THIRD GENERATION WIRELESS TECHNOLOGIES: NEW OPPORTUNITIES FOR COMMUNICATIONS MOBILITY IN SHIP OPERATIONS

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Abstract

Today, communications between maritime transport and the shore is typically provided by VHF radiotelephone near the coast, MF radiotelephone for a range of up to 150 miles, and INMARSAT satellite for worldwide coverage. Meanwhile, on land, in harbour areas, mobile communication is usually provided by handheld VHF or UHF analogue voice-only terminals.

Besides the wireless technologies dedicated for maritime use, however, are the more generic mobile digital communications technologies, which are today represented by GSM, DECT, DSRR, S-PCN, and others. These second generation technologies have so far had little relevance for maritime transport users but applications can immediately be envisaged for UMTS (Universal Mobile Telecommunications System), which is due to come into operation around 2002. UMTS is intended to be universal and ubiquitous, representing a harmonisation of all of the second generation systems, with seamless integration between the terrestrial and satellite components. UMTS will also provide widespread availability of adequate bandwidth to support multimedia services.

The EIES project will demonstrate UMTS-like services using wireless technologies. Applications include:

- CSCW sessions, such as a scenario in which a ship at sea consults shore-based experts regarding non-routine engine repair;
- Dissemination of multimedia weather forecasts to ships;
- Use of handheld multimedia terminals by harbour officials engaged in berthing operations and customs officers.

By demonstrating these applications, EIES will seek to contribute to the standardisation of the mobility aspects of UMTS, particularly concerning satellite/terrestrial inter-working, wireless mulimedia and personal/terminal mobility within harbour areas.

GLOSSARY

BPSK	Binary Phase Shift Keying
CEPT	Committé Européen Posts & Telecoms
CSCW	Computer Supported Cooperative Work
DECT	Digital European Cordless Telecoms
DLA	Dynamic Link Allocation
DSP	Digital Signal Processing
DSRR	Digital Short Range Radio
ETSI	European Telecoms Standards Institute
FEC	Forward Error Correction
GIS	Geographical Information System
GMDSS	Global Maritime Distress & Safety System
GPS	Global Positioning System
GSM	Global System for Mobiles
HSD	High Speed Data
INMARSAT	International Mobile Satellite Organisation
ISDN	Integrated Services Digital Network
LEO	Low Earth Orbit
MBS	Mobile Broadband System
MDN	Mobile Data Network
MF	Medium Frequency
MMI	Man-Machine Interface
PMR	Public Mobile Radio
Q-o-S	Quality of Service
RF	Radio Frequency
SCPC	Single Channel per Carrier
S-PCN	Satellite Personal Comms Network
TETRA	Trans European Trunked Radio
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecoms System
UPT	Universal Personal Telecoms
UUS	User-to-User Signalling
VHF	Very High Frequency

INTRODUCTION

Radio communications has, over the last ten years, seen a very rapid pace of technological development - on land. For instance, the GSM cellular network permits subscribers to roam between cells, between competing networks, to migrate between countries and even to carry their subscriber identity between handsets using smart cards. The wireless communication of data has become widespread and wireless multimedia communications are becoming feasible. The integration of GPS with terrestrial radio systems such as MDN and PMR has opened up a new range of applications for GIS. The operators of terrestrial networks such as GSM, however, face a dilemma with regard to the extent of landmass that their networks cover. Providing coverage in rural areas is expensive but users will only subscribe if they think they are going to get coverage wherever they go. The solution is seen to lie in the integration of terrestrial networks with satellite networks. The satellite network can then act as a means of filling in the gaps in the terrestrial coverage, as well as a kind of overflow on occasions that the terrestrial infrastructure becomes saturated. This satellite/cellular integration is an objective of UMTS.

Radio communication on the sea has evolved less quickly. There are quite disparate VHF, MF and satellite networks. There is no roaming between cells (e.g. individual VHF coastal stations). Data communication is still rare and voice communication relies heavily on pre-digital technology which is extravagant in its use of spectrum and inefficient in protecting the transmission from corruption by interference. Whilst GMDSS is bringing about some digitisation, the prospect of seamless integration between satellite and terrestrial networks envisaged by UMTS could, it is argued in this paper, have an even more profound impact on maritime communications.

