full deployment, around 2 satellites will be visible at any time at a geographic location at a latitude of 50°. Each satellite is able to allow 6 MESs to transmit data bursts at the same time. The burst requires 5 kHz of bandwidth with a burst length of 55 milliseconds (typical) to about 500 milliseconds (maximum). The modulation scheme used is a symmetric differential phase shift keying. To minimise the probability of interference to terrestrial systems from MES uplinks, a dynamic channel activity assignment technique is used, which allows the satellite to assign unoccupied channels to S-PCS<1 GHz MES transmitters which are requesting an uplink for data bursts. Further details on the LEOTELCOM-1 system can be found in Annexes 1 and 2.

4.1.2 Background information on the concerned frequency bands

The 137-138 MHz band is allocated to the Space Operation, Space Research and Meteorological-Satellite Service on a primary basis and the Fixed and Mobile (except aeronautical mobile (R)) Service on a secondary basis. MSS (space-Earth) is allocated on a co-primary basis within the sub-bands 137-137.025 MHz and 137.175-137.825 MHz and a secondary basis within 137.025-137.175 MHz and 137.825-138 MHz. Coordination is required under S9.11A. The applicable MSS coordination threshold for terrestrial services is -125 dBW/m^2/4 kHz for MSS downlink emissions for those MSS systems Advanced Published before 1 November 1996.

For MSS systems for which complete Appendix 3 coordination information had not been received by the Radio Bureau as of 1 November 1996 (except for replacement satellites for the systems for which complete Appendix 3 information had been received by the Radio Bureau prior to that date) the coordination threshold is -140 dBW/m^2/4 kHz with respect to AMS(OR) in those countries listed in footnotes S5.204 & S5.206. For other countries and for systems for which Appendix 3 coordination information had been received by the Radio Bureau as of 1 November 1996 (i.e. LEOTELCOM-1), the threshold is –125 dBW/m^2/4 kHz. See Annex 1 to Appendix S5 (WRC-97) (formerly Resolution **46**).

The 148-149.9 MHz band is allocated to the Fixed, Mobile (except aeronautical mobile (R)) and the Mobile-Satellite Service (Earth-to-space) on a co-primary basis and is heavily used by terrestrial fixed and mobile services including Private Mobile Radio (PMR) and military radio systems. Operation of the MSS within this band is limited to non-geostationary satellite systems and is subject to co-ordination under S9.11A. In addition, it should be noted that although the MSS is allocated on a primary basis, RR S5.219 states that, for countries designated therein, MSS systems shall not constrain the development and use of this band by fixed, mobile and space operation services. Furthermore RR S5.221 states that the MSS shall not cause harmful interference to, or claim protection from, stations of the fixed or mobile services in the countries listed. These should be taken into account when considering compatibility studies between MSS and other Fixed and Mobile services in the 148-149.9 MHz band.

The 149.9-150.05 MHz band is allocated to the Radionavigation-Satellite Service and the Mobile-Satellite Service (Earth-to-space) on a co-primary basis. Operation of the MSS within this band is limited to non-geostationary satellite and is subject to co-ordination under S9.11A. RR S5.220 states that MSS shall not constrain the development and use of the RNSS. The RNSS allocation in this band will cease to exist as of 1 January 2015. Within the UK, this band is used for sonobuoys operating on agreed frequencies. LEOTELCOM-1 is planning land earth stations uplinks in this band.

4.1.3 Studies Conducted to date

The studies conducted to date have addressed the impact of narrowband FDMA MSS MESs of the LEOTELCOM-1 system on several types of terrestrial mobile systems and the radio astronomy service.

An initial study indicated that, with the received threshold level of -128.5 dBm, the Dynamic Channel Activity Assignment System (DCAAS) is able to detect terrestrial transmissions with an EIRP of less than 0.1W. A further study addressed the impact of S-PCS<1 GHz MES (narrow band fashion) operating in adjacent channels to analogue PMR equipment.

For the conditions stated in these analyses, the probability of MSS MES interference into analogue PMR equipment operating with or without selective calling is sufficiently low such that studies conclude that sharing between non-trunked analogue PMR equipment and the MSS MES operating in narrow band fashion is feasible.

The results of initial field trials involving an analogue trunked MS system and the LEOTELCOM-1 system indicate the following:

- Burst transmissions from a single MES transmitting within the necessary receiver bandwidth of, and in the geographic proximity of, a terrestrial analogue voice mobile station attempting to establish a call to another terrestrial analogue voice mobile will prevent the terrestrial analogue voice mobile station from establishing its call.

- The tested analogue terrestrial base station configuration did not appear to demodulate MES transmissions, but instead, it appeared to treat these transmissions as noise.

These initial field trials led to a more detailed theoretical study. The further studies have concentrated on the compatibility between the LEOTELCOM-1 system and the trunked PMR schemes used in this band. A major study was commissioned to investigate the compatibility based on live data from several CEPT-countries where available. This detailed study indicates that, under assumptions representing normal operating conditions, the interference potential is relatively low, about 0.1%. Under assumptions representing extreme operating conditions, the probability of interference to certain channels increases substantially therefore one administration is conducting additional studies to further quantify the interference potential.

An additional study of sharing between LEOTELCOM-1 MESs and the Radio Astronomy Service based on average and extreme potential interference situations indicates that the LEOTELCOM-1 MESs will not cause interference to radio astronomy observations. In addition, the radioastronomy community has concluded that LEOTELCOM-1 emissions are acceptable, provided the system complies with the standards and specifications given.

4.1.4 Conclusions Relating To LEOTELCOM-1

Based on studies conducted, the following conclusions relating to LEOTELCOM-1 have been reached:

4.1.4.1 Downlink Band Issues

In the frequency band 137 - 138 MHz (downlink), the LEOTELCOM-1 system will not exceed the applicable pfd threshold at the earth's surface established by Annex 1 of Appendix S5 (Rev.WRC-97) therefore no co-ordination is necessary with terrestrial services, and no further action is necessary.

4.1.4.2 Uplink Band Issues

Based on the results of its study efforts, it was concluded that subject to the operational constraints given in this section, the probability of interference from LEOTELCOM-1 MESs to terrestrial analogue PMR base and mobile stations is sufficiently low that it is expected to result in little significant degradation of service availability.

Sharing between LEOTELCOM-1 MESs and mobile service systems, based on studies taking into account a LEOTELCOM-1 constellation of a maximum of 48 satellites and 6 receivers per satellite is possible and adequate interference protection will be afforded to other primary services if the following baseline operating constraints are placed on MES transmissions:

System NAME : LEOTELCOM-1	
OPERATIONAL CONSTRAINTS	
Up-link designated bands	148-150.05 MHz
Down-link designated bands	137-138 MHz
Multiple access method	FDMA
Modulation method	Narrow band Frequency or Phase modulation
Maximum MESs e.i.r.p. spectral density	10 dBW/4kHz
Technique to avoid causing interference from MESs	Dynamic channel avoidance assignment system (DCAAS as described in Annex 2 of ITU-R Recommendation M 1039) such that mobile earth stations avoid transmitting on the same frequency being actively used by terrestrial fixed or mobile stations.
Maximum burst duration for MESs transmission	500 msec
Maximum duty cycle for MESs	Not greater than 1% in any 15 minute period for any single channel
Maximum duty cycle for system control bursts	Not greater than 1% in any 15 second period for any single channel
All MES traffic with the exception of the system control bursts	Consecutive transmissions from a single earth station on the same frequency shall be separated by at least 15 seconds

Trunked mobile radio and data systems are more susceptible to MES interference. Depending on the nature of the affected terrestrial system it may be necessary for some Administrations to implement additional national measures.

4.1.4.3 Sharing With the Radio Astronomy Service

The operations of LEOTELCOM-1 will not cause interference to the Radio Astronomy Service, based on the studies described in section 4.1.3, above.

4.1.4.4 Land Earth Stations

Land earth stations, even when operating in mobile satellite service bands, should be co-ordinated under existing procedures. Accordingly, no special provisions are necessary with respect to land earth stations.

4.2 LEOTELCOM-2

4.2.1 General System Description

The LEOTELCOM-2 wide band DS-SSMA system will comprise 6 satellites in its full constellation with no more than 1 satellite visible at any time at a geographic locations of latitude 50°. Each satellite is able to allow 15 MESs to transmit data bursts at the same time. The burst requires 855 kHz of bandwidth with a maximum burst length of 450 milliseconds. The modulation scheme used is MSK. To further reduce the probability of interference from MESs to terrestrial systems, a spread spectrum modulation scheme, enabling low EIRP densities and a very low average duty cycle is envisaged. The population of E-SAT terminals will be approximately distributed as follows:

54 % of the terminals will transmit monthly
11% of the terminals will transmit weekly
35 % of the terminals will transmit on a daily basis

Further details on the LEOTELCOM-2 system can be found in Annexes 1 and 3.

4.2.2 Background information on the concerned frequency bands

Background information on the concerned bands can be found in section 4.1.2

4.2.3 Studies Conducted to Date

The studies conducted to date have addressed the impact of wideband MSS MESs of the LEOTELCOM-2 system on several types of terrestrial mobile systems, and Radio-Astronomy services.

4.2.3.1 In-band compatibility with Terrestrial Mobile Systems

A study based on the parameters of the former LEOTELCOM-2 satellite network , examines the compatibility between a direct sequence spread spectrum multiple access (DS-SSMA) system in the S-PCS<1 GHz and terrestrial systems in the PMR service upon shared use of the band 148-150.05 MHz . The document shows that, assuming the DS-SSMA limit of 106 dBpW/4 kHz for the EIRP density of an MES, according to the European Norm EN 300 721, in the occupied bandwidth within the band 148-150.05 MHz, this resulted in a coordination distances of around 1.6 km for urban areas and 7.4 km for rural areas. These results are based on a modified Hata-model, approved by SE/PT 21 applying an average receiver sensitivity of -90 dBm.

Taking into account the results of the study above and applying the Monto-Carlo simulation to determine the location percentage, sharing between S-PCS<1 GHz systems in DS-SSMA technology and analogue non-trunked PMR systems seems to be feasible in the frequency band 148-150.05 MHz, except for "peak traffic area" conditions. In cases of peak traffic areas the probability of interference could be up to 8.5%, or is even higher if MESs transmit simultaneously in a limited peak traffic area. The noise level will increase following the formula 10*log(n), where n is the number of MESs.

Another study on the feasibility of sharing between the LEOTELCOM-2 system and terrestrial systems, based on a statistical analysis addressed in-band and out-of-band interference. The in-band percentage of time of interference was found to be lower than 0.23%, in the worst case scenario. It was found that further studies were necessary, in particular with respect with the influence of PMR system antenna height. At the same time, Rec. ITU-R M.1039 was updated, and a set of parameters for PMR systems has been made available in Doc. 8D/208 (Study Period 98-99). Based on these new elements, an updated study was submitted. This new study was based on a statistical approach, and assessed the probability of interference between MESs compliant with the European Norm EN300721, and a VHF PMR system as described in Document ITU-R 8D-208. The calculated interference probability is 0.00505%, in the worst case situation (interference into the PMR base station, in a rural environment).

Because LEOTELCOM-2 will have terminals at fixed locations with a pre-defined emission schedule, the potential of interference to PMR could be reduced using the following techniques:

- Scheduling the emissions of the MESs at non-rush hours
- Spreading the emissions across the satellite footprint.

4.2.3.2 Out-of-band compatibility with Terrestrial Mobile systems

With regard to out-of band compatibility LEOTELCOM-2 terminals will comply with the European Norm EN300721. As already mentioned in §4.2.3.1, a study addressed out-of-band compatibility issues, in addition to in-band compatibility with terrestrial mobiles. The percentage of time of interference was calculated to be lower than 0.03%, when considering a worst case situation: rural environment, PMR channel frequency at the edge of the ETSI out-of-band emission mask (border between in-band and out-of-band).

4.2.3.3 Sharing studies with Radio-Astronomy Services

A study on the protection of the radio astronomy in the 150.05 – 153 MHz, the 322 – 328.6 MHz and the 406.1 – 410 MHz band from the downlink emissions of the LEOTELCOM-2 system, demonstrates that by using a payload low-pass filter attenuating by 60 dB at frequencies higher than 148 MHz, (necessary in order to avoid internal interference into the LEOTELCOM-2 satellite receive antenna in the 148 – 149 MHz band), no interference is expected since there is a safety margin of at least 60 dB between the protection criteria defined in ITU-R RA.769-1 and the LEOTELCOM-2 satellite emissions in the relevant RAS band.

In addition a study addressing the uplink case showed that MESs of the LEOTELCOM-2 satellite systems operating at fixed locations in the band 148 – 148.855 MHz in Earth-to-space direction meet the protection requirements of the above mentioned ITU-R Recommendation when located beyond 7.3 km from a radio observatory site.

4.2.4 Conclusions regarding LEOTELCOM-2

4.2.4.1 Downlink Band Issues

In the frequency band 137 - 138 MHz the LEOTELCOM-2 system will not exceed the applicable coordination threshold established by Annex 1 of Appendix S5 of the Radio Regulations, therefore no coordination with terrestrial services is necessary.

4.2.4.2 Uplink Band Issues

Based on the results of its study efforts, it has been concluded that subject to the operational constraints given in this section, the probability of interference from LEOTELCOM-2 MESs to terrestrial analogue PMR base and mobile stations is sufficiently low that it is expected to result in little significant degradation of service availability.

Sharing between LEOTELCOM-2 MESs and mobile service systems is possible and adequate interference protection will be afforded to other primary services if the following baseline operating constraints are placed on MES transmissions:

System NAME : LEOTELCOM-2	
OPERATIONAL CONSTRAINTS	
Up-link designated bands	148-148.855 MHz
Down-link designated bands	137.0725-137.9275 MHz
Maximum number of active satellites	6
Multiple access method	CDMA
Maximum MESs e.i.r.p. spectral density	-14 dBW/4kHz
Technique to avoid causing interference from MESs	- The MESs only transmit when polled. - The MESs are located at fixed and known locations.
Maximum burst duration for MESs transmission	450 msec
Minimum time between bursts	15 seconds
Maximum Duty Cycle	0.25% in any 15 minute period

Some issues, related to in-band and out-of-band sharing with terrestrial mobile networks in UK, are outstanding, pending studies and conclusion from the UK administration.

4.2.4.3 Sharing with the Radio Astronomy

The operations of LEOTELCOM-2 will not cause interference to the Radio Astronomy Service, based on the studies described in section 4.2.3.3, above.

4.2.4.4 Land Earth Stations

Land earth stations, even when operating in mobile satellite service bands, should be co-ordinated under existing procedures. Accordingly, no special provisions are necessary with respect to land earth stations.

4.3 MLMS

4.3.1 General System Description

The MLMS system comprises 2 satellites and a very low number of terminals (36.000). Only a limited number of the terminals will be operated in Europe. MLMS plans to operate as follows : downlink at 400.6 MHz and uplink at 388 MHz mainly outside Europe. The MESs of the MLMS system are designed to operate with a transmit power of 1 W e.i.r.p. and a Code Division Multiple Access - Binary Phase Shift Keying (CDMA-BPSK) modulation scheme. The MES emission bandwidth is given as 1.5 MHz with a bit rate of 2103 bits/s. Further details on the MLMS system can be found in Annexes 1 and 4.

4.3.2 Background information on the concerned frequency bands

The 335.4-399.9 MHz band is allocated to the Fixed and Mobile Services on a primary basis. S5.254 allows the MSS use of the bands 235 - 322 MHz and 335.4 - 399.9 MHz for bi-directional service links subject to agreement obtained under Article S9.21. These bands are heavily used by the military in various countries.

ERC Decision (96)04 assigns the band 385-390/395-399.9 MHz for civil TETRA systems as one of the four possible bands. However, ERC Decision 96(04) also decides that the bands 410-430 MHz and/or 870-876/915-921 MHz should be used as preference bands. If these bands are not available or additional spectrum is required, the bands 450-470 MHz and/or 385-390/395-399.9 MHz should be used.

At least one CEPT-country uses and some other countries intend to use the band 385-390 MHz linked with 395-399.9 MHz for civil TETRA.

The 400.15 - 401 MHz band is allocated to the Meteorological Aids Service, Meteorological-Satellite Service (space-to-Earth), Mobile-Satellite Service (space-to-Earth) and Space Research Service (space-to-Earth) on a co-primary basis and the Space Operation Service (space-to-Earth) on a secondary basis.

4.3.3 Studies to Date

4.3.3.1 Studies to Date with regard to certain military radio applications

A compatibility study between MLMS and tactical Radio Relay and Air - Ground – Air, which had been presented in 1994 to NATO / ARFA, was appropriately reviewed.
The reviewed study demonstrated that sharing between MLMS and tactical Radio - Relay and Air- ground - Air stations is feasible when certain operational constraints are applied.

4.3.3.2 Studies to date with regard to TETRA

4.3.3.2.1 Interference from MLMS MES to TETRA base station

A compatibility study and two test campaigns concerning sharing between MLMS terminals and TETRA terminals in the 385-390 MHz linked with 395-399.9 MHz were performed in a coordinated effort of Finland and SAIT Systems. The TETRA characteristics in the studies comply with TETRA standard ETS 300 392. MLMS MES characteristics are reflected in the annex 1 and comply with the EN 300 721, ETS 300.722 and EN 300 832.

4.3.3.2.2 Measurement method and set-up

The MLMS terminal was located during the measurements at different distances (between 1.5 km and 12 km) from the TETRA base station and the effect of the MLMS terminal transmissions to the TETRA base station were measured. The adaptive power control of the TETRA system was disabled during the measurements.

At each location of the MLMS terminal there were maximum three different cumulative BER measurements made with TETRA mobiles moving at different speeds (50 km/h and 10 km/h). All the locations for the TETRA mobile, except in the radial measurement, were chosen in such a way that a TETRA mobile was located close to the edge of the service area of the TETRA base station. The measurement time used for the cumulative BER was approximately 1 minute. Typical BER in the dynamic situation when the TETRA mobile is close to the edge of the service area is of the order of 1% without any interference. According to the TETRA standard the maximum acceptable BER is 4%, which can be used as limit for harmful interference.

4.3.3.2.3 Measurement results

The cumulative BER measurements carried out at several different locations resulted in that the required coordination distance between TETRA base station and interfering MLMS terminal is about 6.5 km.

Radial measurement
In addition, a radial measurement was made in which the TETRA mobile was taken with a speed of 50 km/h radially away from the TETRA base station. In this measurement the MLMS terminal was located at a distance of 1.5 km from the TETRA base station.

From these radial measurement results and the previous measurement results it can be concluded that when the interfering signal (in this case noise like CDMA signal) is more than about 20 dB below the TETRA mobile power level at the TETRA base station, the TETRA system is not interfered.

