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LOW EARTH ORBIT SATELLITE/TERRESTRIAL MOBILE SERVICE COMPATIBILITY

[redacted]

12p

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ABSTRACT

Currently the geostationary type of satellite is the only one used to provide commercial mobile-satellite communication services. Low earth orbit (LEO) satellite systems are now being proposed as a future alternative. By the implementation of LEO satellite systems, predicted at between 5 and 8 years time, mobile space/terrestrial technology will have progressed to the third generation stage of development.

This paper considers the system issues that will need to be addressed when developing a dual mode terminal, enabling access to both terrestrial and LEO satellite systems.

THE FUTURE ROLE OF A MOBILE SATELLITE SERVICE

Terrestrial mobile communication services are now entering the so called "second generation" phase of development. One such example is the pan-European digital GSM service[1][2]; this system is now gradually being introduced into service throughout Europe.

The development of mobile-satellite communication services is progressing in parallel to that of terrestrial services. The first mobile service was introduced by Inmarsat in the late '70s to the maritime sector; Inmarsat is now establishing a land-mobile service with the introduction of the Inmarsat-C and Inmarsat-M systems[3].

Where a terrestrial mobile service is well established, such as in Western Europe, it is unrealistic to think of a competitive satellite service, it is more likely that satellites will provide a complimentary back-up service. This scenario has attracted considerable interest in Europe over the past few years, especially integrating a satellite service with GSM where initially there will be gaps in terrestrial coverage, particularly in rural areas and Eastern European countries[4][5]. Satellite mobile services can play a more dominant role in areas where the mobile/fixed telecommunication infrastructure is non-existent, this will be true in large areas of the third world[6] for example.

By the end of the decade satellite systems will have advanced significantly from current transparent wide beam geostationary systems. Proposals are now being considered for multi-satellite low earth orbit systems with spot beam facilities, such as Iridium[7]. The satellite configuration in an integrated environment has considerable scope for variation.

The three types of satellite orbit generally considered as being able to provide the space element in an integrated service are: geostationary orbit (GEO), highly elliptical orbit (HEO) and low earth orbit (LEO). The advantages and disadvantages of each type of orbit in an integrated network will need to be considered, some of the more obvious of which are summarised in Table 1.0.

LOW EARTH ORBIT SYSTEMS

LEO satellites orbit the earth at altitudes in the range 500 - 2000 km. The orbital period of a LEO is in the region two hours, consequently a satellite will only illuminate a certain coverage area for approximately 2-3 minutes. Hence, for a continuous global communication service it is necessary to place a number of satellites in orbit. LEO satellites can be placed in either an inclined or polar orbit, or a combination of the two.

When used for mobile communications LEO satellites offer several advantages [8]; the altitude of the orbit means that it is possible to relax the constraints on the mobile terminal's transmit power and G/T. Additionally, the round trip propagation delay will be in the region of tens of milliseconds compared with the 250 ms delay of a geostationary satellite. Furthermore, due to the requirement for multiple satellite orbits, at least one satellite will always be in view of a mobile terminal (MT), thus it should be possible to optimise the satellite to MT link when multiple satellites are in view. However, the orbital velocity of a LEO satellite means that transmissions will be subject to a significant Döppler variation. For example, a satellite at an altitude of 800 km, transmitting at 2 GHz, would be subject to a Döppler shift in the region of 45 kHz for a 20° mobile to satellite elevation angle. Additionally, some means of implementing handover between satellites is required to maintain a continuous real time transmission. This will require a large degree of on-board processing (OBP) if the satellite is to control handover. This contrasts with GEO satellite systems where OBP is now only being considered as a future development for commercial services.

NETWORK ENTITIES

An integrated network will consist of a space segment, ground segment, gateway/base stations for fixed/private network access, and some form of network management station, the function of which is to a certain extent dependent on the level of OBP on the satellite.

To enable the routeing of calls it has been proposed[9] that the earth is divided into segments corresponding to satellite coverage areas. Each satellite has an address corresponding to the ground area that it illuminates. A call instigating from one location is routed to the satellite which covers the area of the destination address.

When a satellite crosses from one coverage area to another its address is updated. Consequently, the network configuration will be continuously changing, hence some means of updating each satellite of its position relative to the earth must to be established. There are two possibilities, either:

(a) Each satellite can be updated on its position from the ground;

(b) The satellite's onboard processing will determine its position. This will increase the complexity requirement of the satellite.