It is the aim of the authors to perform, within the framework of the ACTS EIES project, a demonstration with real users, showing the sort of functionality and applications which UMTS should be capable of providing to the maritime community.

SECOND GENERATION MOBILE RADIO

The current status of the principal European second generation terrestrial and satellite wireless communication technologies is follows:

GSM

GSM is now the most widely adopted second generation cellular system in the world. It is primarily a voice network but has data communication facilities up to 9.6 kbps. There are around 20 million subscribers in Europe and many sea-going vessels use GSM handsets for informal and non-regulated ship-to-shore communication, in spite of an inherent limitation in the design which imposes a maximum of 35 km coverage from a base station.

DECT

DECT is a cordless system intended for short range (typically 200 metres) communication. It is mainly intended for use in private networks, which may involve multiple handsets and base stations. Roaming between base stations is possible. Use of a handset on different DECT private networks (e.g. business and residential) is also facilitated. DECT has a very flexible radio interface which, although basic DECT equipment operates voice and data at 32 kbps, permits much higher data rates. 512 kbps data is theoretically possible but equipment operating at this speed is not yet readily available. Such high data-rate DECT equipment has obvious applications for wireless multimedia in harbour areas and on-board ship.

DSRR

Like DECT, DSRR is a short range wireless system for private networks. It is providing low rate voice and data channels with speed of 16 kbps. The system concept was designed for point-to-point communications between base stations and portable or mobile stations in simplex or semi-duplex mode . An interim ETSI standard exists and describes system operation in the 900 MHz frequency range with maximum transmitter power of 4 W. This is one of the advantages of DSRR over DECT (operating at 1.9 GHz with power of 250 mW) which can make DSRR better suited to hostile propagation environments, such as ships and harbours. The allocation of two frequency ranges around 889 and 934 MHz with bandwidth 2 MHz each has been recommended by CEPT for the operation of DSRR systems. In many member countries this has already been implemented or is currently under consideration. However, commercial systems are not yet available. The main reason is the bandwidth limitation in the existing standard which makes the system unsuitable for today’s and emerging applications, such as real time video and high speed data transmission. The restriction to semi-duplex operation is also critical for interpersonnel/interactive applications, like CSCW. The development of an advanced DSRR standard seems therefore to be recommended. It is the objective of the EIES project to investigate the required system functions and to propose an advanced DSRR concept for wireless broadband communications in hostile propagation environments as integral part of UMTS.

MDN, TETRA and PMR

These are terrestrial second generation wireless technologies, particularly used by land mobiles, including delivery vehicles, emergency services and taxis. It is not thought that they have any particular relevance to maritime communications.

INMARSAT

Inmarsat operates 4 satellites in the geostationary orbit providing mobile services with almost global coverage for maritime as well as land-mobile and aeronautical users. The capacity of the system is currently being increased by the launch of a new generation of satellites which are equipped with spot beams. This capacity makes the Inmarsat satellites particularly attractive for mobile broadband applications as part of a future UMTS satellite component. There are various services catering for maritime transport. The principal services are designated Inmarsat-A, -B, -C and -M. Inmarsat-A is an analogue system providing telephony, telex, fax and voice-band data. A 64 kbps so called High Speed Data Service (HSD) is also available. The recently-introduced Inmarsat-B is fully digital and expected to replace the A-System over the next decade. The services provided are the same, but terminals are smaller and cheaper and the call charges are lower. Inmarsat-C is a low rate packet switched service with throughputs up to 600 bps. Although it is widely used for maritime transport applications, such as fleet management, due to the limited bandwidth it will be less relevant for the EIES services. The same applies to the M-System which is providing voice-band services only.

S-PCN

Various non-geostationary satellite constellations, including Iridium, Globalstar and ICO (Inmarsat) are currently under development, with intended launch dates from 1998-2000. Around fifty further LEO constellations have been proposed, although many of them are a long way from realisation. Many of them offer data services, up to 9.6 kbit/s. Currently these satellite constellations are the subject of intense political negotiations and it is not clear which, if any of them, will be allowed to operate in Europe.

UMTS - THE THIRD GENERATION

European industry, and the ACTS community in particular, is currently looking at the evolution of the above second generation systems towards the third generation Universal Mobile Telecommunications System (UMTS), which is due to come into operation around 2002. UMTS is intended to be universal and ubiquitous, representing a harmonisation of all of the second generation systems, with seamless integration between the terrestrial and satellite components. Whilst the transition from the second generation to UMTS is likely to be achieved through a series of incremental changes, Figure 1 represents this evolution.