A qualitative test was also made when the TETRA was in normal ‘speech’ mode. The results showed that when the TETRA mobile was close to the base station, the MLMS transmission had no effect on the speech quality. When the TETRA mobile moved further away from the TETRA base station, the MLMS transmissions interfered with the TETRA system.

When the MLMS terminal short message was send (burst duration of about 1 seconds), it was clearly heard in the TETRA system, because there was a silence of about 1 second in the speech. However, the TETRA call was not dropped because of the interference, it continued immediately after the interference ended. When the 8 second burst (long message) was send the TETRA call was dropped after a few seconds of MLMS transmission. When the MLMS transmission ended, the TETRA call was created within a second, and the system continued to function normally.

4.3.3.2.4 Extending the results to cover typical TETRA base station

The measurement showed that in this measurement set-up, the co-ordination distance between MLMS terminal and TETRA base stations is about 6.5 km. The antenna height of the base station was 25 m, the base station antenna gain 7.5 dBi. If considering a more general TETRA case where the antenna height is 50 m and base station antenna gain is 11 dBi , the co-ordination distance will be about 12.5 km.

The reference sensitivity of the TETRA base station has been defined in order to guarantee less than 4% BER for the uncoded channel. Therefore the measured situation did not really reflect the true edge of the service area, because the reference BER without the MLMS transmissions was about 1%. If it is assumed that the reference BER had been 3% (worst case scenario), then in a Raleigh- fading channel when the BER doubles the (interference+noise)/signal (N/C) power ratio doubles as well and from this it can be calculated that the worst case coordination distance between the TETRA base station and MLMS transmitter is about 25 km.

4.3.3.3 Interference from TETRA mobile to MLMS satellite receiver

The total power received at the satellite receiver from terrestrial mobile stations can be calculated using the model described in the recommendation UIT-R M.1087 (1994).

The following table shows the maximum number of TETRA terminals in the band 387.250 - 388.750 MHz allowed in the footprint of the satellite without causing interference to the satellite receiver for two different traffic loading assumptions (μ = 0.02 Erlang and μ = 0.04 Erlang).

	3 W portable	10 W mobile	30 W mobile
Interfering terminals in the centre of the satellite footprint	1 (μ = 0.02) 1 (μ = 0.04)	1 (μ = 0.02) 1 (μ = 0.04)	1 (μ = 0.02) 1 (μ = 0.04)
Interfering terminals at the edge of the satellite footprint	85 (μ = 0.02) 13 (μ = 0.04)	1 (μ = 0.02) 1 (μ = 0.04)	1 (μ = 0.02) 1 (μ = 0.04)

As it can be seen from the results TETRA terminals cause harmful interference to MLMS satellite receiver even with very small number of terminals. The MLMS receiver is designed to take into account this kind of interference by the implementation of an adaptive noise-cancelling filter on board. The filter is able to adaptively reject some interference in the receiver bandwidth if the sources of interference are relatively stationary.

4.3.3.4 Studies with regard to the Radio Astronomy Service

With regard to the Radio Astronomy Service a study was performed and proved that MLMS downlink will not cause harmful interference to the Radio Astronomy Service in the 406.1 to 410 MHz band.

4.3.4 Conclusions to Date

4.3.4.1 Downlink Band Issues

In the frequency band 400.15-401 MHz (downlink), the MLMS system will not exceed the applicable pfd threshold at the earth's surface established by Annex 1 of Appendix S5 (Rev.WRC-97) therefore no co-ordination is necessary with terrestrial services, and no further action is necessary.

4.3.4.2 Uplink Band Issues

4.3.4.2.1 Conclusions to Date with regard to certain military radio applications

4.3.4.2.1.1 Radio Relay (R/R) versus MLMS-MES

4.3.4.2.1.1.1 MLMS-MES interfering Radio Relay

a. On the basis of an MLMS MES with 0 dBW e.i.r.p. and a maximum allowable jamming power at the R/R receiver of –202 dBW/Hz, interference might occur when an MLMS-MES is located within the 60° beamwidth of the R/R antenna and if the distance between both systems is less than 10 km in the case of suburban- and less than 25 km in the case of rural-environment. These results are based on the Okumura Hata model (CCIR model report 567-3 and ITU-R Recommendation P.529)

b. The probability that one MLMS-MES is in use in a rural environment coordination area, in a fully loaded system, is small (in average 5%) and the probability to get more than one MLMS-MESs in the coordination area in question is less than 0.4% (Poisson distribution).

c. With respect to duration of interference, interference will occur only if the MLMS satellite is in visibility of the MLMS-MESs because a pilot signal from the satellite must be detected first before the MLMS-MESs start to transmit. In case of a single MLMS-MES terminal, the time window where interfering can occur is 81 minutes a day (two satellites, nine usable satellite passes of about 9 min, worst case in Europe).
The length of a typical short message is 1.1 s and the minimum repetition rate is 30 s, the duty cycle is then 3.7%. Therefore, the duration of the possible interference is **180 s per day**.

The length of a typical long message is 8 s and the minimum repetition rate is 45 s. Therefore, the worst MLMS-MES long message activity considering the control bursts necessary for the protocol, is then **204 s per day**.

4.3.4.2.1.1.2 Radio Relay Interfering MLMS Satellite

It is concluded that R/R will interfere MLMS Satellite. However, it is important to remember that the interaction between both systems will always be limited to elevations angle from the R/R to the Satellite is below 30°. This means that R/R will reduce the time availability of the MLMS Satellite but will not prevent it from properly functioning. In addition, it is important to note that the MLMS receiver is designed taking account of this kind of interference by the implementation of an adaptive noise-canceling filter on board. The filter is able to adaptively reject some interferes in the receiver bandwidth if the sources of interference are relatively stationary.

4.3.4.2.1.2 Air Ground Air versus MLMS-MES

4.3.4.2.1.2.1 MLMS-MES interfering A/G/A Ground reception

a. The interfering power level produced by an MLMS-MES on an A/G/A base station is very quickly below the threshold of –125.87 dBm. The threshold level is exceeded when the MLMS-MES, with respect to the A/G/A base station, is inside a 4 km-area in a suburban environment and inside a 12 km-area in a rural environment.

b. In a rural environment, the probability to have a single MLMS-MES in the coordination area, in a fully loaded system, is small (in average 8 %) and the probability to have more than one MLMS-MESs in the coordination area is less than 1% (Poisson distribution).

c. With respect to duration of interference, interference will occur only if the MLMS satellite is in visibility of the MLMS-MESs because a pilot signal from the satellite must be detected first before the MLMS-MESs start to transmit. In case of a single MLMS-MES terminal, the time window where interfering can occur is 81 minutes a day (two satellites, nine usable satellite passes of about 9 min, worst case in Europe).

The length of a typical short message is 1.1 s and the minimum repetition rate is 30 s, the duty cycle is then 3.7%. Therefore, the duration of the possible interference is **180 s per day**.

The length of a typical long message is 8 s and the minimum repetition rate is 45 s. Therefore, the worst MLMS-MES long message activity considering the control bursts necessary for the protocol, is then **204 s per day**.

4.3.4.2.1.2.2 MLMS-MES interfering A/G/A Airborne

a. Any MLMS-MES transmission within the radio horizon distance of an A/G/A Airborne receiver will interfere the reception.

b. With respect to duration of interference, interference will occur only if the MLMS satellite is in visibility of the MLMS-MESs because a pilot signal from the satellite must be detected first before the MLMS-MESs start to transmit. In case of a single MLMS-MES terminal, the time window where interfering can occur is 81 minutes a day (two satellites, nine usable satellite passes of about 9 min, worst case in Europe).

The length of a typical short message is 1.1 s and the minimum repetition rate is 30 s, the duty cycle is then 3.7%. Therefore, the duration of the possible interference is **180 s per day**.

The length of a typical long message is 8 s and the minimum repetition rate is 45 s. Therefore, the worst MLMS-MES long message activity considering the control bursts necessary for the protocol, is then **204 s per day**.

4.3.4.2.1.2.3 A/G/A Ground and Airborne interfering MLMS Satellite

a. Any A/G/A Ground or Airborne transmission will interfere MLMS Satellite. In this case, noise-cancelling filter on board will take care of this kind of interference.

4.3.4.2.2 Conclusions to Date with regard to TETRA

4.3.4.2.2.1 Interference from MLMS MES to TETRA base station

The conclusion of the studies were that the MLMS MES causes interference to TETRA base station within 25 km of the TETRA base station under certain worst case conditions, whereby the TETRA mobile terminal was located at the edge of the base station service area. However, it was also noted that even when the MLMS MES was just within a few kilometres from the TETRA base station it's transmissions did not cause harmful interference to TETRA base station when the TETRA mobile was also close to the TETRA base station. It should also be noted that when the MLMS MES is causing interference to TETRA system it can have an effect up to 50 channels due to it's wide CDMA transmission.

Therefore, introducing operational constraints on the MLMS system and taking into account the low number of MLMS MES, it can be concluded that the probability of interference from MLMS MES to TETRA systems is sufficiently low that it is expected to result in little significant degradation of service availability.

4.3.4.2.2.2 Interference from TETRA to MLMS Space Station

It is very likely that TETRA terminals would also cause harmful interference to the MLMS system even with a only a few numbers of terminals, however, due to the regulatory status the MLMS system shall not claim protection from interference of systems operating in accordance with ITU-R regulations.

4.3.4.2.3 Conclusions to Date with regard to the Radio Astronomy Service

MLMS will not cause harmful interference to the Radio Astronomy Service in the frequency band 406.1-410 MHz.

4.3.4.2.4 NIB Operation of MLMS System

MLMS operations in the 387.250 – 388.750 MHz frequency spectrum shall be on a Non Interference Basis (NIB) in accordance with the RoP of the ITU-R regarding provision S5.254 of the ITU-R RR.

At any time, if stations of services operating in accordance with the table of frequency allocations and/or NATO systems suffer interference from MLMS, MLMS shall take any necessary action to stop the interference, in accordance with ITU procedures. In addition, MLMS may not claim protection from stations of services operating in accordance with the table of frequency allocations and/or NATO systems.

4.3.4.3 Final Conclusions on the operation of the MLMS system

Sharing between MLMS MESs and mobile service systems and between MLMS MESs and NATO systems is possible and adequate interference protection will be afforded to other services operating in accordance with the Table of Frequency Allocations if the following baseline operating constraints are placed on MES transmissions:

System NAME : MLMS	
OPERATIONAL CONSTRAINTS	
Up-link designated bands	387.250-388.750 MHz
Down-link designated bands	400.15-401 MHz
Number of satellites in constellation	2
Maximum number of receivers per satellite	8
Multiple access method	CDMA
Modulation method	CDMA-BPSK
Maximum MESs EIRP	0 dBW
Technique to avoid causing interference from MESs	MES transmits only when satellite is visible
Maximum burst duration for MESs transmission in short messages	1.1 seconds
Short messages – Repetition rate	minimum 30 seconds
Maximum burst duration for MESs transmission in long messages	8 seconds
Long messages – Repetition rate	Maximum three messages during one satellite passage with a minimum time between messages of 45 seconds.
Maximum burst duration for MES long messages control burst	1.1 seconds
Long messages control bursts – Repetition rate	Minimum 30 seconds
Control of Uplink Self Interference and hot spot avoidance	Upon reception of the satellite signal, each terminal will determine a randomly chosen delay up to 60 seconds before starting emission, in order to avoid hot spot emission and collision at the satellite receiver
Restricted duty cycle mode	Shall be applied if the number of MES emissions in CEPT countries exceeds 1000 per day. See note1.
Basis of Operation	See note 2.
Geographical Location of a MES	Shall be determined by the MLMS system, after one transmission from a MES.

Note 1
In the restricted duty cycle mode, all uplink terminal activity in CEPT countries will have to comply with the following four constraints **simultaneously**:

- Duration of activity and muting period: minimum 6 minutes
- Duration of activity window : maximum 3 minutes
- Maximum ratio between activity window and the activity window plus the muting window: maximum 1/3
- Transmission window in CEPT countries are synchronised

Uplink activity of all terminals synchronised in CEPT

On	Off	
X	X	X
Max 180 s		
←	Min 360 s (6 minutes)	→

Other operational constraints of MLMS given in the table shall apply.

Note 2

MLMS shares the 387.250 – 388.750 MHz frequency spectrum on a Non Interference Basis (NIB).

At any time, if stations of services operating in accordance with the table of frequency allocations and/or NATO systems suffer interference from MLMS, MLMS shall take any necessary action to stop the interference, in accordance with ITU procedures. In addition, MLMS may not claim protection from stations of services operating in accordance with the table of frequency allocations and/or NATO systems.

4.4 SAFIR 2

4.4.1 General System Description

The SAFIR 2 system is a frequency hopping constellation comprised of 2 satellites. The system is designed to operate in the frequency bands 400.6 - 400.9 MHz (space-to-Earth) and 399.9 - 400.05 MHz (Earth-to-space). With full deployment only 1 satellite will be visible at any time at a geographic location at a latitude of 50°. The system allows 16 MESs to access the satellite simultaneously using a TDMA access scheme with a superposed FDMA access scheme. The transmission of an MES data telegram lasts about 1s. The SAFIR 2 system has a total capacity of 10000 data telegrams per day and channel in one defined ground spot. Further details on the SAFIR-2 system can be found in Annexes 1 and 5.

4.4.2 Background information on the concerned frequency bands

The 399.9 - 400.05 MHz band is allocated to the Radionavigation-Satellite Service and the Mobile-Satellite Service (Earth-to-space) on a co-primary basis.
Operation of the MSS within this band is limited to non-geostationary satellite and is subject to co-ordination under Article S9.11A. RR S5.220 states that MSS shall not constrain the development and use of the RNSS. The RNSS allocation in this band will cease to exist as of 1 January 2015.

The 400.15 - 401 MHz band is allocated to the Meteorological Aids Service, Meteorological-Satellite Service (space-to-Earth), Mobile-Satellite Service (space-to-Earth) and Space Research Service (space-to-Earth) on a co-primary basis and the Space Operation Service (space-to-Earth) on a secondary basis.

4.4.3 Studies to Date

No sharing studies are needed with regard to the frequency band 399.9-400.05 MHz (Earth-to-space) since there is no utilisation in Europe named in the column „major utilisation„ of the European Common Allocation Table.

The transmitter mask of SAFIR 2 shows that the maximum level of unwanted emissions is below - 150 dB(W/Hz) in the frequency band 406.1 – 410 MHz. Assuming the worst case, i.e. the satellite located in the zenith of a RAS site, the maximum pfd produced by a SAFIR 2 satellite at an altitude of 815 km will be:

$$\begin{aligned} \text{pfd} &= \text{(satellite EIRP)} - 10\log(4\pi r^2) \\ &= -150\ \text{dBW/Hz} - 10\log(4\pi(815\text{km})^2) \\ &= \underline{\underline{-279\ \text{dBW/m}^2\text{/Hz}}} \end{aligned}$$

This value yields a margin of 24 dB to the pfd limit of - 255 dB(W/m^2/Hz) of Recommendation ITU-R **RA.769**.

Uplink and downlink service transmission characteristics are the same in the SAFIR 2 system, hence the same transmission masks apply to the MES. Due to the fact, that only two satellites of the SAFIR2 system are operational in orbit at the same time only one transmission of a single MES can fall into the integration time of 2000 s according to ITU-R RA.769.

The maximum transmission time of a SAFIR 2 MES will be 1 s. A single burst of 1 s within the integration time of 2000 s corresponds to a duty cycle of 0.0005 which represents a reduction of 33 dB in the interference level. In order to properly protect a radio astronomy site, a transmitting MES has to keep a co-ordination distance that provides a sufficient transmission loss. Assuming free space propagation the pfd can be calculated as:

$$pfd = eirp - 10\log\left(4\pi r^2\right)$$

The radius of interference will then be:

$$r = \sqrt{\frac{10^{\left(\frac{eirp-pfd}{10}\right)}}{4\pi}}$$

With the pfd limit (-255 dBW/m^2/Hz) reduced by the duty cycle (33dB) and an antenna gain for the MES of 0dBi towards the horizon, it can be calculated that:

$$r = \sqrt{\frac{10^{\left(\frac{(-150-(-222))}{10}\right)}}{4\pi}}$$

$$r = \underline{\underline{1123\ \text{m}}}$$

Thus, when in ‘line-of-sight’, SAFIR 2 MES will not cause unacceptable interference to RAS sites when located at distances of at least 1123 m of a radio astronomy observatory. In practice there is a very low probability for that constellation, as radio astronomy observatories are commonly ‘hidden’ by the characteristics of the landscape, so that direct visibility from short distance is not available.

4.4.4 Conclusions Relating To SAFIR 2

Based on studies conducted, the following conclusions relating to SAFIR 2 have been reached:

4.4.4.1 Downlink issues

In the frequency band 400.15 - 401 MHz (downlink), the SAFIR 2 system will not exceed the applicable pfd threshold at the earth’s surface established by Annex 1 of Appendix S5 (Rev.WRC-97) therefore no co-ordination is necessary with terrestrial services, and no further action is necessary.

4.4.4.2 Uplink issues

Since there is no utilisation named in the European Common Allocation Table the SAFIR 2 system can operate MESs, limited to LMESs until 1 January 2015, in the frequency band 399.9 - 400.05 MHz. With regard to the RNSS system operating in that frequency band the co-ordination distance between a LMES and a RNSS receiver toward navigable waterways shall be calculated under Draft New Recommendation ITU-R **M. 8/42** "Methodology of Sharing between MSS Systems (E-s) and Existing RNSS Systems (s-E) in the Frequency Bands 149.9 - 150.05 MHz and 399.9 - 400.05 MHz, if necessary.

SYSTEM NAME : SAFIR 2	
OPERATIONAL CONSTRAINTS	
Number of Satellites	2
Up-link designated bands	399.9-400.05 MHz
Down-link designated bands	400.6-400.9 MHz
Multiple access method	TDMA with superposed FDMA
Modulation method	BPSK
Maximum MES e.i.r.p. spectral density	10 dBW/4kHz
Maximum burst duration for MES transmissions	1000 msec

4.4.4.3 Sharing With the Radio Astronomy Service

The compatibility study presented to PT SE28 regarding the protection of the Radio Astronomy Service from unwanted emissions of the SAFIR 2 System (Earth-to-space and space-to-Earth) has demonstrated that the protection requirements of the Radio Astronomy Service are met by a considerable margin. Therefore, the requirement of footnote S5.208A will be fulfilled for the SAFIR 2 system.

4.4.4.4 Land Earth Stations

Land Earth stations, even when operating in mobile satellite service bands, should be co-ordinated under existing procedures. Accordingly, no special provisions are necessary with respect to Land Earth stations. The SAFIR 2 system is currently operating bi-directional feederlinks (uplink and downlink) in the 137.175 – 137.275 MHz band. This is due to the unavailability of the 399.9 - 400.05 MHz band and the 400.15 – 401 MHz band for such operations. Co-ordination of the SAFIR 2 feederlinks in the 137.175 – 137.275 MHz band with LEOTELCOM-1 are continuing.