SATELLITE VISIBILITY

The number of satellites visible to a terrestrial terminal at any one time is dependent the satellite orbital configuration, the minimum elevation angle to the satellite, and the location of the mobile. LEOs are generally classified as being of either polar or inclined orbital type. Inclined orbit systems provide coverage optimised for low to mid latitude regions, however a truly global service can only be provided by a polar type configuration. Polar orbits maximise the satellite density over the polar regions. To illustrate this point a 24 satellite configuration, equally divided into 4 planes, at an orbital altitude of 2000 km, was simulated using SatLab[10]. The result is shown in Figure 1.0.

COVERAGE DURATION

In terrestrial cellular systems handover between cells occurs when a mobile moves from one cellular coverage area to another of better signal quality. Satellite systems can also provide cellular type coverage, to increase spectral efficiency, by the use of multi-spot beams. However, in a satellite system it is the cells, rather than the mobile, that are moving, ie. the mobile appears fixed relative to the cellular motion caused by the satellite. This can easily be illustrated by, for example, considering the velocity of a car travelling at 110 km/h (approximately 70 mph), or in other words 0.03 km/s, to that of satellite at an orbital altitude 2000 km, resulting in a velocity of 6.9 km/s. It can be seen that the mobiles velocity is virtually negligible.

Figure 2.0 illustrates how the time spent within a cell is affected by satellite altitude and the guaranteed minimum elevation angle from a mobile to the satellite. It can be seen that even for a call duration of 3 minutes there will be a requirement for handover between beams.

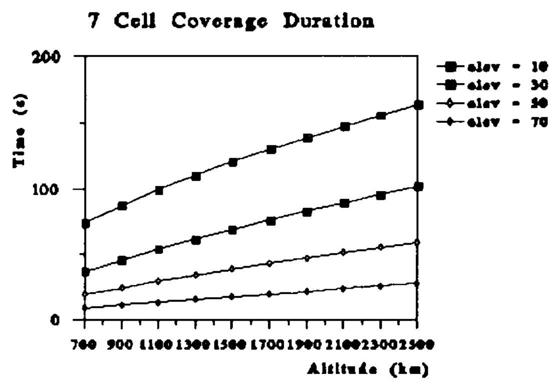

Figure 2.0 7 Cell Coverage duration

TERMINAL POWER REQUIREMENT

The available transmit power of a terminal will be constrained by its physical characteristics. For example GSM terminal classification ranges from vehicle-mounted, through transportable units to hand-held portables. The following link budgets were calculated between a satellite transmitting a 7 beam cellular pattern and a hand-held terminal.

General Link Parameters

Satellite Altitude	2000	km
Minimum Elevation Angle	5	o
Max. Dist. mobile to sat.	4905	km
Satellite Velocity	6.90	kms^{-1}
Orbital Period	127	mins
Pass Duration per Cell	2 mins 42s	
Propagation $Delay_{max}$	16.35	ms

Mobile To Satellite Link

EIRP	-2.0	dBW
Frequency	1.62	GHz
Free Space Loss	170.4	dB
Atmospheric Atten.	0.2	dB
$Gain_{sat}$	19.8	dB
T_{sat}	30.0	dK
G/T_{sat}	-10.2	dBK^{-1}
C/N_0	45.8	dBHz
$Doppler_{max}$	37.1	kHz

Satellite To Mobile Link

EIRP/channel	19.8	dBW
Frequency	2.5	GHz
Free Space Loss	174.2	dB
Atmospheric Atten.	0.2	dB
$Gain_{mob}$	0.0	dB
T_{mob}	25.0	K
G/T_{mob}	-25.0	dBK^{-1}
C/N_0	49.0	dBHz
$Doppler_{max}$	51.7	kHz

CONCLUSION

It can be seen that creating an integrated space/terrestrial network is a complex task. This is especially true for LEO type systems where the space network configuration is constantly changing.

To achieve an integrated network several key issues need to be addressed, for example: the criteria for handover between terrestrial and space links needs to be established. Current terrestrial handover criteria based on signal strength will need to be adapted to take into account the scarcity of the satellite resource; switching between satellite cells, and possibly between satellites, will increase the complexity of the space segment; a terminal capable of handling up to 50 kHz doppler with the possible circuitry required to implement an adaptive modulation and access schemes will need to be developed.