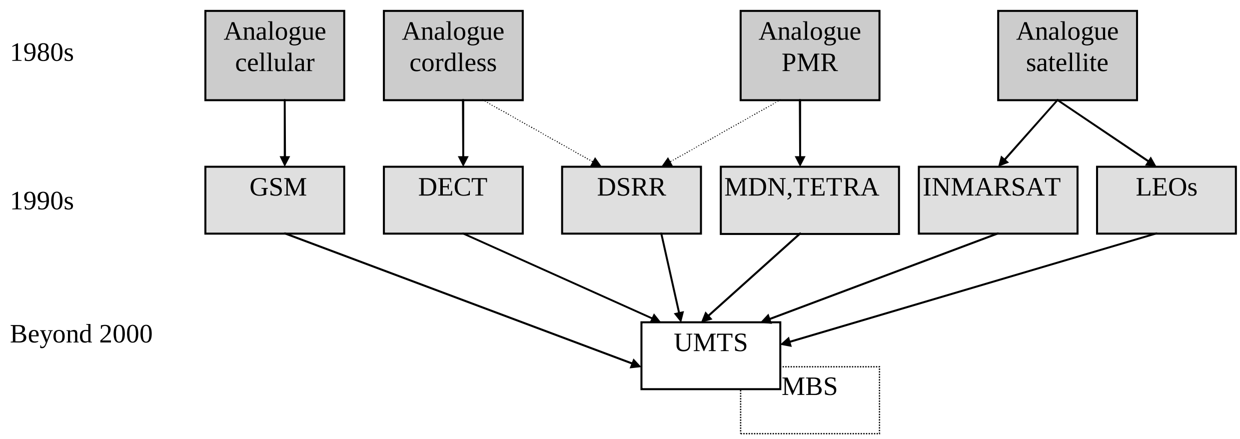

Figure 1: The evolution of terrestrial and satellite wireless communications towards the Third Generation Mobile Systems UMTS and MBS.

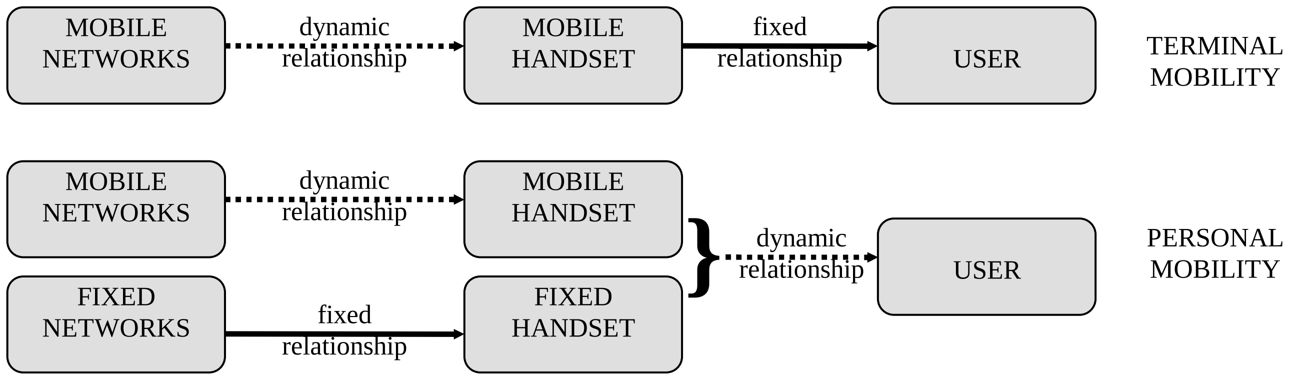

Figure 2. The Universal Personal telecommunications (UPT) concept, defining terminal and personal mobility.

MBS represents a broadband variant of UMTS anticipated to emerge around 2005. It is important to note that UMTS and/or MBS will seek to offer the user a personal wireless communicator, which will operate in both public and private environments and is capable of supporting a wide range of services from multimedia, down to low data-rate messaging, such as e-mail. The mobility functionality, which currently permits roaming and migration between GSM networks, will be expanded to allow full personal and terminal mobility. This concept, known as 'Universal Personal Telecommunications' (UPT), is represented in Figure 2.