4.5 LEOTELCOM-5

4.5.1 General System Description

The LEOTELCOM-5 system is a two way, store and forward packet data communication system that uses a constellation of 48 active, low Earth orbit satellites to provide low data rate communications to and from user Earth stations that may be located throughout the world. The system is designed to provide near real-time data communications at data rates of 2.4, 4.8, and 9.6 kbps and uses frequency division multiple access techniques with narrow band modulation. The system operates on frequencies near 137 MHz (downlink), 149 MHz (uplink) and 400 MHz (downlink).

The satellite constellation consists of eight circular orbit planes inclined at 50 degrees and equally spaced around the equator. There will be six active satellites launched into each plane, for a total of 48 active satellites. The spacecraft altitude will be 950 km, which results in circular beam patterns of 3960 km diameter on the surface of the Earth.

User service terminals may be either mobile or fixed and can both send and receive data. Service terminals are small, with low power and simple antennas, and are battery powered where necessary. Mobile Earth stations may be placed on trucks, trains, ships and planes and may have position location features if needed. Fixed Earth stations may be situated, for example, at businesses, homes, and industrial sites. The terminals will have intermittent use and the network can support millions of service terminals around the world.

The LEOTELCOM-5 system uses a Dynamic Channel Assignment Sub-System (DCASS) on each satellite to detect active Land Mobile Radio (LMR) channels, and thereby to avoid interference from the LEOTELCOM-5 Earth stations to the LMR receivers. Channels are assigned for uplink transmissions only if the DCASS system finds no active use by terrestrial systems. The interference potential is minimized by the capability of the DCASS to determine channel availability every 0.5 seconds.

Further information on specific parameters can be found in Annex 1 while Annex 6 provides a detailed system description.

4.5.2 Background information on the concerned frequency bands

The 137-138 MHz band is allocated to the Space Operation, Space Research and Meteorological-Satellite Service on a primary basis and the Fixed and Mobile (except aeronautical mobile (R)) Service on a secondary basis. MSS (space-Earth) is allocated on a co-primary basis within the sub-bands 137-137.025 MHz and 137.175-137.825 MHz and a secondary basis within 137.025-137.175 MHz and 137.825-138 MHz. Coordination is required under S9.11A. The applicable MSS coordination threshold for terrestrial services is -125 dBW/m^2/4 kHz for MSS downlink emissions for those MSS systems Advanced Published before 1 November 1996.

For MSS systems for which complete Appendix 3 coordination information had not been received by the Radio Bureau as of 1 November 1996 (except for replacement satellites for the systems for which complete Appendix 3 information had been received by the Radio Bureau prior to that date) the coordination threshold is -140 dBW/m^2/4 kHz with respect to AMS(OR) in those countries listed in footnotes S5.204 & S5.206. For other countries and for systems for which Appendix 3 coordination information had been received by the Radio Bureau as of 1 November 1996 (i.e. LEOTELCOM-1), the threshold is –125 dBW/m^2/4 kHz. See Annex 1 to Appendix S5 (WRC-97) (formerly Resolution **46**).

The 148-149.9 MHz band is allocated to the Fixed, Mobile (except aeronautical mobile (R)) and the Mobile-Satellite Service (Earth-to-space) on a co-primary basis and is heavily used by terrestrial fixed and mobile services including Private Mobile Radio (PMR) and military radio systems. Operation of the MSS within this band is limited to non-geostationary satellite systems and is subject to co-ordination under S9.11A. In addition, it should be noted that although the MSS is allocated on a primary basis, RR S5.219 states that, for countries designated therein, MSS systems shall not constrain the development and use of this band by fixed, mobile and space operation services. Furthermore RR S5.221 states that the MSS shall not cause harmful interference to, or claim protection from, stations of the fixed or mobile services in the countries listed. These should be taken into account when considering compatibility studies between MSS and other Fixed and Mobile services in the 148-149.9 MHz band.

The 149.9-150.05 MHz band is allocated to the Radionavigation-Satellite Service and the Mobile-Satellite Service (Earth-to-space) on a co-primary basis. Operation of the MSS within this band is limited to non-geostationary satellite and is subject to co-ordination under S9.11A. RR S5.220 states that MSS shall not constrain the development and use of the RNSS. The RNSS allocation in this band will cease to exist as of 1 January 2015. Within the UK, this band is used for sonobuoys operating on agreed frequencies.

The 400.15 - 401 MHz band is allocated to the Meteorological Aids Service, Meteorological-Satellite Service (space-to-Earth), Mobile-Satellite Service (space-to-Earth) and Space Research Service (space-to-Earth) on a co-primary basis and the Space Operation Service (space-to-Earth) on a secondary basis.

4.5.3 Studies Conducted to date

Several analysis were conducted to determine the probability of interference at PMR receivers based on the satellite network characteristics given in Annex 1 with up-link data rates of 2.4, 4.8 and 9.6 kbps and MES transmission frames of a length of 450 ms. Further main features of the analysis are as follows: the transmission power ranges from 1.75 W for 2.4 kbps up-links and 3.5 W or 7 W for 4.8 kbps uplinks and 9.6 kbps up-links respectively while in one particular study a transmission power of 7 W was used for all datarates.

Three different PMR scenarios of three different CEPT countries have been studied on the basis of parameters mainly provided by these countries. The sharing scenario of traffic channels in analogue PMR systems co-frequency sharing with mobile earth stations in the MSS was modeled using a statistical simulation model similar to that described in Annex 3 in ITU-R Recommendation M.1039-2.

4.5.3.1 Case 1:

The parameters for the PMR network of Case 1 are based on the planning parameters for such a network used in one CEPT country. It should be noted that this country utilizes a channel spacing of 20 kHz, hence the analysis is based on this value.

The following MES parameters were used for the MESs of the LEOTELCOM-5 system in order to conduct the study:

Parameter	Value
MES Power / EIRP	7 W / 8.5 dBW for 9.6 kbps 3.5 W/ 5.4 dBW for 4.8 kbps 1.75W/ 2.2 dBW for 2.4 kbps
Antenna Gain / Polarization	0 dBi / Vertical
Antenna Height	1.5 m
Data Rate	2.4, 4.8, 9.6 kbps
Channel Bandwidth	5, 10, 15 kHz

For the terrestrial systems the following parameters provided by Country 1 were used to model the PMR scenario:

Parameter	Mobile Station	Base Station
Transmitter Frequency	146-174 MHz	146-174 MHz
Channel Spacing	20 kHz	20 kHz
Transmit Power	37.8 dBm	37.8 dBm
Receiver IF Bandwidth	12 kHz	12 kHz
Antenna Height	~3 m	12 m
Antenna Gain	0 dBi	0 dBi
Coverage Radius	10 km	10 km
Receiver Sensitivity (static)	-109.8 dBm	-109.8 dBm
Fade Depth	8 dB	8 dB
Receiver Sensitivity (dynamic)	-101.8dBm	-101.8dBm
Receiver Protection Ratio (C/I)	8 dB	8 dB

The simulation to calculate the interference is described in ITU-R Recommendation M.1039-2. One million simulation trials were evaluated as described below. The probability of interference was then calculated as the number of trials resulting in interference divided by 1 million.

1) A PMR base station is randomly selected at the center of one of the M most populous cities within the geographic region. (Cities with a population greater than 0.5 million are used. M equals 86 for Europe.)
2) A PMR mobile station location is randomly selected, in the same city as the base station, using a circular mass distribution from 0 km to the PMR coverage radius. (Coverage radius = the distance from the PMR base station to where the mobile station received power equals the receiver sensitivity (faded)). The propagation model used is the model in Annex 2 in ITU-R Recommendation M.1039-2 – the propagation loss model as originally provided by WP 3M in 3M/TEMP/10, 5 May 1998.
3) A PMR center frequency is selected in the 148-149.9 MHz band as 1XY.Z MHz + (n + 0.5) x 20 kHz, where n is randomly selected from 0 to 49. (For different channel spacings, use an n value where (n + 1) x channel spacing = 1 MHz).
4) 128 active MESs are randomly sited over the geographic region.
5) For each MES the distance from the MES to the PMR station is computed.
6) For each MES a center frequency is selected as 1XY.Z MHz + (n + 0.5) x 2.5 kHz, where n is randomly selected from 0 to 399, for the uniform spacing of MES channels. For the interstitial spacing of MES channels, the MES channels are only placed at the channel boundaries of the PMR channels.
7) The received interference power (I) at the PMR station (either mobile or base) is computed by integrating the aggregate received MES power spectral density over the PMR receiver IF bandwidth.

8) MES transmitters separated from the PMR victim receiver by more than the radio horizon for that path are not taken into account. The radio horizon from the MES to the mobile receiver is determined from:

$$RH_{MES\text{-}Mobile}\,(\text{miles}) = [2 \times \text{Height}_{MES}(\text{feet})]^{1/2} + [2 \times \text{Height}_{PMR\text{-}Mobile}(\text{feet})]^{1/2}$$

1 ft. = 0.3048m
1 mile = 1.609km

The radio horizon from the MES to the base station is determined in a similar manner.

9) The received signal power (C) at the PMR station is calculated using the propagation loss model referenced in step 2, with X dB additional loss to account for carrier fading.
10) If C/I is less than the protection ratio, then the trial has resulted in interference.

4.5.3.2 Case 2:

In the second analysis the parameters for the MESs are the same as in the study described in section 4.5.3.1. The parameters for the PMR systems are provided mainly by another country and are as follows:

Parameter	Mobile Station	Base Station
Transmitter Frequency	152.900-154.875 MHz	147.900-149.875 MHz
Channel Spacing	--	25 kHz
Number of Channels	80	80
Class of Emission	--	16KF3E
Transmit Power	--	47.0 dBm
Receiver IF Bandwidth	16 kHz*	--
Antenna Height	~3 m*	70 m (typical)
Antenna Gain	0 dBi*	0 dBi, max. 3 dB
Coverage Radius	30 km	30 km
Receiver Sensitivity (static)	-109.8 dBm*	--
Fade Depth	8 dB*	8 dB*
Receiver Sensitivity (dynamic)	-101.8 dBm*	--
Receiver Protection Ratio (C/I)	8 dB*	--

* Parameter values were not provided, thus they are estimated values.

The simulation of the probability of interference is based on the description in section 4.5.3.1 but the value for n in this case is randomly selected from 0 to 39 due to the channel spacing of 25 kHz.

Only the base station to mobile link has frequencies that overlap with LEOTELCOM-5 uplink frequencies. There are 76 mobile channels of 25 kHz width that overlap with the LEOTELCOM-5 uplink frequencies. The LEOTELCOM-5 MESs are licensed in the U.S.A. to operate in 1210 kHz of bandwidth. Therefore, in the sharing model, a common bandwidth of 1210 kHz is used, centered on 149 MHz. The modeled results then give the probability of interference into a PMR receiver that operates on a frequency that is shared with the LEOTELCOM-5 MES uplinks. For those channels that operate at frequencies where the MES uplinks do not operate, the probability of interference is zero.

4.5.3.3 Case 3:

In the third analysis the parameters for the MESs differ from those of the analysis described above. Instead of using different MES transmit power levels for different datarates the transmit power has been set at maximum for all datarates. Also different antenna heights have been used in this analysis ranging from 1.5m – 5m. The complete set of MES parameters are found in the table below:

A geographic density of MESs is used that is representative of the total population of a specific country compared to the total population of the European countries. This would represent the compatibility scenario where the density of MESs in a country is proportional to the population of the country, rather than the assumption of uniform distribution across the land area of the beam coverage, as had been used in the prior LEOTELCOM-5 study.

The calculation of the MES density to be used in the LEOTELCOM-5 model is given table below.

Modeling of MES Density in a Specific Country to be Proportional to the Population of the Specific Country

Population	57,384,000
Coverage Area Population	617,049,616
Population Ratio	0.093
Area (km^2)	244,103
Coverage Area (km^2)	12,000,000
Area Ratio	0.020
Number of Active MESs in Beam Area (Prior Case)	128
MES Density (Prior Case), MES/km^2	1.067×10^{-5}
Number of Active MESs in the specific country (Prior Case)	2.60
Proportional Number of Active MESs in the specific country (In this case)	11.90
Augmentation Factor needed to achieve MES density in the specific county proportional to population	4.58
Number of MESs to be used in simulation model (this case)	4.58 x 128 = 586

The technical parameters used for the LEOTELCOM-5 MESs can be summarized as follows:

Parameter	Value
MES Power / EIRP	7 W / 8.5 dBW for 9.6 kbps, 4.8 kbps, and 2.4 kbps
Antenna Gain / Polarization	0 dBi / Vertical
Antenna Height	1.5 m, 3m, 5m
Data Rate	2.4, 4.8, 9.6 kbps
Channel Bandwidth	5, 10, 15 kHz
MES Uplink Frequencies	148-149.9 MHz

The parameters for the PMR systems are provided mainly by a third country and are as follows:

Parameter	Mobile Station	Base Station
Transmitter Frequency	148.01875-148.98125 MHz	--
Channel Spacing	12.5 kHz	12.5kHz
Number of Channels	78	--
Transmit Power (System 1 – channels J58-J99) (System 2 – channels J22-J58)	 41.0 dBm (System 1) 37.8 dBm (System 2)	--
Channel Center Frequency Range System 1 – channels J58-J99 System 2 – channels J22-J58	 148.45625-148.98125 MHz 148.01875-148.45625 MHz	
Bandwidth used+ for System 1 for System 2	 525 kHz 612.5 kHz	
Receiver IF Bandwidth	--	8.5 kHz*
Antenna Height	1.5 m	75 m
Antenna Gain	0 dBi*	0 dBi*
Coverage Radius	23 km	23 km
Receiver Sensitivity (static)	--	-109.8 dBm*
Fade Depth	8 dB*	8 dB*
Receiver Sensitivity (dynamic)	--	-101.8 dBm*
Receiver Protection Ratio (C/I)	--	10 dB

* Parameter values were not provided, thus they are estimated values.

+ Some Channels are shared between systems

To allow comparisons with earlier compatibility studies performed with regard to protection of terrestrial services busy hour traffic statistics for two specific trunked services operated in this country have been taken into account.

In order to perform the simulation for case 3 it should be noted that the following changes were made from the technical characteristics and models used in the simulations above:

1. MES geographic density was increased to be proportional to the UK population percentage in the satellite beam coverage area, 9.3%.
2. MESs were operated in the entire 1.9 MHz uplink band, 148-149.9 MHz.
3. MES antenna heights used were 1.5m, 3m, and 5m.
4. MES EIRP was 7W/8.5dBW for all three data rates, 2.4, 4.8, and 9.6 kbps.
5. Busy hour traffic statistics were applied to the gas and electric utility PMR channels.

4.5.3.4 Protection of the Radio Astronomy Service

A study on the protection of the radio astronomy service in the bands 150.05 – 153 MHz, 322 – 328.6 MHz and 406.1 – 410 MHz from the downlink emissions of the LEOTELCOM-5 system demonstrates that there is a safety margin of approximately 22 dB between the protection criteria defined in ITU-R RA.769-1 and the LEOTELCOM-5 satellite emissions in the relevant radio astronomy band at 150 MHz. In the band 322-328.6 MHz and 406.1-410 MHz, it has been demonstrated that the LEOTELCOM-5 system is designed to provide a safety margin of 10 dB for the protection of the Radio Astronomy Service. This is achieved by the use of spectrum roll-off and transmitter filtering on the spacecraft.

The same study also addressed the LEOTELCOM-5 MES uplinks in the band 148-149.9 MHz and it was shown that the probability of interference of is less than 1%, (0.19% and 0.78% for 2,000 second and 20,000 second RA observation periods, respectively), in the RAS band 150.05-153.0 MHz.

4.5.4 Conclusions Relating To LEOTELCOM-5

Based on studies conducted, the following conclusions relating to LEOTELCOM-5 have been reached:

4.5.4.1 Downlink Band Issues

In the frequency bands 137-138 MHz and 400.15-401 MHz, the LEOTELCOM-5 system will not exceed the applicable pfd threshold at the earth's surface established by Annex 1 of Appendix S5 (Rev.WRC-97) therefore no co-ordination is necessary with terrestrial services, and no further action is necessary.

4.5.4.2 Uplink Band Issues

4.5.4.2.1 Case 1:

For analogue non-trunked PMR systems, the highest probability of interference (0.009%), see table below, was for randomly positioned, 9.6 kbps MES channels interfering into the base station receiver. For a 450 ms interfering signal, this may be interpreted as one interference event every 82 minutes (450 ms/0.009%) for a continuously operating mobile to base station link. For 0.01 Erlangs traffic loading on the PMR channel, the 450 ms interference event would occur once every 6 days on that channel.

MES Bit Rate	PMR Mobile Receiver		PMR Base Receiver	
	Random	Interstitial	Random	Interstitial
9.6 kbps	0.0020%	0.0018%	0.0092%	0.0084%
4.8 kbps	0.0018%	0.0000%	0.0080%	0.0000%
2.4 kbps	0.0007%	0.0000%	0.0047%	0.0000%

The impact of the potential interference may be assessed by evaluating the change in PMR channel availability/unavailability caused by the modeled interference. If the PMR channel were a high reliability channel with 99% availability/1% unavailability, the LEOTELCOM-5 MES interference (worst case) into analogue PMR systems would cause the availability to decrease to 98.991 % and the unavailability to increase to 1.009%. For analogue PMR systems, the interference effect on the channel availability/unavailability is not significant.

It should be noted that the analysis was performed without using the DCASS system to detect active PMR channels. If the DCASS system were used and it had a 90% effectiveness in detecting active channels, the modeled probabilities of interference would be reduced by a factor of 10. For 95% DCASS effectiveness, the interference would be reduced by a factor of 20, and so forth, which results in all cases in even lower interference probabilities than those already calculated.

4.5.4.2.2 Case 2:

The probabilities of interference as modeled for these analogue non-trunked PMR system are extremely low. For the interstitial placement of MES channels no interference condition was found in the number of cases run in the statistical model. For the 0.0000% entries in the table, no interference condition (C/I less than 8 dB) was found in the number of cases run in the statistical simulation model.

MES Bit Rate	**PMR Mobile Receiver**	
	Random	**Interstitial**
9.6 kbps	0.0010%	0.0000%
4.8 kbps	0.0002%	0.0000%
2.4 kbps	0.0005%	0.0000%

The highest probability of interference (0.001%) was for randomly positioned, 9.6 kbps MES channels interfering into PMR mobile receivers. For a 450 ms interfering signal, this may be interpreted as one interference event every 12.5 hours (450 ms/0.001%) for a continuously operating base station to mobile link. For 0.01 Erlangs traffic loading on the PMR channel, the 450 ms interference event would occur once every 52 days on that channel.

