Mobile and Personal Communications
E. Del Re (Editor)

OVERVIEW OF COST 227 RESULTS

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ABSTRACT

COST 227 Action "Integrated Space/Terrestrial Mobile Networks" is focused on the evaluation and identification of different requirements and aspects concerning a future scenario of integration between terrestrial and satellite mobile networks.

This paper describes the structure, the objectives and the major achievements of the COST 227 Action.

1. ACTION DESCRIPTION

COST 227 "Integrated Space / Terrestrial Mobile Networks" started on April 26, 1991 and ended on April 25, 1995. The participating Countries and Organizations are: Belgium, Czech Republic, France, Germany, Greece, Hungary, Italy, Poland, Portugal, Slovenia, Switzerland, United Kingdom and the European Space Agency (ESA).

The participating Bodies are: Alenia Spazio (ASP, Italy), CNET France Telecom (CNET, France), CSELT (CSELT, Italy), DLR (DLR, Germany), Ecole Polytechnique Federale de Lausanne (EPFL, Switzerland), ESTEC (ESA, The Netherlands), France Telecom / ENST (ENST, France), Franco-Polish School (FPS, Poland), Instituto Superior Tecnico (IST, Portugal), ISPT (ISPT, Italy), "Jozef Stefan" Institute (JST, Slovenia), National Technical University of Athens (NTUA, Greece), PKI Institute (PKI, Hungary), Swiss Telecom PTT (STLPTT, Switzerland), Roke Manor Research (RMR, United Kingdom), SAIT Systems (SAIT, Belgium), Nuova Telespazio (TPZ, Italy), University of Aveiro (UA, Portugal), University of Bradford (UB, United Kingdom), University of Bristol (UBRSTL, United Kingdom), University of Florence (UF, Italy), Czech Technical University of Prague (UP, Czech Republic), University of Surrey (US, United Kingdom).

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2. OBJECTIVES OF THE ACTION

Mobile communications, in particular personal communications, are an extremely interesting emerging area in Information Technology and satellites will play a fundamental role in providing the required services to the users [1], [2].

The objective of this Action is to study and define feasible systems for mobile communications based on the integration between a satellite network and a terrestrial network, where the integration should aim at:

a) providing, as far as possible, the largest set of common services,

b) identifying the largest possible set of common functions at the mobile terminal,

c) identifying the largest possible set of common functions at the ground infrastructure.

Different levels of integration between the two networks are possible [3]. As a basis for defining the levels of integration, the CCIR ("Comité Consultatif International des Radiocommunications") has defined five such levels, described below in order of increasing commonality between the two networks:

Geographical Integration - In this case, rather than speaking of integration, it would be better to say that the satellite system is complementary to the terrestrial one, its main objective being to offer communications services to areas not served via ground infrastructures. The two networks are independently conceived, so that they are based on different technologies and, in general, offer different services to the users. This means that in this case the generic user has to choose to buy either a "terrestrial" or a "satellite" terminal or, as an alternative, a dual-mode terminal able to switch from one system to the other. Furthermore, the kind of terminal owned by each user, has to be known by a fixed user originating the call, in order to correctly route the call via the terrestrial or the satellite network.

Services Integration - Also in this case the two networks can be based on different technologies, they being still distinct. The substantial difference, with respect to the geographical level of integration, resides in the fact that the satellite system parameters are now chosen to support services compatible with those provided by the cellular system, in this case with a lower service quality. This means that the same mobile terminal is able to access both the systems. It is sufficient, in fact, that the terminal is able to provide appropriate protocol conversions.

Network Integration - This integration level is characterized by network infrastructures common to both the systems. It should be noted that this approach does not prevent from designing the satellite system without imposing rigorous compatibility constraints with the terrestrial system. On the contrary, it can still be based on techniques and system parameters optimized for satellite applications. To clarify, the advantage of this type of integration is an easier service utilization for the mobile subscribers. Common network infrastructures, in fact, allow a fixed user to ask for a connection with a mobile user without the worry of selecting the call routing (via terrestrial or satellite network) or the knowledge of which kind of terminal is owned by the mobile user. A unique calling number identifies in this case the generic mobile subscriber, and the mentioned actions are handled by the network managing units.

Techniques Integration - The only, even if substantial, difference of this approach with respect to the previous one, concerns the techniques characterizing the satellite system. In this case, in fact, the same (or at least as similar as possible) techniques of the terrestrial system, in terms of access scheme, protocols, bit rates, etc., are also adopted for the satellite one. The advantage of such a solution is a considerable reuse of the cellular technologies for the implementation of the dual-mode mobile terminal. This could utilize, in fact, common baseband, protocol and modulation equipment for both the operating modes, whereas, due to the different frequency bands characterizing the terrestrial and satellite systems, a duplication of some equipment, such as RF circuitry and ad-hoc antenna is needed.

System Integration - According to the last integration level, the satellite is no long seen as an alternative routing, also able to support communications in geographical areas not covered by the terrestrial system, but, finally, as a part of a unique (really integrated) system. According to this solution, handover of calls in progress between terrestrial and satellite cells could be realized each time it becomes necessary, because of partial channel occupancy, degradation of some links, and so on. It has to be noted, however, that re-routing procedures can be performed only if the mobile user is equipped with a dual-mode terminal.

The aim of this Action is to consider feasible technical solutions able to provide, as far as possible, the highest level of integration [1], [2], [4].

3. METHOD OF WORKING

The activities of the Action have been divided into three tasks. Each task has a number of working packages, as listed below. The partners involved are indicated by their acronyms for each activity.