KEY ISSUES IN STANDARDISATION

Key issues in the standardisation of UMTS include:

- integration of the satellite component with the terrestrial infrastructure;
- low bit-rate multimedia (for maritime users, could UMTS and MBS be the same thing?);
- personal mobility.

The EIES project's Wireless Multimedia Demonstrator aims to make a significant user-driven contribution to the standardisation of these aspects of UMTS.

SATELLITE / CELLULAR INTEGRATION

From the maritime transport perspective, the key issue in the standardisation of UMTS is the extent to which the satellite and terrestrial networks will become integrated. Very considerable cost savings could be anticipated if ship-to-shore communications could be seamlessly diverted from a satellite network to a terrestrial one, as the vessel approaches land.

Global Integration: Terrestrial/satellite and satellite/terrestrial handover are transparent to the user. Global availability.

System Integration: Very high level of infrastructure and handset commonality. Dynamic link allocation (DLA) [2] and terrestrial/satellite handover occur.

Network Integration: Enough commonality in the network infrastructure for the satellite and terrestrial networks to become seamless from the perspective of a fixed network subscriber calling a mobile.

Techniques Integration: Although the satellite and terrestrial radio access networks may retain significant differences, there is enough commonality of protocols, access schemes, etc for significant sharing of baseband circuits in a dual-mode handset.

Applications Integration: The applications supported by the disparate satellite and terrestrial networks are the same, thus achieving greater opportunities for inter-working and integration in dual-mode handset.

Handset Co-location: Handsets are co-located enabling the user to switch between disparate networks. At this level of integration, if dual-mode handsets exist, they are essentially co-located single-mode handsets, sharing the same MMI.

Inter-working: Some simple communication between disparate coexisting networks is possible.

Coexistence: Spectrum and orbit allocations ensure that geographical coexistence of disparate satellite and terrestrial mobile networks is possible.

Table 1 A Hierarchy Representing the Extent of Integration between Satellite and Terrestrial Mobile Networks [1].

Many technical barriers have to be overcome before UMTS will allow this. Above all there are the complexities associated with handover between terrestrial and satellite networks and the reverse direction, which because of transmission delays, is more difficult to achieve. Further technological barriers must be overcome in the integration of dual-mode handsets. Hence it is currently unclear what level of satellite/terrestrial integration will be attained, as defined in the hierarchy presented in Table 1.

The mobile demonstration which the authors intend to conduct under the EIES programme, will help to define the extent of satellite/cellular integration required in order for significant benefits to accrue to the maritime transport community.

LOW BIT-RATE MULTIMEDIA

The wireless access technologies to be used in the EIES demonstrator are in the range 64 to 512 kbps. These data rates are low compared to the MBS vision (2 to 155 Mbps). EIES will strive to indicate how the radio spectrum, which is a scarce and valuable commodity, especially on satellite links, can be conserved for UMTS-like multimedia transmissions.

PERSONAL COMMUNICATIONS

The harbour is a very appropriate environment in which to study the mobility requirements of a group of users of hand portable wireless multimedia terminals. It is planned that within EIES, port authorities, including customs officers and those engaged in berthing operations, will be able to contribute to a study on personal and terminal mobility within harbours, using DECT equipment.

EIES MOBILE DEMONSTRATOR

EIES MOBILE PILOT CONFIGURATION

This is shown in Figure 3. It involves ship-to-shore communication via Inmarsat satellite when the vessel is at sea and via DSRR in the harbour and harbour approaches. In harbour mobility is provided by DECT, whilst wireless communications within the vessel could be provided by either DSRR or DECT.

INMARSAT/DSRR/DECT ASPECTS

For the demonstration of the EIES services, the Inmarsat-B HSD service is most suited. It is a bearer service providing transparent, synchronous links between briefcase size satellite terminals and ISDN access points. The user rate is 64 kbps (1 ISDN B-channel). A signalling channel (D-channel) accessible with user equipment, however, is not available. This means that user equipment can not be connected via ISDN-So interfaces to the satellite service. Furthermore, ISDN standard features, like User-to-User Signalling (UUS) are not supported. Although this represents a functional limitation and requires dedicated terminal interfaces, the HSD service is suitable for integration into the EIES demonstrator due to the bandwidth and coverage provided to maritime users being on ships or at shore. An operational limitation is the need to have line-of-sight access to the space segment. Indoor operation of the satellite terminals is therefore not possible. A limitation which suggests the use of wireless connections between indoor user equipment and outdoor terminals.