The impact of the potential interference may be assessed by evaluating the change in PMR channel availability/unavailability caused by the modeled interference. If the PMR channel were a high reliability channel with 99% availability/1% unavailability, the LEOTELCOM-5 MES interference (worst case) into these PMR systems would cause the availability to decrease to 98.999 % and the unavailability to increase to 1.001%. This level of interference has negligible effect on the channel availability/unavailability.

As noted in section 4.5.4.2.1, the analysis was performed without using the DCASS system to detect active PMR channels.

4.5.4.2.3 Case 3:

4.5.4.2.3.1 Results for a specific Trunked PMR Systems (System 1)

The simulation results are given in the table below for MESs sharing with the trunked PMR system 1. For the 0.0000% entries in the table, no interference condition (C/I less than 10 dB) was found in the number of cases run in the statistical simulation model. The results presented and discussed are for PMR voice channels only.

Sharing Model Results
Probability of Interference at a PMR Receiver of System 1
for MESs Sharing with Analogue Trunked PMR Systems at 149 MHz
(Random and Interstitial Placement of MES Channels,
Geographic Region – Europe, DCASS not used,
PMR Voice Channel Utilization Factor – 0.035)

MES Ant. Ht.	**5m**		**3m**		**1.5m**	
	Channelization		**Channelization**		**Channelization**	
MES Bit Rate	**Random**	**Interstitial**	**Random**	**Interstitial**	**Random**	**Interstitial**
9.6 kbps	0.0055%	0.0086%	0.0046%	0.0071%	0.0035%	0.0053%
4.8 kbps	0.0055%	0.0085%	0.0046%	0.0071%	0.0035%	0.0049%
2.4 kbps	0.0037%	0.0000%	0.0033%	0.0000%	0.0028%	0.0000%

For the trunked PMR systems, the highest probability of interference (0.0086%) was for 5m MES antenna height and for interstitial placement of 9.6 kbps MES channels causing interference into the PMR base station receiver. For a 450 ms interfering signal, this may be interpreted as one interference event every 87 minutes (450 ms/0.0086%) for a mobile to base station voice channel during the busy hour.

If the PMR channel were a high reliability channel with 99% availability/1% unavailability, the LEOTELCOM-5 MES interference (worst case) into gas utility PMR systems would cause the availability to decrease to 98.9914 % and the unavailability to increase to 1.0086%. This amount of interference would have little effect on the channel availability/unavailability.

4.5.4.2.3.2 Results for a specific Trunked PMR Systems (System 2)

The simulation results are given in the table below for MESs sharing with the trunked PMR system 1. For the 0.0000% entries in the table, no interference condition (C/I less than 10 dB) was found in the number of cases run in the statistical simulation model. The results presented and discussed are for PMR voice channels only.

Sharing Model Results
Probability of Interference at a PMR Receiver of System 2
for MESs Sharing with Analogue PMR Systems at 149 MHz
(Random and Interstitial Placement of MES Channels,
Geographic Region – Europe, DCASS not used
PMR Voice Channel Utilization Factor = 0.0179)

MES Ant. Ht.	**5m**		**3m**		**1.5m**	
	Channelization		**Channelization**		**Channelization**	
MES Bit Rate	**Random**	**Interstitial**	**Random**	**Interstitial**	**Random**	**Interstitial**
9.6 kbps	0.0260%	0.0432%	0.0226%	0.0366%	0.0170%	0.0268%
4.8 kbps	0.0282%	0.0425%	0.0237%	0.0354%	0.0183%	0.0242%
2.4 kbps	0.0187%	0.0000%	0.0164%	0.0000%	0.0136%	0.0000%

For trunked PMR system 2, the highest probability of interference (0.043%) was for 5m MES antenna height and for interstitial placement of 9.6 kbps MES channels causing interference into base station receivers. For a 450 ms interfering signal, this may be interpreted as one interference event every 17 minutes (450 ms/0.043%) for a mobile to base station voice channel during the busy hour.

If the PMR channel were a high reliability channel with 99% availability/1% unavailability, the LEOTELCOM-5 MES interference (worst case) into PMR systems 2 would cause the availability to decrease to 98.957 % and the unavailability to increase to 1.043%. This amount of interference would have little effect on the channel availability/unavailability.

As noted in section 4.5.4.2.1, the analysis was performed without using the DCASS system to detect active PMR channels.

4.5.5 Final Conclusion

4.5.5.1 Sharing with the Land Mobile Service

From the modeling performed on LEOTELCOM-5 MES uplinks co-frequency sharing with analogue PMR systems in the 148-149.9 MHz band, it may be concluded that there would be no significant degradation of service availability for the PMR systems.

Sharing between LEOTELCOM-5 MESs and mobile service systems is possible and adequate interference protection will be afforded to other primary services if the following baseline operating constraints are placed on MES transmissions:

System NAME : LEOTELCOM-5	
OPERATIONAL CONSTRAINTS	
Up-link designated bands	148-149.9 MHz
Down-link designated bands	137-138 MHz and 400.15-401 MHz
Maximum number of active satellites	48
Maximum number of receivers per satellite	15
Multiple access method	FDMA
Modulation method	OQPSK
Maximum MESs e.i.r.p. spectral density	10 dBW/4 kHz
Technique to avoid causing interference from MESs	Dynamic Channel Assignment Sub-System (DCASS) as described in Annex 6, Section 2.3.2
Maximum burst duration for MESs transmission	450 msec
Maximum duty cycle for MESs	Not greater than 1% in any 15 minute period for any single channel
Maximum duty cycle for system control bursts	Not greater than 1% in any 15 second period for any single channel
All MES traffic with the exception of the system control bursts	Consecutive transmissions from a single earth station on the same frequency shall be separated by at least 15 seconds

The studies treat the interference scenario purely on statistical terms. With regard to sharing between LEOTELCOM-5 and terrestrial analogue trunked PMR systems it may be necessary for some Administrations to implement additional national measures. Trunked mobile radio and data systems could be more susceptible to MES interference since there might be short transmissions of these systems that may be less likely to be detected by the satellite and hence a higher level of interference than calculated in the simulations may occur.

4.5.5.2 Protection of the Radio Astronomy Service

The operations of LEOTELCOM-5 will not cause interference to the Radio Astronomy Service, based on the studies described in section 4.5.3.4, above.

4.5.5.3 Land Earth Stations

Land earth stations, even when operating in mobile satellite service bands, should be co-ordinated under existing procedures. Accordingly, no special provisions are necessary with respect to land earth stations.

ANNEX 1 : TECHNICAL PARAMETERS USED IN SHARING STUDIES FOR CANDIDATE SYSTEMS

	LEOTELCOM-1	LEOTELCOM-2	MLMS	SAFIR 2
Orbital Parameters				
# of Satellites	48	6	2	2
Altitude (km)	825 1000 775	800	850	815
Inclination (°)	45 0 70,108	90	98.7	98.7
Orbit Planes	4 1 2	2	1	2
Satellite/plane	8 8 4	3	1	1
Right Ascension of	0,90 0	70, 160	--	--
Ascending Node (°)	0,180			
	180			
	270			
Subscriber Uplink				
Band (MHz)	148-150.05*	148.0-148.855	387.25-388.75	399.9-400.05
Tx Power (W)	5	4.9	1	3
Tx EIRP (dBW)	nominal 7	5.4 (peak)	0	max 10
Max Tx Antenna Gain	0.5 dBi, linear	0.5 dBi	--	6 dBi
Tx Antenna Pattern	Dipole	Dipole	--	--
Chn BW (kHz)	5	855	1500	1.8
Rate (kbps)	2.4/SDPSK	0.8/MSK	2.1/BPSK	0.6BPSK
Polarization	Linear	LHC	LHC or V	RHC
Sat Rx G/T (dB/K)	-26	-24.8	--	--
Max Rx Antenna Gain	0 dBi	4 dBi	--	7 dBi
Rx Antenna Pattern	10 log cos2ø	Pseudo-isoflux	--	--
max # of sim MES Tx/Sat	6	15	8	16
Subscriber Downlink				
Band (MHz)	137-138	137.0725-	400.15-401	400.6-400.9
Tx Power (W)	18.2	137.9275	2	7
Tx EIRP (dBW)	13.6	-1.9	5	max 10
Max Tx Antenna Gain	0 dBi	2.1	--	1.5 dBi
Tx Antenna Pattern	Toroidal	4 dBi	--	--
Chn BW (kHz)	15/25	Pseudo-isoflux	700	2.4
Rate (kbps)	4.8/9.6/SDPSK	855	8.4/OQPN	0.3/FSK
Polarization	RHC	4.8/MSK	LHC	RHC
Subsc. Rx G/T (dB/K)	-28.6	LHC	--	--
Max Rx Antenna Gain	0.5 dBi, linear	-21.2	--	6 dBi
Rx Antenna Pattern	10 log cos2ø	0.5 dBi	--	--
		Dipole		
Gateway Downlink				
Band (MHz)	137-138	137.0725-	400.15-401	137.175–137.275
Tx Power (W)	4.9	137.9275	2	10
Tx EIRP (dBW)	7.0 (peak)	0.9	5	8
Max Tx Antenna Gain	0 dBi	4.9	--	-1 dBi
Tx Antenna Pattern	--	4 dBi	--	--
Chn BW (kHz)	50	Pseudo-isoflux	700	30
Rate (kbps)	57.6/OQPSK	855	8/OQPN	2.4, 4.8/FSK
Polarization	RHC	0.8/MSK	LHC	RHC
Gwy Rx G/T (dB/K)	-12.8	LHC	--	--
Max Rx Antenna Gain	17 dBi, RHC	-12	--	9 dBi
Rx Antenna Pattern	--	18 dBi	--	--
		X-Yagi or Helix		

Gateway Uplink				
Band (MHz)	148.0-150.05	148.0-148.855	387 - 390	137.175–137.275
Tx Power (W)	250 (peak)	800	3	10
Tx EIRP (dBW)	40 (peak)	45	15	17
Max Tx Antenna Gain	17 dBi	18 dBi	--	9 dBi
Tx Antenna Pattern	--	X-Yagi or Helix	--	--
Chn BW (kHz)	50	50	700	30
Rate (kbps)	57.6/OQPSK	9.6/FSK	2.1/BPSK	2.4, 4.8/FSK
Polarization	RHC	LHC	LHC	RHC
Sat Rx G/T (dB/K)	-33.3	-24.8	--	--
Max Rx Antenna Gain	0 dBi, RHC	4 dBi	--	-1 dBi
Rx Antenna Pattern	Toroidal	Pseudo-isoflux	--	--

*MSS networks using dynamic channel assignment techniques, such as those described in Rec. ITU-R **M.1039**.

	LEOTELCOM-5
Orbital Parameters	
# of Satellites	48
Altitude (km)	950
Inclination (°)	50°
Orbit Planes	8
Satellite/plane	6
Right Ascension of Ascending Node (°)	0, 45, 90, 135, 180, 225, 270,315
Subscriber Uplink	
Band (MHz)	148-150.05*
Tx Power (W)	7
Tx EIRP (dBW)	8.5
Max Tx Antenna Gain	0 dBi
Tx Antenna Pattern	omni
Chn BW (kHz)	15
Rate (kbps)	9.6/OQPSK
Polarization	linear
Sat Rx G/T (dB/K)	-22.9
Max Rx Antenna Gain	-2 dBi (gain at nadir)
Rx Antenna Pattern	isoflux
max # of sim MES Tx/Sat	15
Subscriber Downlink	
Band (MHz)	137-138, 400.15-401
Tx Power (W)	25
Tx EIRP (dBW)	19.7
Max Tx Antenna Gain	-2 dBi (gain at nadir)
Tx Antenna Pattern	isoflux
Chn BW (kHz)	25 35
Rate (kbps)	24/OQPSK
Polarization	RHC
Subsc. Rx G/T (dB/K)	-30.8
Max Rx Antenna Gain	0 dBi
Rx Antenna Pattern	omni

Gateway Downlink	
Band (MHz)	400.15-401
Tx Power (W)	15
Tx EIRP (dBW)	17.5
Max Tx Antenna Gain	5.7 dBi at 15°
Tx Antenna Pattern	isoflux
Chn BW (kHz)	60
Rate (kbps)	50/OQPSK
Polarization	RHC
Gwy Rx G/T (dB/K)	-9.9
Max Rx Antenna Gain	16 dBi
Rx Antenna Pattern	directional
Gateway Uplink	
Band (MHz)	148-150.05
Tx Power (W)	Up to 150
Max Tx EIRP (dBW)	39.8
Max Tx Antenna Gain	18 dBi
Tx Antenna Pattern	directional
Chn BW (kHz)	50
Rate (kbps)	50/OQPSK
Polarization	RHC
Sat Rx G/T (dB/K)	-22.9
Max Rx Antenna Gain	5.7 dBi at 15°
Rx Antenna Pattern	isoflux

*MSS network using dynamic channel assignment techniques, such as those described in Rec. ITU-R **M.1039**.

ANNEX 2 : LEOTELCOM-1/ORBCOMM SYSTEM

1 LEOTELCOM-1/ORBCOMM SYSTEM DESCRIPTION

The LEOTELCOM-1 System, named ORBCOMM, is a wide area, packet switched, two-way data communication system. Communications to and from Mobile Earth stations (MESs) and Gateway Earth stations (GESs) are accomplished through a constellation of low-Earth orbit (LEO) satellites. LEOTELCOM-1Gateways are connected to dial-up circuits, private dedicated lines or the Internet.

The LEOTELCOM-1 System consists of a Network Control Center (NCC) that manages the overall system worldwide and three operational segments:

- A space segment consisting of 48 LEO Satellites;
- A ground segment consisting of GESs and control centers located throughout the world; and
- A subscriber segment consisting of MESs used by LEOTELCOM-1 System subscribers to transmit and receive information to and from the LEO Satellites.

RF communication within the LEOTELCOM-1 System operates in the very high frequency (VHF) portion of the frequency spectrum between 137 and 150 MHz. The LEOTELCOM-1 Satellites have a subscriber transmitter that provides a continuous 4800 or 9600 bps stream of packet data. Each Satellite also has multiple subscriber receivers that receive short bursts from the MESs at 2400 bps. The ORBCOMM System is capable of providing near real-time wireless data communications service around the world.

All communications within the LEOTELCOM-1 System must pass through a Gateway. A LEOTELCOM-1 Gateway consists of one Gateway Control Center (GCC)—the facility that houses the computer hardware and software that manages and monitors message traffic—and a GES. The GES provides the link between the Satellite constellation and an ORBCOMM GCC.

EXAMPLE: A typical messaging scenario will proceed, as shown in the following sequence, illustrated in Figure 1:

1. A LEOTELCOM-1 System subscriber enters a message in a subscriber communicator (an MES).
2. The MES transmits the message to the Satellite that receives, demodulates, reformats and retransmits the message to a GES.
3. The GES receives the message and sends it to a GCC over a dedicated connection.
4. The GCC re-sends it to its final destination using the access method (Dedicated access, dial-up access, e-mail, etc.) chosen by the subscriber.
5. The message is received at its destination.

A message from the home base to the subscriber follows the reverse route: Home base to the GCC, GCC to GES, GES to Satellite, and finally Satellite to the MES and user display. Even “direct” subscriber-to-subscriber transmissions must pass through an ORBCOMM Gateway.

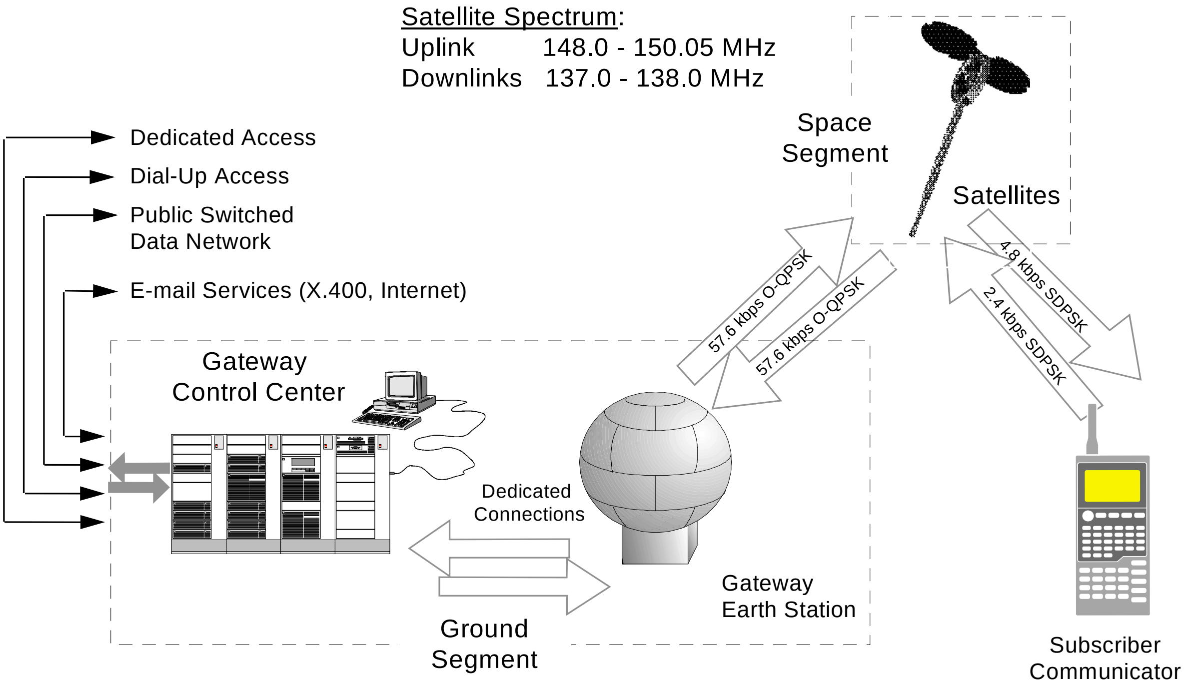

Figure 1 - ORBCOMM System Overview

2 LEOTELCOM-1 RF COMPATIBILITY TECHNIQUES

The 148.0 - 149.9 MHz band is heavily used by terrestrial systems. In order to operate, the LEOTELCOM-1 system must scan and identify channels within this band that are not being actively used during the 5 second scan duration. LEOTELCOM-1 has developed a Dynamic Channel Activity Assignment System (DCAAS) to identify channels being actively used by terrestrial services and to avoid those channels.

There is no way known for an FDMA system such as LEOTELCOM-1 to operate in the 148 - 149.9 MHz band without some scheme, such as DCAAS. Any attempt to receive on a channel being actively used by a terrestrial transmitter would result in interference to the satellite and the loss of MSS data.