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	Geostationary	Low Earth Orbit	Elliptical
No. of Satellites	1-2	20-70	3-4
Visibility	Poor	Good - Excellent	Good
Relative Network Complexity	Low	Multi-Satellite Switching (Iridium) Low (Transparent Satellites)	Low 2-3 Satellite Switching/Day

Technology	Established	New	Experimental
Round Trip Propagation Delay (ms)	240	7-15	200-260

Table 1.0 Orbital Configuration Performance Summary Chart

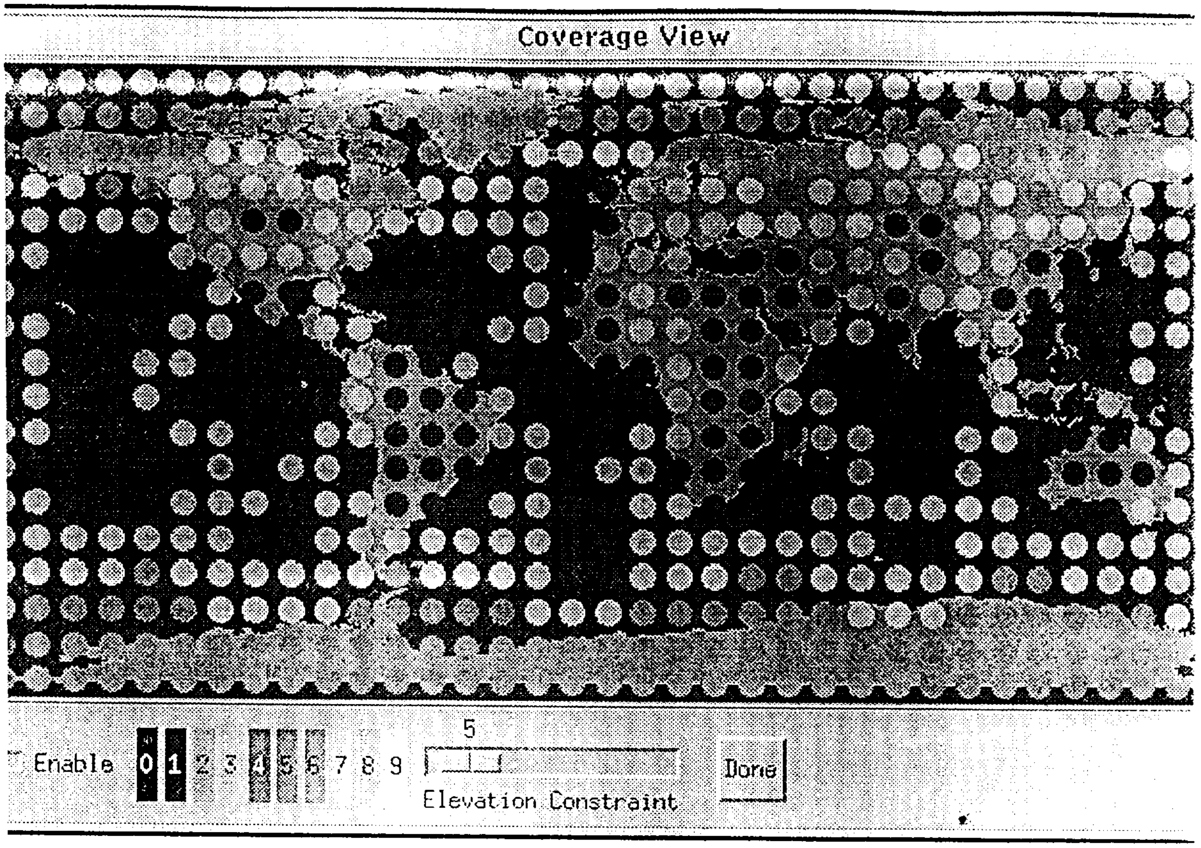

Figure 1.0 24 Satellite - 6 Satellites per Plane, 2000 km Altitude Configuration

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15. Supplementary Notes

16. Abstract

Satellite-based mobile communications systems provide voice and data communications to users over a vast geographic area. The users may communicate via mobile or hand-held terminals, which may also provide access to terrestrial cellular communications services. While the first and second International Mobile Satellite Conferences mostly concentrated on technical advances, this Third IMSC also focuses on the increasing worldwide commercial activities in Mobile Satellite Services. Because of the large service areas provided by such systems--up to and including global coverage--it is important to consider political and regulatory issues in addition to technical and user requirements issues.

The official Proceedings included approximately 100 papers presented in 11 sessions: the direct broadcast of audio programming from satellites; spacecraft technology; regulatory and policy considerations; hybrid networks for personal and mobile applications; advanced system concepts and analysis; user requirements and applications; current and planned systems; propagation; mobile terminal technology; modulation, coding and multiple access; and mobile antenna technology. This Addendum contains papers that were presented at the Conference but arrived too late to be included in the Proceedings, which was distributed at the Conference. In addition, this document contains the final attendee list for the Conference.

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