Prototype DSRR equipment will be the result of an in-house development project on the part of MediaMobil Communication and Marac Electronics. The DECT equipment is under development within another ACTS project.

SYSTEM FUNCTIONS AND SERVICE FEATURES

The main system functions and service features are:

- mobile access: automatic identification of available wireless links (Inmarsat, DSRR, DECT);
- fixed access: ISDN basic rate lines (using inverse multiplexing for n x 64 kbps user rates);
- selection of wireless links based on user defined criteria, such as charges, bandwidth, Q-o-S;
- common MMI for all types of communicators (access systems) used (handset co-location concept);
- end-to-end connection control mobile-to-fixed network and vice versa;
- synchronous transmission channel (layer 1) transparent to all types of error control protocols (layer 2) and communication protocols (layer 3 and higher (TCP/IP, X.25, H.320, H32M and others));
- bearer rates n x 64 kbps (with satellite component 64 kbps only).

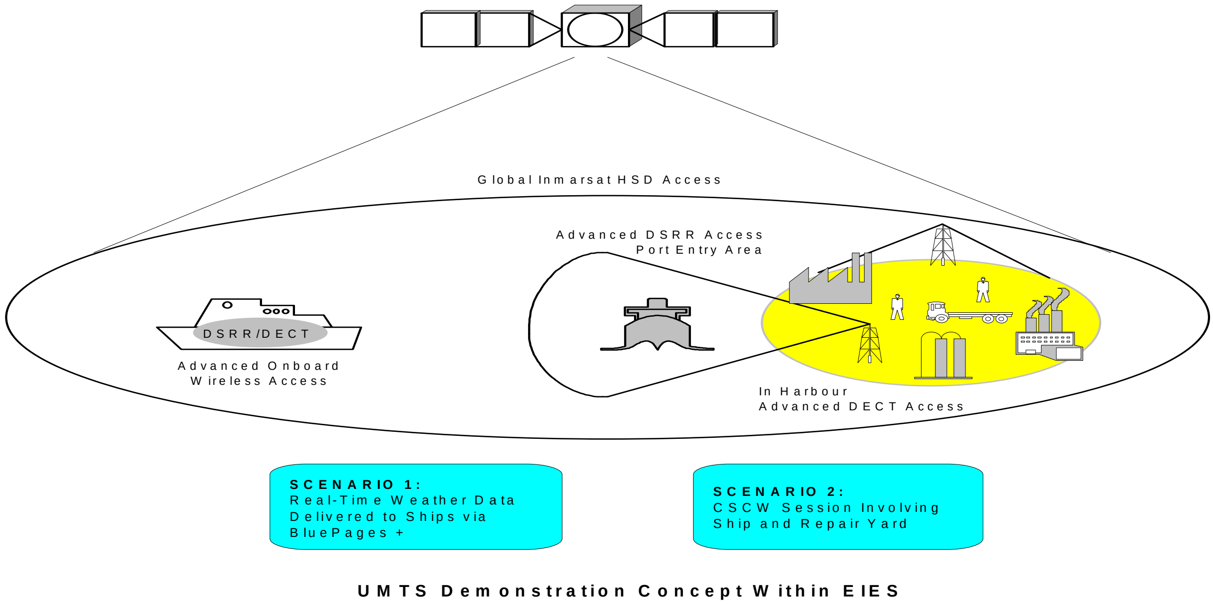

Figure 3 The Mobile Demonstrator within the EIES project

REALISATION OF PROTOTYPES

A prototype implementation of a DSRR system has been developed in the framework of the RACE MOEBIUS project (Mobile Experimental Broadband Interconnection Using Satellites). The application case was non-routine ship-to-shore communication in the event of problems with onboard systems, like the engine or electronic devices. The ship-to-shore link was established through the Inmarsat system. Onboard the ship, the satellite service was extended via the DSRR wireless link to below deck locations. This enabled the delivery of expertise from shore directly to the location of the problem in compliance with the stated needs of the users involved in the project. There was, however, no integration between the satellite service and the DSRR system beyond the interconnection of the communication channels and some basic call control functions (called inter-working in the integration hierarchy). The MOEBIUS DSRR concept is described in [3].