The overall sharing approach used by LEOTELCOM-1 consists of four aspects:

- The DCAAS system avoids assigning active Mobile channels (eirp toward the satellite > 0.1 W in 3 kHz) to MESs for uplink transmissions. The system scans the frequency band for inactive channels approximately every 5 seconds. The DCAAS system will not permit the MESs to transmit if there are no inactive channels available.
- Should the DCAAS system inadvertently assign an active channel, there is a very low probability that a transmitting MES is sufficiently near to a receiving mobile unit to be detected.
- The short burst duration of LEOTELCOM-1 MES transmissions further minimizes any interference effects.
- The structure of the MES message transmission session is such that even if interference does occur, it will not continue or re-occur.

More detailed descriptions of each of these aspects of LEOTELCOM-1's approach to interference avoidance are provided in the following sections. Each section is followed by sub-sections that summarize the results of analyses or tests that validate each aspect of the overall approach.

3 DCAAS

The first level of the LEOTELCOM-1 uplink interference avoidance approach is the Dynamic Channel Activity Assignment System (DCAAS), which consists of a receiver and processing unit on the satellites. DCAAS scans the MES uplink band for terrestrial transmissions in 2.5 kHz intervals, identifies channels which are not in use and assigns these channels for uplink use by the MESs. The objective is to avoid interfering with terrestrial receivers preventing MES transmissions on active mobile channels.
It is important to note that:

- A LEOTELCOM-1 MES can transmit only if it receives a downlink signal from the LEOTELCOM-1 satellite telling it which uplink channels may be used.
- If the DCAAS system cannot find an inactive channel at a particular point in time, DCAAS will not permit the MESs to transmit.

In addition to scanning for inactive channels, the DCAAS processor predicts which of the available channels are most likely to be available for the next 5 seconds.

Figure 2 is a graphical representation of the various factors that affect the channel selection and implementation process described below.

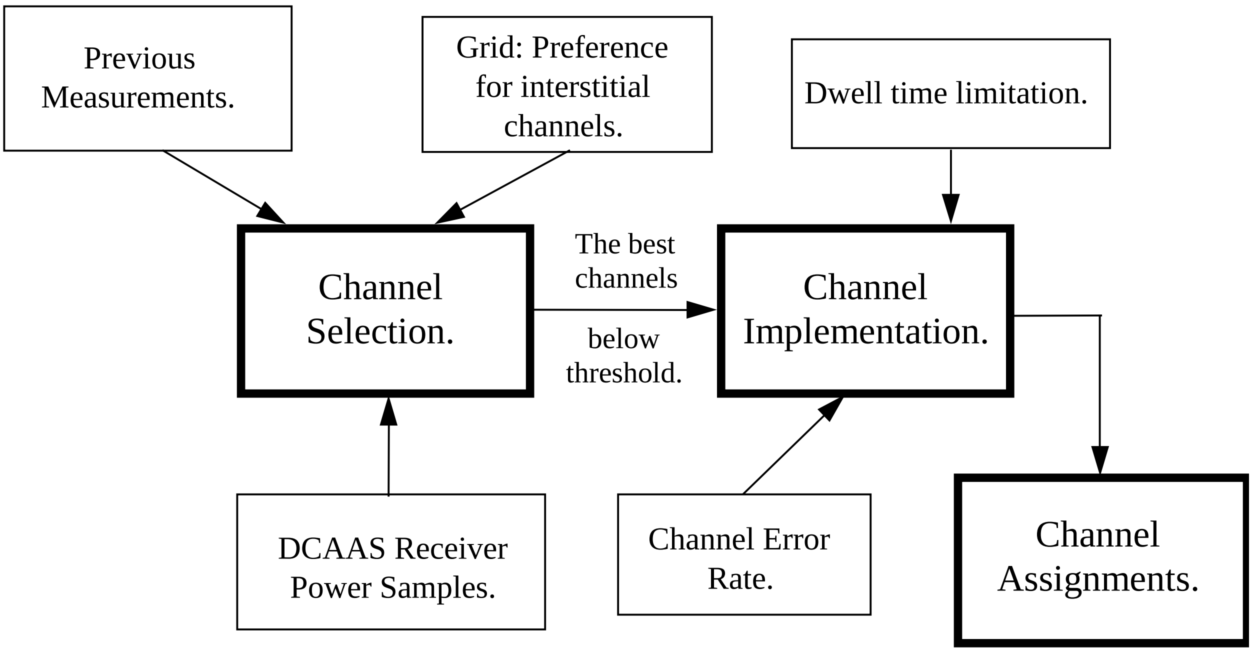

Figure 2 - DCAAS Operation

Channel Selection

There are three inputs to the algorithm that identify the preferred channels available on each scan:

1. **Power Sampling.** The first selection criterion involves power sampling. One satellite receiver operates in DCAAS mode and scans all channels in the selected operating range. Channels for which the power samples fall below a specific threshold are declared to be potentially available. The power sample threshold determination is a strict decision and thus carries the highest weight of the channel selection criteria.
2. **Grid Preference.** The second channel selection criteria is referred to as the grid preference. Around the world there are many wireless systems (including paging and cellular systems) which are assigned channels on several channelization plans or grids. The LEOTELCOM-1 System is designed to give preference to channels spaced midway between these standard terrestrial emitters. This preference carries more weight in the channel selection algorithm than the quality factor, but less than the hard threshold decision.
3. **Quality Factor.** The third channel selection criteria considers power sample measurements made over the previous 5 seconds and is referred to as the quality factor. The quality factor is a measure of the current and past power levels of the channel, as determined by an LEOTELCOM-1 proprietary algorithm.

Once all factors are taken into account, the preferred channels are selected from the available channels and passed to the channel implementation portion of the algorithm.

Channel Implementation

Once the channel selection process determines the preferred channel frequencies, the channel implementation process assigns these channels for random access (acquire/communicate transmissions) and reservation channel (messaging transmissions) use. The remaining channels go into a reserve pool. The reserve pool is used if a channel dwell-limiting timer expires for the random access receivers, or if the performance measurement thresholds (error rates) are exceeded.

Four conditions regulate channel switching for the satellite receivers:

1) exceeding the error rate threshold of a random access receiver;

2) exceeding the error rate threshold of a reservation receiver;

3) channel selection process using new DCAAS scan data shows power level exceeding the quality factor threshold on the currently assigned channel; and

4) expiration of the channel dwell limiting timer.

Under normal conditions of moderate to heavy traffic loading, the satellite will change the uplink channel to a different frequency in about 1-2 seconds if the bit error rate threshold on that channel is exceeded. Under light traffic loading conditions, there may be insufficient uplink signals to evaluate the bit error rate, and so the channel frequency will not be changed until the next DCAAS scan is completed, in a maximum of about 5 seconds plus a short processing time. During this time, however, there will be very few MES transmissions because the situation can only occur under very light traffic loading conditions.

As can be seen, DCAAS uses the data from the current scan to identify channels which appear to be inactive, then combining the information from the current scan with information from previous scans, makes a prediction as to which of these available channels are likely to remain inactive.

Probability of DCAAS assigning an active channel

In some cases, the DCAAS receiver on the LEOTELCOM-1 satellite may not be able to see terrestrial mobile transmitters due to an obstruction, such as a building, along the Earth-to-space path between the mobile transmitter and the LEOTELCOM-1 satellite, or ground reflection losses for the terrestrial mobile. In addition, the DCAAS monitoring system may not detect short burst low duty cycle terrestrial data traffic. In this case, the DCAAS receiver might not sense the mobile transmitter, and therefore might assign that active channel to an MES transmitter.

The probability of this occurring will vary depending on location and local topography. Att. 20 of WP8D/200 estimates a value for this probability of obstruction at 20%, based on the rate of service inability for cellular phones in Japan. This would seem to be an upper bound on the probability since it applies to a terrestrial path, while the Earth-to-space path between the Mobile transmitter and the LEOTELCOM-1 satellite would have a minimum elevation angle of 5º.

Additional factors reduce the probability of DCAAS assigning an active channel, but are difficult to quantify. These include the following:

- If the frequency band is heavily used by the terrestrial mobile services employing frequency re-use, there is a high probability that a second mobile transmitter visible to the LEOTELCOM-1 satellite is also using that same channel, thereby preventing DCAAS from assigning that channel.
- If the Earth-to-space path from a mobile transmitter to an LEOTELCOM-1 satellite is blocked, there is a certain probability that the terrestrial path between the MES and the mobile receiver is also blocked. It can be expected that in areas where the probability of blockage on the Earth-to-space pass is highest, the probability of blockage on the terrestrial path is also high.
- Also, if the Earth-to-space path from a mobile transmitter to an LEOTELCOM-1 satellite is blocked, there is higher probability that the MES is also blocked from the satellite, reducing the probability that an MES could be transmitting in that area.
- The predictive algorithm in the DCAAS processor will evaluate the probability that its available channels will remain interference free until the next scan is complete. This takes into account data from recent scans, so that a channel used by a terrestrial Mobile transmitter that suddenly vanishes behind an obstruction will probably not be assigned for use if other channels are available.

Taking into account all of these factors to obtain a single probability for DCAAS assigning an active channel would be an extremely difficult task, and the probability would change from one geographic area to another and with the level of frequency re-use by the terrestrial services. LEOTELCOM-1 estimates the probability of DCAAS assigning an active channel to be considerably lower than the upper bound Japanese estimate.

DCAAS TESTS

Tests performed independently by the German administration have verified that the initial two LEOTELCOM-1 satellites were able to detect and avoid terrestrial transmitters with an eirp lower than 0.1 W (Document SE28(97)66, section 6.c).

4 LEOTELCOM-1 DATA SESSION

The structure of an LEOTELCOM-1 data session will also tend to reduce interference. Once power is applied, the MES automatically searches through an internally stored list of downlink channels. If the MES has not locked on to a satellite signal since power was applied and there is no satellite signal at any of the stored channels, a search of all possible channels in the 137 to 138 MHz band is conducted.

Once a satellite signal is found it must be received continuously for 2 seconds to begin a data transfer session. During this time, the MES receives the necessary control information. which includes the timing, the LEOTELCOM-1 Gateways connected to the Satellite, and the current uplink random access channels. *The MES must receive this information before it can transmit data to the Satellite.*

Figure 3 is a graphical representation of the data session process, which is described below.

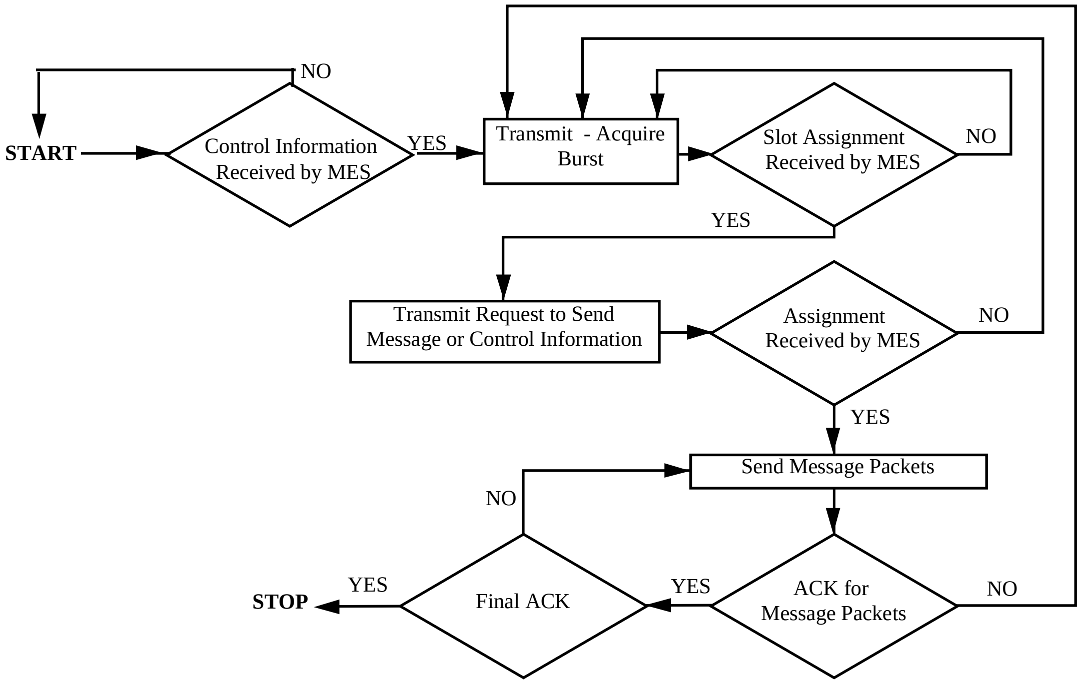

Figure 3 – MES Data Transfer Session Flowchart

Acquire/Communicate Burst Process

If the MES has a message to send, the MES-Originated data transfer session begins with a data transfer setup process called Acquire/Communicate. The MES first transmits an ultra-short acquire burst to initiate the data transfer setup process. The transmission frequency of the burst is randomly chosen from the list of available uplink random access channels provided by the satellite. This list of available channels changes frequently according to the DCAAS process.

The satellite will receive the acquire burst correctly if there is no interference and no time-overlapping bursts on the same receive channel within the 5 000 km diameter Satellite footprint. Reception of the acquire burst by the satellite initiates a proprietary communications protocol/handshake between the satellite and the MES.

The acquire/communicate burst process can include either the transfer of a data report, which contains six bytes of user defined data, or a request to send a larger amount of data (referred to as a „Message Request“) and is, in total, less than 60 ms of transmit time.

As shown in Figure 3, whenever a longer burst is unsuccessful for any reason, the acquire burst is the *next* burst from the MES. This helps avoid harmful interference to a nearby terrestrial user.

Sending Message Packets

Following a successful Message Request from an MES, the satellite responds with an assignment containing a time slot, an uplink frequency channel and the length of the first packets to be transmitted. The time slots and channels are selected by the satellite, which is also frequency hopping its receivers. The channels used for sending message packets are different than those used for random access, and can differ from packet to packet.

Following an MES message burst, the satellite sends an acknowledgment that also, if necessary, contains an assignment to send the next packet. This process continues until the message is completely and successfully transferred from the MES to the GSS. A long message may require multiple message burst transmissions.

ANNEX 3 : LEOTELCOM-2/E-SAT SYSTEM OVERVIEW

1 PURPOSE

The purpose of the E-SAT system, notified under the name of LEOTELCOM-2, is to provide low cost Little LEO satellite communications services to customers world-wide. The E-SAT System is used to transfer data from industrial data acquisition equipment in fixed geographical locations that do not require real time messaging.

Typical target applications for E-SAT messaging services are:

- Electric, Gas Meters.
- Pipeline Meters.
- Buried Fuel - Leak Detection.
- Propane/Butane Storage Meters.
- Vending Machine Monitoring.
- Engine Unit Monitoring.
- Environmental and Agricultural Monitoring.
- Road Traffic Monitoring.

2 PRINCIPLES

The E-SAT communication system provides non-real time two-way communications between a central “user access segment” and numerous remote “fixed assets”. The communication traffic is mostly dedicated to collecting data stored in the applications “mailboxes” and secondarily to commands or unscheduled communications.

The system space segment includes a controlled constellation of 6 satellites in low polar orbit, connected to the ground segment by VHF links, defined by the E-SAT FCC license.

The satellite repeaters operate in a “ store and forward ” mode, with a variable storage time between reception and transmission, since earth stations are not located in the service areas, allowing use of the same VHF bands for service and feeder.

Transmission links overview

3.1 General

The “ service links ” are the RF interface between satellites and terminals.

The “ feeder links ” are the RF interface between satellites and gateway stations.

The “ Inbound link” connects the terminal to the gateway through the satellite “ transparent inbound repeater ” and associated “ signal storage memory ”.

The “ Outbound link” connects the gateway to the terminals, through the satellite “ regenerative outbound repeater ” and associated “ data storage memory ”.

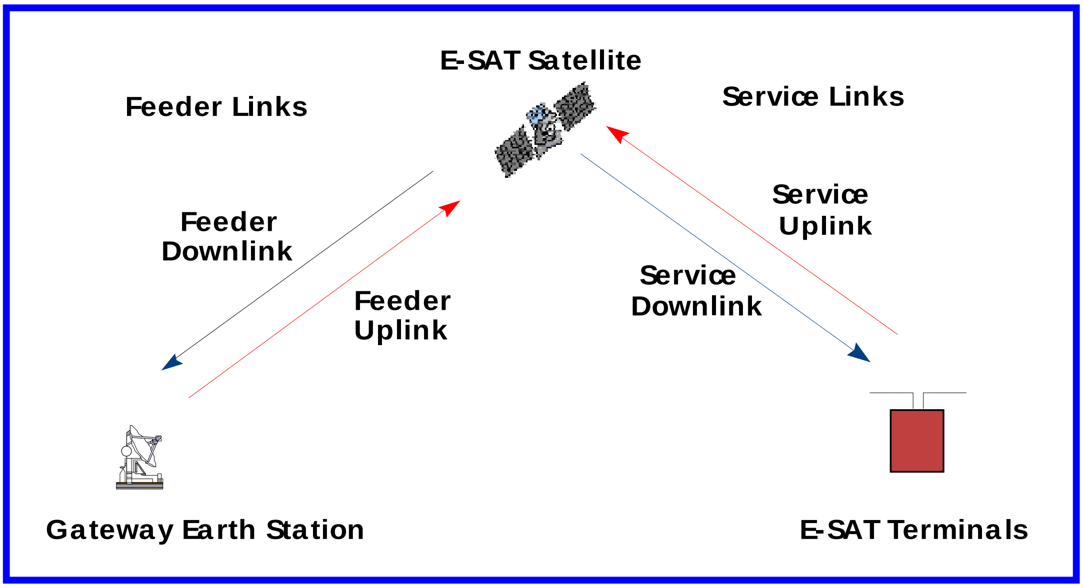

Figure 4: System links

3.2 Frequency plan

The VHF channels are defined as:

- Wide up-link: 148 -148.855 MHz.

  The VHF wide-band up-link channel allocation is used as inbound service up-link for terminals.

- Narrow up-link: 148.855-148.905 MHz.

  The VHF narrow band up-link channel allocation is used for the Telecommand channel and outbound feeder uplink.

- Down-link: 137.0725-137.9275 MHz.

  The VHF wide-band down-link channel is used either as service down-link for terminal command and polling, as inbound feeder down-link to gateways, and telemetry link for the satellite control.

3.3 Interferers handling

The E-SAT uplink band is shared with PMR (land mobile services) and pagers, characterised as narrow band (10 to 50 kHz) transmissions with medium to high power.

The inbound repeater, due to this band sharing and jamming environment, includes a spectrum processing circuit able to suppress a maximum of narrow band signals, while minimising distortion of the E-SAT signals: this system is known as a “ frequency domain adaptive filtering ” or FDAF.

3.4 Multiple Access principle

The terminals transmits short 450msec bursts containing 36 Bytes of user’s data, together with synchronisation and error detection and correcting codes, in DS-SSMA. A unique spreading code is used for all terminals, and multiple access separation is done by natural time de-correlation.

The inbound up-link bursts from the terminal are synchronised with the downlink, and triggered either by recognition of individual or generic polling in the outbound downlink.

4 E-SAT AIR INTERFACE

4.1 Terminal polling link format

The outbound downlink link is a continuous stream during visibility of a service area, in a TDM multiplex mode, providing synchronisation, system and messaging data to the terminals. The outbound is filled up with interrogation slots, grouped in frames. Each frame holds general system data too, including satellite orbital data, and provides frequency reference and synchronisation.

Terminals have a « unique address » for individual addressing and a « generic address » for multicast addressing.

Modulation and coding characteristics :

- Useful data rate (bits): 4,8 Kb/s
- Modulation in BPSK of the spreading code
- Spreading chips modulating the carrier in MSK

4.2 Terminal uplink data format

The space jamming environment is a key limiting factor in the uplink capacity, the number of simultaneous bursts is thus trimmed to different limits according with areas and time.

The number of ET's messages in each slot is defined by the polling protocol generated in the communication center from the environment knowledge and simulation results.

The terminal up-link burst contains:

- Synchronisation unique word of 8 uncoded symbols.
- System data: ET identifier and parameters, including dating of message.
- User's data: 36 Bytes.

Modulation and coding characteristics :

Inbound signals are burst transmission of about 450ms without dead time between successive bursts. They are transmitted in a DS-SSMA mode.

- useful data rate 800 b/s
- modulation in BPSK of the spreading code by the symbols
- SSMA spreading chips modulating the carrier in MSK

5 CONSTELLATION AND COVERAGE

The E-SAT constellation is designed to allow multiple launch, optimal store and forward mission, and easy visibility management by the terminals.
This polar constellation provides a basic store and forward mission time of one orbit (about 90mn) with a polar or quasi polar gateway.
Orbit control is needed to avoid multivisibility between satellite and terminals or gateways, which will result in mission degradation.

6 SATELLITE DESIGN

The E-SAT satellites have the following characteristics :

- About 130 kg overall mass
- Power system includes fixed body mounted solar panels, and a NiCd storage system.
- Attitude control (ACS) combines gravity gradient coarse stabilisation, improved by magnetotorquers, to provide an earth pointed antenna pattern, using a proven design from Uosat.
- Orbit control (OCS) for orbit phasing and station keeping uses cold gas , with on-board software for thrust control.
- The payload antenna is a quadrifilar helix approximately 1 m length.

7 STATIONS OVERVIEW

The E-SAT system includes initially two ground stations for operation :
A TTC station in Guildford (UK) handles all communications for satellite command and control, and is connected to the colocated Satellite control center.
A Gateway station in Spitzbergen (Norway) handles all mission feeder links to the ESAT satellite payloads. The constellation design and favorable northern location of the Gateway allows communications with each satellite at each orbit.
In case of satellite critical operation phases (LEOP or emergency) the Spitzbergen station can provide partial or full time TTC links.

8 TERMINAL OVERVIEW

The E-SAT system design aims at reducing the cost of the basic E-SAT terminal to allow consumer market applications of meter data gathering.
E-SAT terminals can be installed either with integrated antennas inside the applications, as well as external roof or pole mounted antennas.
Modular design allows development of various applications from the same « core engine » chip set, including various options of powering (line or battery).
Specific software is included in the terminal design to satisfy FCC, CEPT and ETSI rules, such as burst duty ratio, maximum EIRP, etc.

ANNEX 4 : MLMS SYSTEM OVERVIEW

1 INTRODUCTION

This document provides an overview of the MLMS system and is intended to give the reader an overall understanding of the system's features. Specific attention will be given to its communication system.

2 SYSTEM OBJECTIVE

The MLMS system aims to provide low cost non-real-time data services to areas deprived of terrestrial infrastructure.

Distinguishing the MLMS system further is best done by highlighting some of the specific characteristics that set it apart it from systems with similar objectives.

- ☑ The MLMS service targets customers with headquarters in regions well served by landline networks, but conducting operations or having assets in remote areas.
- ☑ The primary MLMS applications are person-to-person messaging, e-mail and file transfers. Non- real-time remote monitoring is a secondary application and position determination is a value-added service.
- ☑ MLMS will satisfy a frequently expressed demand for long messages (in the Kbyte range), as well as short 'telegrams'.
- ☑ MLMS uses DS-SS in all communication links, with CDMA in the service uplink.
- ☑ The full service can already be provided using a single spacecraft.

3 SYSTEM ARCHITECTURE

The MLMS system architecture is depicted in Figure 5

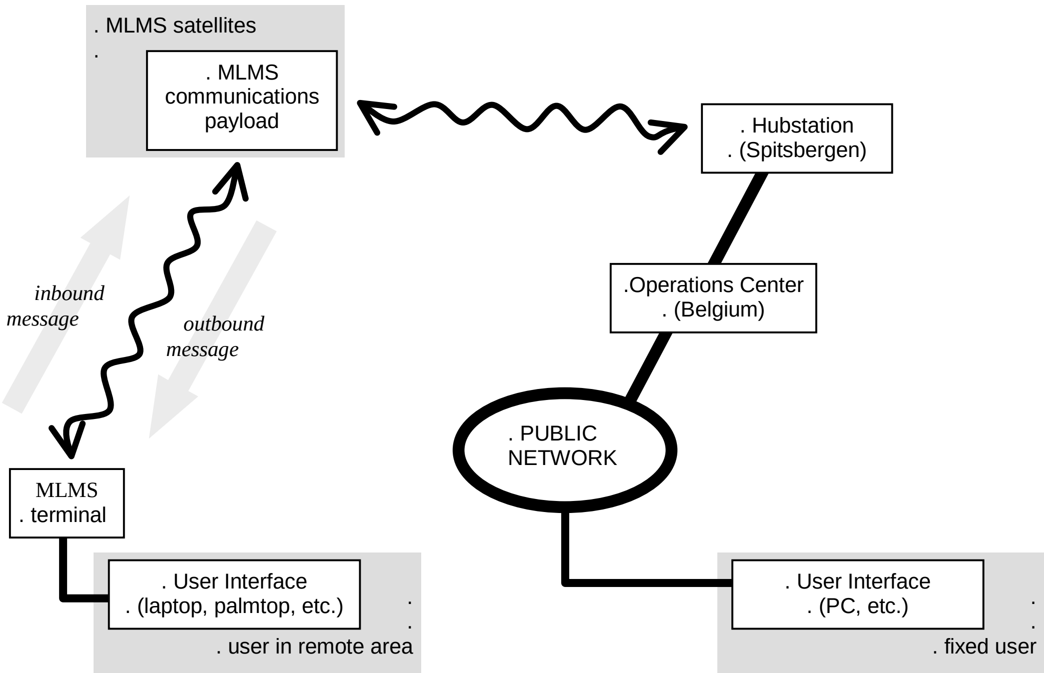

Figure 5: MLMS system architecture

MLMS uses a baseline of two **satellites** in near-polar orbit, each carrying a **communications payload**. Due to the rotation of the Earth, each satellite will see any point on Earth at least twice a day, regions at higher latitudes seeing the spacecraft more often (at 50° latitude, nine passages are generally usable). As a satellite flies over a user in a remote area, it collects the *inbound messages* stored on their **MLMS terminal**, and acknowledges their storage on-board. When the satellite comes in view of the **hubstation**, it beams the messages down for distribution to the **'fixed user'** via **public networks**. In the other direction, the **hubstation** uploads the satellites with *outbound messages* identified for all the terminals it will be in contact with during its next orbit.

The system offers fixed users landline access using Internet E-mail connection to the **Operations Center**. In practice fixed users will have personal computers on their premises allowing them to send and receive messages as well as display the position of their terminals on a map. The standard short message is 150 Bytes in length, but nothing precludes MLMS from handling messages in the kByte range in both directions. Once an *inbound message* is embarked on-board the satellite, its delivery to the **fixed user** occurs within one orbit, or less than two hours (aside from the Internet). Satellite waiting times can extend to 12 hours at most.

The baseline two-satellite MLMS system will be capable of ferrying 10.000 1kByte pages per day in the inbound direction, and 17.000 in the outbound direction. Its main efficiency lies, however, in the performance of its random access scheme to the spacecraft. This is a consequence of the spread-spectrum techniques used in the communications links.

3.1 Space segment

Using a single satellite orbiting the Earth in polar or near-polar orbit, it is already possible to offer global messaging. As the Earth rotates, any point on the Earth's surface will eventually come into view of the satellite at least twice a day for 5 to 15 minutes. The baseline MLMS system will operate with two satellites. This provides minimum in-orbit redundancy and satisfies the capacity requirements of the initial business plan. More satellites yield higher capacity, redundancy, and -if placed in an appropriate 'constellation'- enhanced service times. However, MLMS does not aim to provide shorter service times, it will basically remain a daily global mail service.

For a first communications platform in orbit, the ‘Attached Payload’ approach was selected. This is simply a set of electronic boxes fastened onto a main passenger spacecraft. The Attached Payload fulfills all the communications functions required by the system, while benefiting from the main spacecraft's power resources and attitude control. It constitutes a low-cost, low-lead-time way of demonstrating the essence of the mission.

To enjoy more launch flexibility, the second spacecraft will be developed as a fully autonomous Free-Flyer with solar generator and attitude control. This 65 kg-class microsatellite uses passive (gravity-gradient) as the main stabilization mechanism.

3.2 Ground segment

The Ground Segment is comprised of a TTC Ground Segment for Telemetry and Control, and a mission Ground Segment. This last is the landline tail ultimately linking the Fixed Users to the system, and managing their subscriptions and messaging activities.

3.2.1 The TTC ground segment

A 2.4 m dish is installed at SAIT-Devlonics, Kortrijk, Belgium to support the S-band tele-command and telemetry operations.

3.2.2 The mission ground segment

The MLMS mission ground segment is the core of the MLMS system. It allows communication between Fixed Users, connected to an X.400 network or the Internet on one hand, and Subscribers who submit their messages to the MLMS subscriber terminals on the other hand. The MLMS mission ground segment is the gateway between an electronic mail standard (Internet Mail) and an MLMS-specific electronic mail protocol.

The following processing entities or functional units are part of the MLMS mission Ground Segment. They control the transfer of messages and their conversion through the MLMS ground station.

The MLMS Access Unit serves as a bridge between the Internet Mail, and the MLMS messaging system. The Access Unit is composed of an Internet Server, an Internet and an internal Gateway module. The Gateway module converts messages between the Internet standard in the internal MLMS one.

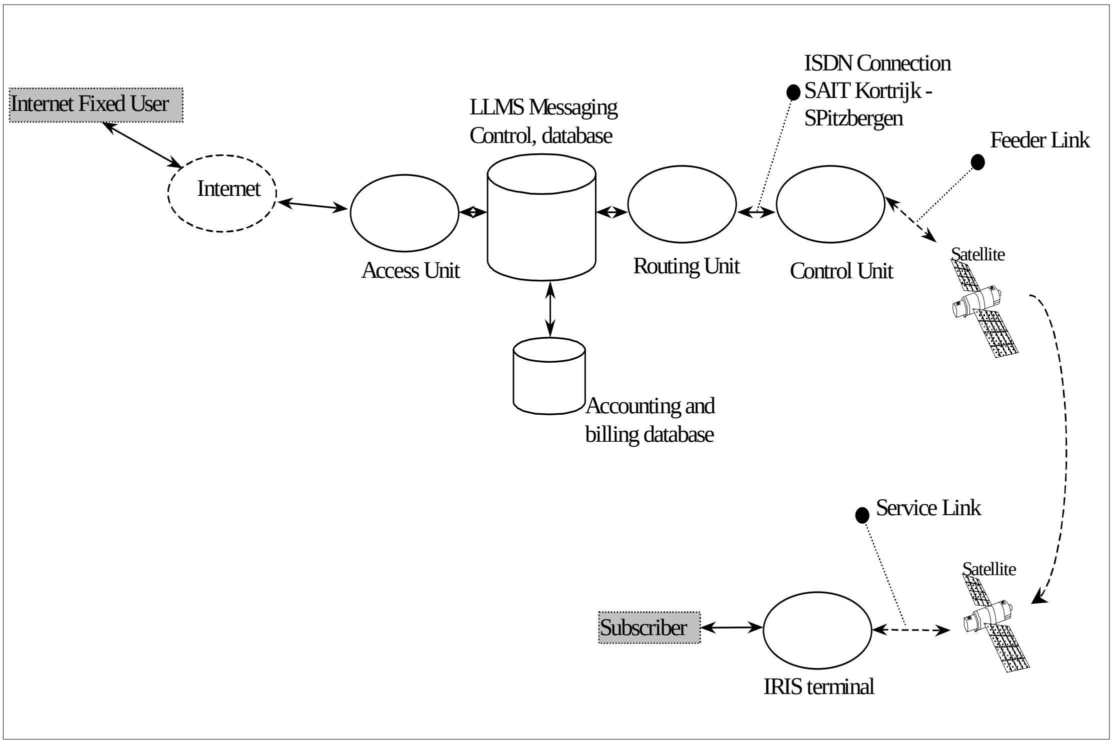

Figure 6: The detailed MLMS system architecture

The **Messaging Control** is the key unit within the mission Ground Segment. It controls the access to the MLMS system, has knowledge of all MLMS users and MLMS terminal properties. It keeps track of which user is registered on which terminal, it keeps track of the terminal positions, it keeps tracks of all messaging activity. It controls all MLMS users access rights. The messaging control is connected to a billing system to perform invoicing.

The main function of the **Routing Unit** is to select a satellite passage for sending a message to a MLMS terminal according to the message arrival time, priority, expiry time, and message type. The Routing Unit calculates, for each forward message, in which passage it should be uploaded to the satellite and at which time it is estimated the terminal will be visible for the satellite and therefore the time at which the satellite should try the message transmission. For return messages coming from the Satellite and Control Unit, the Routing Unit calculates the terminal position from the satellite communication parameters.

The **Control Unit** accesses the Satellite using the Feeder Link Modems and Antenna system to upload and download messages in bulk to/from the Satellite.

All the different modules mentioned above communicate with each other using sockets (TCP/IP), permitting the modules to work on different sites. Different sockets are using for the incoming and the outgoing communication direction. The Access Unit, Messaging Control and Routing Unit are physically located at SAIT-Devlonics in Kortrijk, Belgium. The Control Unit is situated at 78° northern latitude atop the Platoberget mountain near the town of Longyearbyen, Svalbard, where the Norwegian Space Centre maintains a satellite communications site. The location was selected because its high latitude affords visibility during each of the 14 daily orbits of the satellite. The Routing Unit and Control Unit communicate using sockets via an ISDN BA communications line.

3.3 User terminal

The terminal for a Little LEO store-and-forward messaging system does not need to have the hand-held aspect and size of a vocal personal communicator. In most applications, it will be used in fixed -though easily changeable- sites rather than truly mobile ones. For example, it is less important for the antenna to be built into the terminal than to be able to connect an external antenna affording better satellite visibility. The user terminal is an intelligent 'Load and Forget' satellite modem, meaning that once the message is loaded into it, it will automatically handle all transactions with the satellite when it passes over. Figure shows the terminal connected to a personal organiser and to a quarter-wave ground-plane antenna.

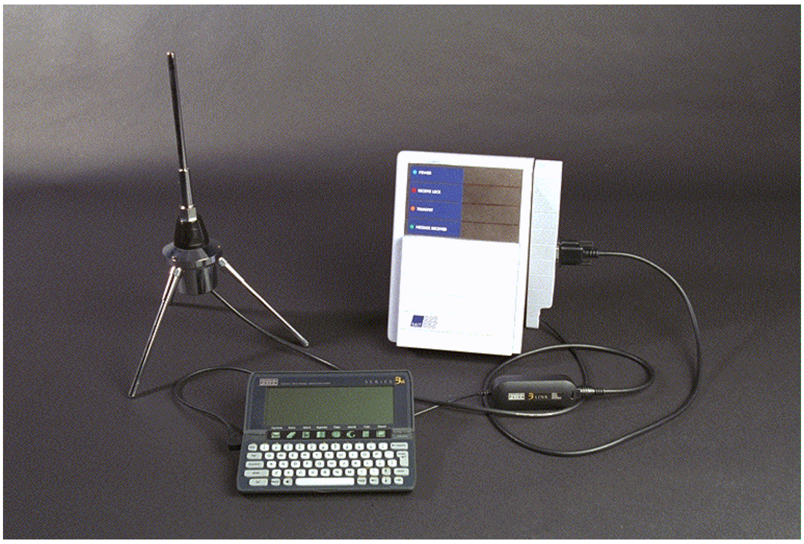

Figure 7: MLMS User Terminal

TRANSMISSION 1200 bits/s user data rate Tx Power typ. 0.4W @ 388 MHz (BPN - BW =1.5 MHz) RECEPTION 4800 bits/s user data rate 400.6 MHz (OQPN - BW =790 kHz) STANDARD INTERFACES 1 standard RS-232 +1 RS-232 opto-isolated/NMEA 183 General-Purpose I/O 4 indicator LEDs DC Adapter Antenna connector (BNC)	ANTENNA Drooped-Dipole 'Harpoon' antenna (LHCP) or Quarter-Wave 'Ground-Plane' antenna BATTERIES 6 x UM-3 NiCd, Alcaline, NiMH External charging only AUTONOMY 5 hours continuous receive / 100 hours standby PHYSICAL Dimensions 200 x 150 x 50 mm Weight < 1kg without batteries TEMPERATURE RANGE 0 to 50°C or -20 to +70°C

Table 1: Main terminal characteristics

4 COMMUNICATION SYSTEM

4.1 The use of spread spectrum

A fundamental technical property of the MLMS system is the use of spread-spectrum in both the up- and downlink.

Direct-sequence spread-spectrum is especially advantageous as the access technique in the **uplink**, i.e. with CDMA as the means for ground-based terminals to access the satellite, using a single spreading code.

The centrally interesting feature of CDMA is that, when two (or more) messages sent by terminals arrive in quasi-simultaneity at the satellite, one of the messages has a high probability of getting through. This tolerance to collisions enables true random access at a single frequency without the need for transmitting terminals to be polled or having to sense activity by another terminal. It also makes CDMA superior to other schemes because it is less sensitive to system congestion through access retries.

To eliminate this last risk completely, the satellite will use the downlink to collectively instruct the terminals on the repetition period of their calls. It can be shown that there is an optimum calling rate, as seen by the satellite, which will maximize the probability that users will get their message uploaded. By using this adaptive control, the satellite can actively maintain traffic at the point of optimal efficiency, avoiding system congestion due to destructive collision of messages (which has a residual probability even in CDMA) and self-noise. This traffic control is also extremely important from the viewpoint of **reducing interference to other systems,** by limiting access attempts to the strict minimum.

The spread spectrum-system nature of the links also provides for a convenient intra-system localisation. MLMS uses a combined Doppler and ranging method to determine the position of its terminals.