The existing prototype system consists of a base station and a portable radio set. The base station is connected to the satellite terminal interface, the portable set to the user equipment. In the case of the MOEBIUS demonstrator this was a H.320 multimedia conferencing system. The air interface is using SCPC transmission mode. Multiple access is not supported. The modulation scheme is filtered BPSK and FEC rate 1/2 convolutional coding is applied to the information data using Viterbi decoding in the receiver. The baseband section is controlled by a processor. Functions include interfacing with the user equipment, encoding and decoding of the information data as well as control of the modem/RF section (transmission rate, frequency, power). A simple MMI using push buttons and an LCD display is also available.

The scope of the system evaluation in the framework of MOEBIUS was mainly limited to testing of the technical performance including transmission measurements in order to verify the concept for ship-board wireless communications with high data rates. Transmission trials onboard of the railway ferry Railship III are described in [4]. Based on the results of measurements of the received signal levels and bit error rates for different above-to-below deck link configurations, the coverage of the DSRR system has been evaluated in terms of the maximum distance between the base and portable radio sets. The results are summarised in Table 2. The maximum distances refer to an above deck base station antenna and a portable set operated in the environment given in the first column.

Comprehensive test results for the spatial and temporal fading performance of ship-board wireless links in the 900 MHz frequency range can be found in [5].

Portable Radio Set Environment	Attenuation Coefficient (measured)	Maximum Distance Base-to-Portable
Above Deck	4	230 m
Bridge / Radio Room	5	80 m
Engine Room	6	40 m
Crew / Passenger Rooms	7	25 m
Cargo Decks	8	15 m

Table 2 Results of Ship-board DSRR Performance Tests from the RACE MOEBIUS Project.

In the framework of EIES the existing prototype will be further developed to enable wireless access to the EIES services from ships entering the port area as well as at sea. In the first case the base station will be linked to an ISDN network interface, in the latter case to an Inmarsat-B HSD terminal which will provide the link to the shore network. The system functions required to demonstrate the UMTS like functionality will be implemented by modification of the baseband and modem section using DSP technology. This will allow the flexible adaptation of the system interfaces (communication and signalling channel as well as MMI) to the service needs and the demonstration of the advanced features discussed in this paper.

CONCLUSIONS

Maritime transport could derive considerable advantage from UMTS, the third generation mobile communications system, in which existing terrestrial and satellite communications networks will merge into one homogenous system, capable of supporting wireless multimedia and UPT. The Mobile Demonstrator within the EIES project will endeavour to demonstrate UMTS-like wireless multimedia within a maritime transport environment, with ship-to-shore communications via Inmarsat satellite and DSRR, as well as DECT based in-harbour communications. Scenarios involving real maritime transport users will demonstrate CSCW sessions involving non-routine ship engine repair, the dissemination of weather forecasts and harbour operations involving berthing and customs. In this way EIES intends to contribute to the standardisation of UMTS and to the resolution of key issues in standardisation, namely satellite/cellular integration, low bit-rate multimedia and UPT.

The ultimate effect of this work should be a third generation mobile system which takes proper account of the needs of the maritime transport community.

REFERENCES

[1] Hartigan, P F, Dewell, R D 1996, 'The Extent of Integration Between Satellite and Terrestrial Networks in Future Mobile Communications', IEE Conference on satellite Systems for Mobile Communication and Navigation, London, IEE ref 1996/424.

[2] Hartigan, P F, 1994, 'Dynamic Link Allocation in Integrated Satellite / Terrestrial Communications Networks', IEE Colloquium on Spectrally Efficient Techniques for Satellite Communications, London, IEE ref 1994/082.

[3] MOEBIUS Deliverable: "Local Data Radio Link - Part 1: Concept Definition", Document R2040/UHB/FB1/DS/L/041/b1, June 1993.

[4] A. Schubert, T. Antoulinakis, I. Mourtsiadis: "Radio Link for Unimpeded Data and Digital Video Transmission from Confined Spaces", Seminar on Advanced Communications in Shipping, Athens, June 1994.

[5] A. Schubert: "Ship-Board Cordless Extension of Mobile Satellite Communication Links Supporting Multimedia Services", RACE Mobile Telecommunications Workshop, Amsterdam, May 1994.