4.2 Access protocol

The above features are highly instrumental in keeping the overall access protocol simple: once locked onto the downlink's carrier and timing references, terminals having a message to transmit do so.

For short messages (132 Bytes, lasting about 1 second), a terminal will make random access attempts to the spacecraft until the message gets through. The attempts are random (no polling of the terminals), however they are performed in timing slots and with call intervals collectively imposed by the satellite via the downlink. In this manner, adaptive control of the calling rate seen by the satellite is obtained. This ensures that the satellite always operates its three on-board receivers in an optimum way. This marshalling of access attempts also reduces the interference by terminals to other systems. Under fully loaded conditions it is expected that a terminal might need three access attempts to get a short message through. The minimum time between two trials is fixed by SE28's operational constraints to 30 seconds.
For longer messages, in the Kbytes range, a random access scheme is not practicable. The terminal will first make a channel request by means of a short message as just explained. The spacecraft will then allocate to the terminal one of its three receivers for the long message itself. Normally we assume that on average 3 trials are necessary (in a fully loaded system) in order to be assigned one of the three satellite receivers. Once a satellite receiver is assigned, the terminal can transmit long messages in following sequence transmit 8 seconds (1.5 Kbytes) followed by a silence of 45 seconds. The system can accept operating constraints such that the terminal transmits a maximum of three 8-second bursts in a passage. This protocol is presented in the figure below.

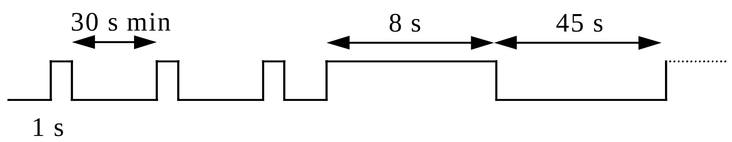

Figure 8: Long messages protocol

4.3 Communication links characteristics

For all the links, the data are grouped in slots. Different slot sizes are used for the different kind of transmission (Feeder down-link: 243 bytes, Feeder up-link: 243 bytes, Service down-link: 75bytes, Service up-link: 75 bytes for LONG and SHORT formats). These data are successively encoded by a Reed-Solomon encoder and a convolutional encoder. All the transmissions are modulated using DS-SS (Direct Sequence, Spread-Spectrum). Each transmitted bit is spread using a sequence of chips of length 'L'. The chip rate 'fchip' is chosen for the up-links equal to 70 MHz/65 and 70 MHz/130 for the downlinks. The spreading length 'L' is chosen to match the required bit rate.

The service downlink is used to reach the terminals with dedicated or broadcast-type messages. It has a single channel with a 4,800 bits/s user data rate organised as a time-domain multiplex. In this direction, the modulation is Offset-Quadrature Pseudo Noise (O-QPN) with 2 bits per symbol. With careful implementation, this spectrally efficient technique allows power-efficient class-C amplifiers to be used on-board the spacecraft while keeping out-of-band emissions low. This is important to protect nearby Radioastronomy Service bands. (see [Delogne & Van Himbeek (1)])

The feeder up- and downlinks operate at the same centre frequency as their corresponding service links. The data rate is increased to values allowing the up/downloading of the spacecraft's on-board message store. The spreading code is reduced accordingly, so that the spectral occupancy is the same as for the corresponding service link. The link budget is restored by the use of high-gain tracking antennas at the hubstation. In both directions, the modulation is O-QPN with 6 bits per symbol.

Table 2 summarises the characteristics of the various communication links.

	Service Downlink	**Service Uplink**	**Feeder Downlink**	**Feeder Uplink**
Centre Frequency (MHz)	400.6	388.0	400.6	388.0
Useful Data Rate (bits/s)	4709	1177	71112	71112
Bit rates (bits/s)	8413	2103	16827	16827
Channels	1	3 or 8 *	1	1
Code Length (chips)	128	512	32	64
Chip Rate (kchips/s)	538	1,077	538	1,077
Modulation	O-QPN	BPSK	O-QPN	O-QPN
	769	1,540	769	1,540

* Following the satellite generation

Table 2: Communication links characteristics

4.4 Payload architecture

4.4.1 Attached Payload

The message storage and retrieval functions are handled by a redundant OBC architecture with 5 MB message store.

The transmit section is a fairly straightforward chain of baseband modulation and up-conversion.

The most critical part is the three-channel spread-spectrum receiver. For the reception of short, random access messages, a Fast Acquisition Unit performs rejection of discrete in-band jammers, down-conversion of the filtered output to baseband, and correlation to the single code access code used. This unit is capable of discriminating access attempts emanating from several terminals. It continuously monitors the number of access attempt it sees, enabling the implementation of the adaptive control scheme mentioned previously. When the Acquisition Unit has locked onto a terminal's signal, it hands over the parameters of the corresponding correlation peak to one of three Tracking Units. These perform the actual despreading and demodulation. For long messages, a Tracking Unit -which is in fact a full spread-spectrum receiver in its own right- is dedicated to the special code used for that communication, by-passing the Acquisition Unit entirely. The total average orbital power consumption of the Attached Payload is about 67W.

4.4.2 Free flyer

With the free flyer, the communication architecture described above is embodied in a 65 kg microsatellite supplying no more than 35 W of power. Within this budget, the payload is even made more capable, i.e. with 8 receive channels instead of 3 and 2 transmit channels instead of 1. This will be achieved through:

- The use of custom on-board microelectronics. An ASIC will perform the CDMA modem function including fast acquisition and interference-filtering
- An enhanced High-Power Amplifier design, based on a technique called Envelope Elimination an Reconstruction, with an efficiency of 30 to 50 %

The launch is targeted for end 2001.

4.5 Link budget

Table 3 lists the antennas used in MLMS.

	terminal	ground station	satellite
Antenna Name	"harpoon" (crossed dipole)	directional auYagi	Helix
Elevation range	10° - 90°	0° - 90°	65° - 0° (nadir angle)
Gain	0.6 dB - 3.1 dB *	13.5 dB	0.9 dB – 3.4 dB
Axial ratio	0.23 - 0.69 *	0.8 (estimated)	0.23 – 0.64

* Simulated value

Table 3: MLMS antennas

Table 4 gives the characteristics of the transmitters and receivers. For the feeder down link, and additional loss of 2 dB has to be taken into account (due to interaction between the non-constant envelope of the feeder downlink signal and the on-board C-class amplifier).

environmental parameters	terminal	satellite	feeder
TX power (dBm)	26	32	35
TX loss (dB)	1	0	2
RX loss (dB)	1	0	2
RX noise factor (dB)	3	6.5	3

Table 4: MLMS TX & RX characteristics

The required E_b/N_0 is about 6 dB both the service and feeder links.

The link budget takes into account :

- transmit power & transmit losses
- TX & RX antenna gains
- path loss & the worst case antenna coupling (perpendicular main axes of polarisation ellipse)
- receiver losses and noise figure

The link budget does not take into account :

- atmospheric losses (negligible at 400 MHz)
- multi-path, fading and shadowing effects
- man-made interference and jamming

5 GLOSSARY

BPSK ------------------------------- Binary Phase Shift Keying
DS-CDMA------------------------- Direct Sequence - Code Division Multiple Access
MLMS------------------------------ Micro LEO Messaging System
O-QPN ----------------------------- Offset Quadrature Pseudo Noise
OBC -------------------------------- On Board Computer
SS ----------------------------------- Spread Spectrum

6 REFERENCE

[1] P. DELOGNE & C. VAN HIMBEECK : 'Interference of Little-LEO Satellites on Radioastronomy - A Case Study', *Ursi Radio Science Bulletin, n°275, Dec. 1995* (Reproduced in Revue HF Tijdschrift N°1/1996)

ANNEX 5 : SAFIR-2 SYSTEM OVERVIEW

1 GENERAL

SAFIR-2 is designed to provide unidirectional transmission of short positioning telegrams from moving assets like trucks or containers to user stations.

The service operates in a non real time store and forward mode.

The system includes one HUB station in Bremen to operate the satellite and a 16 Channel User Mobile Station based on advanced DSP technology.

SAFIR-2 orbits as an autonomous free flying satellite in a 830 km sun synchronous orbit after the successful launch from Baikonur Cosmodrome on 10th of July 1998.

Following frequencies are allocated for communication between satellite and the Ground Station

Downlink frequency: at 400.6 - 400.9 MHz
Uplink frequency: at 399.9 - 400.05 MHz

1.1 Frequency Hopping Telemetry System

1.1.1 Basic Requirements

Main purpose of the FHT telemetry system is to acquire and to transmit to ground so called position telegrams from movable assets on ground. Position telegrams contain ID-number of the asset, time, and high resolution GPS position. The daily amount of telegrams processed by the system can reach commercial dimensions, i.e. 5.000 - 10.000 per day per 50 kHz bandwidth.

The acquisition of telegrams has to work independently of actual position, geographical distribution or density of assets to be tracked.

All radiofrequency transmissions must be achieved with high reliability in the 400 MHz band allocated to OHB.

1.1.2 General Architecture

The FHT Telemetry system consists of several identical units on board of SAFIR 2, a number of Mobile User Stations and the SAFIR 2 HUB station in Bremen.

The overall scenario is as follows: Mobile User Stations acquire GPS position, generate position telegrams and transmit them to SAFIR 2 at times of contact.
Telegrams are stored by the satellite and forwarded to the SAFIR HUB Station, from where they are distributed by terrestrial data nets to customers.

1.1.3 Group Structure of User Terminals and TDMA Access Scheme

Satellite access time is divided in time slots in the order of 1 sec, all Mobile User Terminals are grouped in groups of 16 units.

At the beginning of each time slot, the satellite sends out a trigger signal and thus initiates the transmission activity of a specific group of terminals. This initial signal of the satellite serves as time trigger, as synchronisation reference and contains in digital form the number of the group to be called up.

Figure 9 shows the principle of this TDMA access scheme.

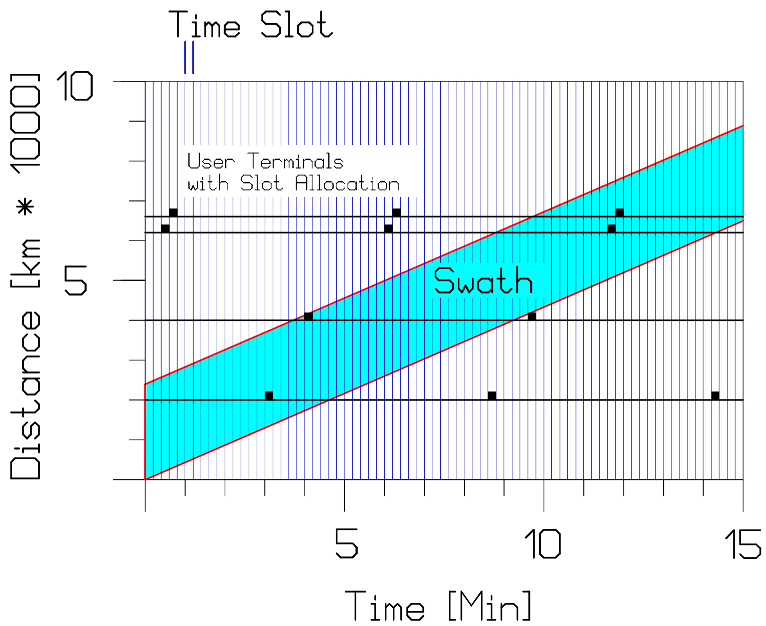

Figure 9

Fig.9: One-dimensional plot of the satellite contact area on ground travelling with time. User ground terminals at arbitrary positions can always find a time slot to address the satellite without collision with other terminals

1.1.4 Fine Structure of Terminal Groups and FDMA Access Scheme

Within each time slot, 16 terminals transmit simultaneously their telegrams on 16 different frequencies in a band of 50 kHz bandwidth, see Fig. 2.

A single noise peak can according to our experience destroy a complete telegram. Therefore each terminal will during the transmission perform a hopping of frequencies according the scheme shown in Fig. 3. This Frequency Hopping in combination with a FEC makes the system insensitive against disturbances: individual disturbance peaks can only affect a fraction of each telegram and this destroyed fraction can be repaired by FEC. The frequency hopping scheme used in SAFIR-2 is shown in Fig. 11.

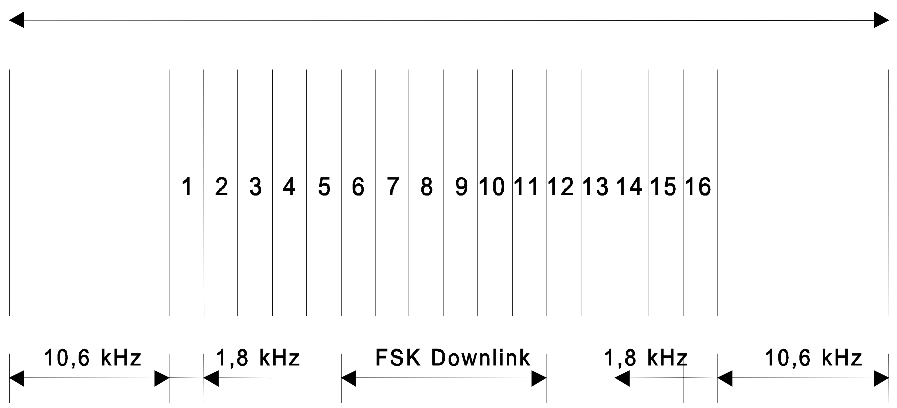

Fig. 10: Channel structure in one band of 50 kHz bandwidth as used in SAFIR-2

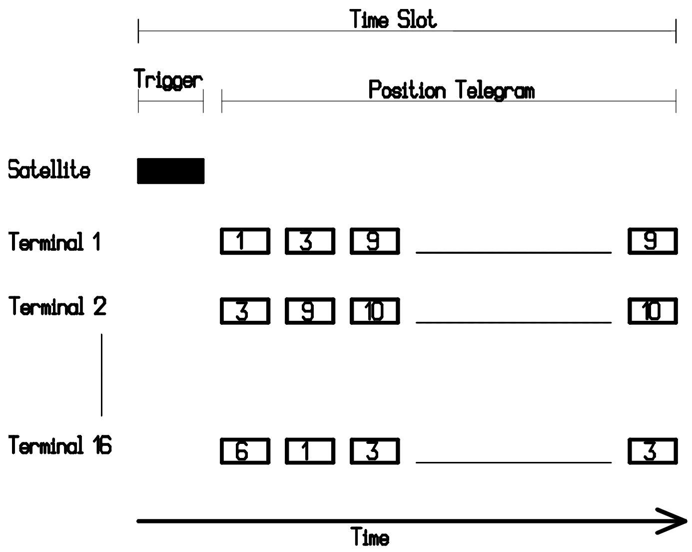

Figure 11

Fig.11: Frequency Hopping Scheme as applied during one time slot. Transmission of telegrams is realized in various bursts at different frequencies. The number in each burst indicates the frequency channel (1...16)

1.1.5 Synchronisation of Terminal Transmissions and Compensation of Doppler Shifts

Communication of User Terminals with the satellite in a time slot is initiated by the satellite. At the beginning of each slot, the satellite sends out a trigger signal (see Fig. 11) that fulfils 3 essential functions:

- trigger the transmission of terminals
- allows for synchronisation of terminal transmit frequencies: due to Doppler shifts always associated with LEO telecommunication, each terminal may receive the satellites trigger signal at a different frequency. Terminals detect the received frequency very precisely, compare with the internally stored non-Doppler shifted value and adapt their own transmit frequency in a way that the satellite will receive all 16 terminals of one slot fully Doppler-compensated - thus it is guaranteed, that the 16 frequencies as received by the satellite do not overlap and are at their exact position
- call up the specific group of 16 terminals allocated to the slot

1.1.6 Summary

The system described above is designed to acquire position telegrams from arbitrarily moving and distributed assets. The position of the assets must not be known. The system works equally, if all terminals are in 1 town or distributed over continents or the world. Collision of transmissions is excluded by the applied architecture.

ANNEX 6: LEOTELCOM-5/Leo One System

1 Overview

The Leo One system[1] is a two way, store and forward packet data communication system that uses a constellation of 48 active, low Earth orbit satellites to provide low data rate communications to and from user Earth stations that may be located throughout the world. The system is designed to provide near real-time data communications at data rates of 2.4, 4.8, and 9.6 kbps and uses frequency division multiple access techniques with narrow band modulation. Frequencies of operation are below 1 GHz (137, 149, and 400 MHz).

The gateway Earth stations of the Leo One network operate in conjunction with and as an extension of terrestrial data networks to enable messaging between terminals not within the same satellite beam. Through local service providers the Leo One network will be capable of providing a wide variety of wireless data applications including both time-sensitive and data-intensive applications, such as, asset tracking, fleet management, facility monitoring, remote control, meter reading, two-way alphanumeric paging, e-mail, mobile messaging and location for the transportation and shipping industries, data acquisition, security, search and rescue, weather data, and business transactions.

2 System Concept

2.1 Satellite Constellation

The Leo One satellite constellation consists of eight circular orbit planes inclined at 50 degrees and equally spaced around the equator. There will be six active satellites launched into each plane, for a total of 48 active satellites. The spacecraft altitude will be 950 km, which results in circular beam patterns of 3960 km diameter on the surface of the Earth. The satellite orbits and coverage patterns are shown in Figure 1.

The number of orbit planes and the inclined orbits provide system coverage to ± 65 degrees latitude with 15 degrees or higher elevation angle from the ground station to the satellite. For Earth stations at latitudes up to 65 degrees there is always at least one satellite in view, and much of the time multiple satellites are in view.

2.2 Leo One Network

The Leo One network provides the satellites, the terminals, and the communications links to provide data message interconnectivity between users and within user networks over most of the globe.

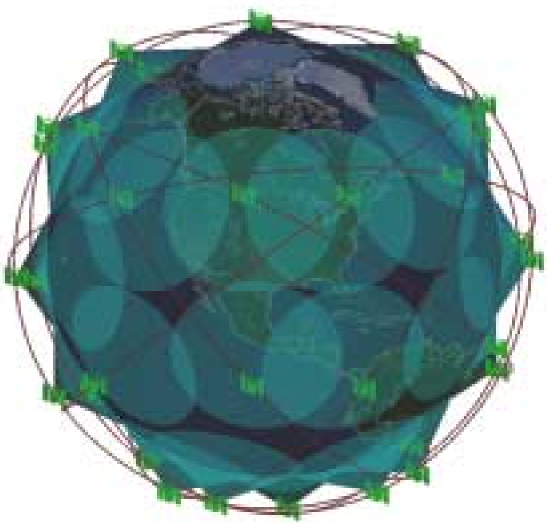

Figure 1 – Orbits and coverage patterns for Leo One system

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[1] The Leo One system has the ITU-R designation of LEOTELCOM-5.

2.2.1 Network Structure

The elements of the Leo One network are shown in Figure 2. Satellites provide communications links to and from user and gateway terminals. Existing terrestrial networks are used to link gateways to other gateways and to users, as required.

User service terminals may be either mobile or fixed and can both send and receive data. Service terminals are small, with low power and simple antennas, and are battery powered where necessary. Mobile Earth stations may be placed on trucks, trains, ships and planes and may have position location features if needed. Fixed Earth stations may be situated, for example, at businesses, homes, and industrial sites. The terminals will have intermittent use and the network can support millions of service terminals around the world.

System gateway terminals will be situated at a limited number of fixed locations (about 20) throughout the world. System gateways send and receive data to and from service terminals through the satellites and through existing terrestrial networks to end users. Service terminal data packets sent to the satellite are stored briefly until a downlink to a system gateway is established. System space and ground elements are almost always within view of each other and communications are therefore provided on a near real-time basis.

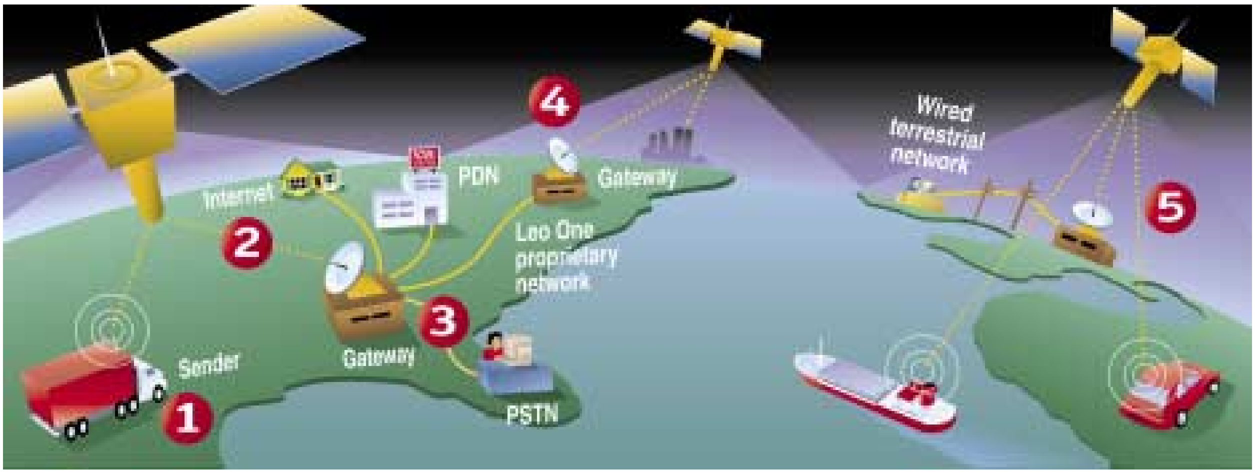
When a terminal is activated it is assigned to a Home Gateway and a corresponding Leo One address is assigned. All messages to and from that terminal are processed through its assigned home gateway. The Home Gateway is a physical and logical entity (computer/router) connected to the worldwide Leo One terrestrial backbone. Terrestrial telecommunication links from the Home Gateway to end users of the terminal information provide the external user connections to the Leo One Network.

Satellites in the Leo One network provide communications links to and from both service terminals and gateway terminals. Receive and transmit antenna beams cover large Earth areas (3960km diameter), and transmitter powers provided are sufficient to communicate with adequate margin dependent on terminal antenna gain and coverage. Gateway Earth stations are higher in EIRP because of higher gain antennas and the need for highly reliable feeder links.

Figure 2 – Leo One Network and Operation

Messages will be sent between users – persons or machines – where one or both are equipped with a Leo One satellite service terminal.

1. A satellite service terminal sends a message to the nearest in-view Leo One satellite.	2. The satellite forwards the message to a gateway for validation and optimal routing.	3. The gateway forwards the message to its recipient via the best route – satellite, Internet, private data network (PDN), or the public switched telephone network (PSTN).	4. In some cases, the receiving gateway will route the message to another gateway and then through a satellite communications path for delivery.	5. Messages can also be initiated by users connected to the wired terrestrial network, routed to a Leo One gateway, and delivered via a Leo One satellite to a service terminal.



2.2.2 Network Access Method

Network access is controlled by the satellites. Each satellite has an on-board Dynamic Channel Assignment Sub-System (DCASS) which identifies and then authorizes for use those uplink channels that are currently not in use by existing terrestrial services. Each satellite has a sensitive, band-scanning receiver that quickly and continuously scans the assigned uplink band at 149 MHz and digitally processes the received signal to determine those frequency slots that have no energy above a threshold level. Those slots with energy below the threshold are considered temporarily unused and are available for uplink use. Channel quality measures are derived and enter into a maximum likelihood channel selection process to identify those channels with the highest probability of providing the required quality of service. The selected uplink channels are "broadcast" by the satellite every one-half second. This information must be received by a service terminal prior to a transmission.

Service terminal uplink access is through defined time slots with guard time slots to allow for range variations and timing errors. This slotting in effect provides a time division multiple access (TDMA) for each uplink channel. The time slots are defined every one-half second on each satellite downlink broadcast message. The access protocols vary by assigned slot type. Text packets use a reservation aloha format with slots reserved using network access slots. The network access slots use a random access modified slotted aloha format. Monitor packets also use a random access modified slotted aloha format. Polled/paging requests use a reservation format where the individual terminal slot assignments are made on the downlink broadcast message. Acknowledgement packets also operate on a defined slot assignment made on the downlink broadcast message.

To facilitate frequency sharing with the terrestrial networks in the uplink bands, constraints are placed on user Earth stations regarding the duty cycle, the burst length, and the time between uses of a particular frequency. In the United States, FCC footnote 323 requires transmission no more than 1% of the time during any 15 minute period, single transmission time to not exceed 450 ms in duration, and consecutive transmissions from a single mobile Earth station on the same frequency to be separated by at least 15 seconds. Similar constraints will be used in all areas served by Leo One.

The satellite receives and demodulates the signal, and stores the data packet, or remodulates and transmits it to a Gateway Earth station if one is in view. Stored data is forwarded to a gateway when a gateway comes into view based on message priority and timeliness quality of service requirements. The data packet contains destination information, which is then used by the gateway to forward the message to the home gateway. The home gateway processes and forwards the message to the end user via the Internet, a private data network (PDN), or the public switched telephone network (PSTN).

Message transmissions from service terminal to satellite are 2.4, 4.8, or 9.6 kbps, with filtered OQPSK (Orthogonal Quadrature Phase Shift Keying) modulation. Satellite to service terminal downlinks are 24 kbps. The gateways transmit and receive at 50 kbps.

The capacity of the network is determined by the number of available channels on each satellite. Each satellite supports 15 service uplink channels and one service downlink channel. Additionally, one gateway uplink feeder channel and one gateway downlink feeder channel are available on each satellite.

2.3 Frequency Sharing and Interference Avoidance Techniques of Leo One

User uplinks are able to share frequencies with existing terrestrial services by making use of temporarily unused terrestrial channels. Sharing is facilitated by 1) the use of DCASS to avoid channels that are currently in use, and 2) the inherent low probability of interference resulting from network design elements that result from a) the large antenna beam size and the wide geographical distribution of Leo One terminals and b) terminal and packet transmission constraints.

2.3.1 Network Design Elements that Mitigate Against Interference

The Leo One satellite antennas with large beam size view an Earth surface area of about 12.3 million square kilometers. A Leo One service terminal, when transmitting to the satellite has the potential to cause interference into terrestrial receivers that lie within the radio horizon of the terminal relative to the terrestrial receiver (about 34 km distance to the radio horizon for a terrestrial base station receiver and 12 km for a mobile receiver). Thus the potential interference zone for a Leo One service terminal would be about 3600 square kilometers maximum. Only one user uplink at a time can operate on a given channel within the satellite beam. Otherwise, there would be self-interference within the satellite network. By the ratio of areas, the probability of that one terminal uplink being close enough to interfere with a given terrestrial receiver is no greater than 0.0003. This probability is further reduced by the low probability of the terminal uplink being on the same channel as the terrestrial receiver. The result is an inherently low probability of interference based on beam size, random user terminal location, and random channel selection. The DCASS channel selection process is intended to assure that currently active channels are not used, making a very low probability of occurrence of interference significantly lower.

Should interference occur, the effects of the interference event are mitigated by the constraints on terminal operations - the short duration (less than 450 ms), the low duty cycle (less than 1%), and the separation of repeat transmissions from the same terminal (15 sec.).

2.3.2 DCASS Active Channel Avoidance

The first line of protection against interference to terrestrial networks is the DCASS interference avoidance technique. With DCASS, the occurrence of interference will be extremely rare. In a case where DCASS does not detect an active terrestrial channel because of low power, blockage, or some other effect, the probability of interference to a particular receiver is inherently low as previously discussed in Section 2.3.1.

The Leo One system uses a Dynamic Channel Assignment Sub-System (DCASS) on each satellite to detect active Land Mobile Radio (LMR) channels, and thereby to avoid interference from the Leo One Earth stations to the LMR receivers. Channels are assigned for uplink transmissions only if the DCASS system finds no active use by terrestrial systems. The interference potential is minimized by the capability of the DCASS to determine channel availability every 0.5 seconds.

2.3.2.1 Operation of DCASS

Multiple spectrum samples are processed by the DCASS system on-board the satellite to determine channel availability every 0.5 seconds. Thus, the system has the capability of detecting a new use of an LMR channel within 0.5 seconds. The detection sensitivity is such that signals with less than 50 mW of EIRP directed towards the satellite from anywhere within the satellite beam coverage pattern can be detected. Thus, even signals with substantial signal blockage can be detected. The Leo One network uses a “Listen before Transmit” approach with the “Listening” being done by the DCASS systems in the satellite. Each satellite “broadcasts” to the Earth stations the list of currently available uplink channels every 0.5 seconds. The Earth station transmitter must first receive the downlink channel broadcast of currently available channels before selecting a channel for uplink transmission, thus ensuring interference does not occur.

3 Technical Characteristics of the Leo One System

Technical characteristics are contained in the Annex of Annex 6. Included are the radio frequency parameters - frequencies, parameters of service terminals, gateways, and satellites, and radio frequency link budgets for the several typical communications links in the network. Satellite physical parameters (weight, power, and size) are also included.

Annex of Annex 6

Technical Characteristics of Leo One System

A.1 Radio frequency Parameters

The frequencies and available bandwidths used by Leo One for uplinks and downlinks are listed in Table A-1.

Table A-1

Leo One Frequencies

Downlink	Available Bandwidth	Uplink	Available Bandwidth
4.6 User Links			
400.15-400.505 MHz 400.645-401 MHz 137-137.025 MHz	355 kHz 355 kHz 25 kHz	148-148.250 MHz 148.75-148.855 MHz 148.955-149.810 MHz	250 kHz 105 kHz 855 kHz
4.7 Gateway Links			
400.15-400.505 MHz 400.645-401 MHz 137-137.025 MHz	355 kHz 355 kHz 25 kHz	149.95-150.0 MHz 137-137.025 MHz	50 kHz 25 kHz

Radio frequency characteristics of user terminals, gateway terminals, and Leo One satellites are given in Tables A-2, A-3, and A-4

Table A-2

Service Terminal Characteristics

Transmit Power	7W, 8.5 dBW
Transmit Antenna Gain	0 dBi
Transmit Channel Bandwidth/Data Rate	15 kHz/9.6 kbps 12.5 kHz/4.8 kbps 10 kHz/2.4 kbps
Modulation	Filtered OQPSK (Orthogonal Quadrature Phase Shift Keying)
Polarization	Linear(uplink), Circular (downlink)
Receive Channel Bandwidth/Data Rate	25 kHz/24 kbps at 137 MHz 35, 55 kHz/24kbps at 400 MHz
Maximum Receive Antenna Gain	0 dBi

Table A-3
System Gateway Terminal Characteristics

Transmit Power	Up to 150 W
Maximum Transmit Antenna Gain	15 - 18 dBi
Maximum Transmit EIRP	39.8 dBW
Transmit Channel Bandwidth/Data Rate	50 kHz/50 kbps
Modulation	Filtered OQPSK/Orthogonal Quadrature Phase Shift Keying
Polarization	Circular
Receive Channel Bandwidth/Data Rate	25 kHz/24 kbps at 137 MHz 60 kHz/50 kbps at 400 MHz
Maximum Receive Antenna Gain	15-17 dBi

Table A-4
Satellite Characteristics (for Service Links)

Transmit Power	17.5 W at 137 MHz 17.5 - 34 W at 400 MHz
Transmit EIRP	13.3 dBW (at nadir) at 137 MHz 10.4 dBW (at nadir) at 400 MHz
Transmit Antenna Gain	-2 dBi (at nadir)/ 5.7 dBi (at 15°)
Transmit Channel Bandwidth/Data Rate	25 kHz/24 kbps at 137 MHz 35, 55 kHz/24 kbps at 400 MHz
Modulation	Filtered OQPSK/Orthogonal Quadrature Phase Shift Keying
Polarization (Transmit)	Circular
Number of Data Channel Receivers	15
Receive Channel Bandwidth/Data Rate	15 kHz/9.6 kbps 12.5 kHz/4.8 kbps 10 kHz/2.4 kbps
Receive Antenna Gain	-2 dBi (at nadir)/5.7 dBi (at 15°)

Example link budget calculations for user terminals and gateway terminals are given in Tables A-5 and A-6.

Table A-5
Example Link Calculations for Leo One Service Earth Station to Satellite Transmissions

	15 DEGREE ELEVATION						90 DEGREE ELEVATION					
	UP-LINK			DOWN-LINK			UP-LINK			DOWN-LINK		
	TSU VHF	TSU VHF	TSU VHF	TSD VHF	TSD UHF	TSD UHF	TSU VHF	TSU VHF	TSU VHF	TSD VHF	TSD UHF	TSD UHF
Peak Transmit Power (Watts)	7	7	7	17.5	17.5	34	7	7	7	17.5	17.5	34
Transmit Antenna Peak Gain (dB)	0	0	0	5.7	5.7	5.7	0	0	0	-2	-2	-2
Pointing Loss (dB)	0	0	0	0	0	0	0	0	0	0	0	0
EIRP (dBW)	8.5	8.5	8.5	18.1	18.1	21.0	8.5	8.5	8.5	10.4	10.4	13.3
Frequency (MHz)	*149.0*	*149.0*	*149.0*	*137.0*	*400.5*	*400.5*	*149.0*	*149.0*	*149.0*	*137.0*	*400.5*	*400.5*
Slant Range (Km)	*2317*	*2317*	*2317*	*2317*	*2317*	*2317*	*950*	*950*	*950*	*950*	*950*	*950*
Polarization Loss (dB)	3	3	3	3	3	3	3	3	3	3	3	3
Gaseous Loss (dB)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Transmission Loss (dB)	146.7	146.7	146.7	146.0	155.3	155.3	139.0	139.0	139.0	138.2	147.5	147.5
Receive Antenna Peak Gain (dB)	5.7	5.7	5.7	0	0	0	-2	-2	-2	0	0	0
Pointing Loss (dB)	0	0	0	0	0	0	0	0	0	0	0	0
Feed Loss (dB)	1	1	1	1	1	1	1	1	1	1	1	1
Receiver Noise Figure (dB)	3	3	3	3	2	2	3	3	3	3	2	2
Antenna Temperature (°K)	*288*	*288*	*288*	*760*	*200*	*200*	*288*	*288*	*288*	*760*	*200*	*200*
Receiver/ Feed Noise Temperature (°K)	*438*	*438*	*438*	*438*	*289*	*289*	*438*	*438*	*438*	*438*	*359*	*359*
System Noise Temperature at Ant (°K)	726	726	726	1198	489	489	726	726	726	1198	559	559
G/ T (dB/ °K)	-22.9	-22.9	-22.9	-30.8	-26.9	-26.9	-30.6	-30.6	-30.6	-30.8	-27.5	-27.5
Uncoded Burst Data Rate (Kbits/ sec)	2.4	4.8	9.6	24	24	24	2.4	4.8	9.6	24	24	24
Required Eb/ No (dB)	5.5	5.5	7.5	7.5	7.5	5.1	5.5	5.5	7.5	7.5	7.5	5.1
Implementation Loss (dB)	2	2	2	2	2	2	2	2	2	2	2	2
Required C/ No (dB-Hz)	41.3	44.3	49.3	53.3	53.3	50.9	41.3	44.3	49.3	53.3	53.3	50.9
Link Margin (dB)	26.1	23.1	18.1	16.7	11.2	16.5	26.2	23.2	18.2	16.7	10.7	16.0
Peak Flux Density in 4 kHz (dBW/ m^2)				**-125.2**	**-125.2**	**-125.1**				**-125.1**	**-125.1**	**-125.0**

TSU = Terminal-Satellite Uplink
TSD = Terminal-Satellite Downlink

Table A-6
Example Link Calculations for Leo One Gateway Earth Station to Satellite Transmissions

	4.8 15 Degree Elevation		4.9 90 Degree Elevation	
	Up-Link	**Down-Link**	**Up-Link**	**Down-Link**
Peak Transmit Power (Watts)	150	5	150	5
Transmit Antenna Peak Gain (dB)	18	5.7	18	-2
Pointing Loss (dB)	1	0	1	0
EIRP (dBW)	38.8	12.7	38.8	5.0
Frequency (MHz)	150	400.5	150	400.5
Slant Range (km)	2317	2317	950	950
Polarization Loss (dB)	1	1	1	1
Gaseous Loss (dB)	0.5	0.5	0.5	0.5
Total Transmission Loss (dB)	144.8	153.3	136.2	145.5
Receive Antenna Peak Gain (dB)	5.7	17	-2	17
Pointing Loss (dB)	0	1	0	1
Feed Loss (dB)	1	1	1	1
Receiver Noise Figure (dB)	3	2	3	2
Antenna Temperature (K)	288	200	290	200
Receiver/Feed Noise Temperature (K)	438	289	438	359
System Noise Temperature at Antenna (K)	726	489	728	559
G/T (dB/K)	-22.9	-9.9	-30.6	-10.5
Uncoded Burst Data Rate (kbits/sec)	50	50	50	50
Required Eb/No (dB-Hz)	8.5	8.5	8.5	8.5
Implementation Loss (dB)	2	2	2	2
Required C/No (dB-Hz)	57.5	57.5	57.5	57.5
Link Margin (dB)	42.2	20.6	42.2	20.1
Peak Flux Density in 4 kHz (dBW/m^2)	--	-133.8	--	-133.8

A.2 Satellite Parameters

The characteristics of Leo One satellites are listed in Table A-7

Table A-7
Satellite Parameters

Weight	190 kg
DC Power	560 W, end of life
Size	---
Launch Vehicle	“Rockot”
Design Life	7 years