Task 1 - Satellite System Architecture , chaired by Mr. Giulio Zanotti (TPZ)

1.1 Orbit Selection	(ASP, CNET, CSELT, ESA, TPZ, US)
1.2 Satellite Payload	(TPZ, US)
1.3 Type of Coverage	(ESA, US)
1.4 Frequency Band	(ESA, TPZ, US)

Task 2 - Network Aspects , chaired by Mr. Ray E. Sheriff (UB)

2.1 Role of Satellite	(CSELT, UA, UB, US)
2.2 Resource Assignment	(CSELT, DLR, ENST, EPFL, UA, UB, UF, US)
2.3 Mobility Management	(ASP, CSELT, DLR, ENST, UA, UB, UF, US)

Task 3 - Radio Interface , chaired by Dr. Jonathan P. Castro (EPFL)

3.1 Modulation, Coding and Equalization (CSELT, JSI, IST, NTUA, UP, US)

4. MAJOR ACHIEVEMENTS

4.1. Summary of Task 1 results

Orbit Selection

General advantages and disadvantages characterizing the candidate orbital solutions (Geostationary Orbit, GEO, Low Earth Orbit, LEO, Intermediate Circular Orbit, ICO, Medium Earth Orbit, MEO, and Highly Elliptic Orbit, HEO) were first of all pointed out [5]. Secondarily, the most significant architectural parameters and associated performance, relevant to some specific solutions (like the LOOPUS concept, the M-HEO concept and the MAGSS-14 and JOCOS systems [6]), were provided to give an overview of solutions based on orbits different from the well known GEO and LEO ones. Finally, link budgets considerations and performance evaluations were performed for four specific satellite systems, each employing one of the four mentioned classes of orbits (i.e., GEO, ICO, LEO, HEO).

Results of the performance evaluation and consequent orbital comparison, carried out through a number of dedicated simulation runs, suggested to consider ICO and LEO solutions for hand-held applications, whereas HEO and GEO solutions seem more suitable in case of vehicular user terminals [7].

Satellite Payload

Referring to the above candidate orbital solutions, Iridium, Globalstar and MAGSS-14 systems were analyzed to point out the need and the feasibility of specific technologies on board the satellite, such as digital beam forming technology, strategic to realize the cellular coverage via satellite, or Solid State Power Amplifiers (SSPA), allowing a significant mass saving (and then a reduction of launch costs) without reducing the amplification efficiency.

As far as the MAGSS-14 system is concerned, analogue and digital solutions were considered and compared for the Payload Processor Unit (PPU). It resulted that a digital processing payload has a significant mass advantage over analogue payloads and also provides high RF power efficiency, beam reconfiguration possibility, routing flexibility, adaptability to variations of traffic distribution, whereas an analogue payload is completely transparent, indifferent to access schemes and is power/bandwidth flexible [8], [9], [10].

Coverage Area

Different multi-beam coverage models were considered during the above mentioned comparative analysis in evaluating the performance of the candidate orbital solutions (see the "*Orbit Selection*" topic in this Sub-section.). In that analysis, the relationship among orbital altitude and frequency band versus size (hence number) of spot-beams were particularly considered [7].

The choice of the coverage has hence to be made taking into account this relationship. The analysis discourages for example the use of high frequencies (like Ka band) for LEO applications, because the on board antenna directivity at these frequencies, associated to the low orbital altitude, would require a huge number of spots to realise an acceptable satellite coverage area.

Frequency Band

The activities within this research area focused on the results of the last World Administrative Radio Conference (WARC'92). All the revisions to the Radio Regulations were presented, to highlight, in particular, the new frequency allocations, the sharing criteria, the modifications to the old ones and the additional frequency co-ordination problems introduced by the new allocations.

In the light of the Conference results, L, S and Ka bands were suggested as candidate frequencies (among all the available ones) for future mobile communication systems. In particular, only L and S bands seem applicable in case of LEO and ICO systems, whereas all the three bands can be suitable for the other orbital solutions [11].

4.2. Summary of Task 2 results

Role of Satellite

The satellite component of an integrated network is expected to fulfil three roles:

a) extension of terrestrial coverage to outside of the terrestrial cellular boundaries;

b) provision of emergency and back-up services to the terrestrial network;

c) provision of additional channels to the terrestrial cellular network.

The first two of the above roles can be considered as being complementary to the terrestrial service. The final role is supportive, which will lead to a decrease in the blocking probability of the terrestrial network, or alternatively an increase in the network capacity for the same grade of service. The effectiveness of the satellite's supportive role will largely be determined by the resource assignment strategy adopted by the network.

Mobility Management

As in terrestrial systems, the mobile-satellite network must perform management functions requiring signalling, in addition to user channel provision. In satellite systems which employ spot-beams, the user terminal will conduct this signalling through these same spot-beams. The mobility management function of a Personal Communication Network (PCN) enables active mobile user terminals to be tracked anywhere within its total coverage area. When a mobile terminal (MT) terminated call arrives at the Satellite-PCN (S-PCN) network, the MT must be located in order that the connection to it can be made. This is the task of network Mobility Management (MM) [12], [13], [14]. Two types of location technique were considered, and their effect on the mobility management signalling and protocols was outlined:

a) "MT-Position" Approach

> The MT-position approach relies upon the use of a satellite-based radio location determination system, for example the Global Positioning System (GPS) or some GPS-type system.

b) "MT-Diversity" Approach

> The MT-diversity approach uses the inbuilt resources of S-PCN without needing any external information. The only information known to the MT in this system is which spot-beams are covering its position at any one time; this information is gathered by monitoring all of the possible Broadcast Control CHannels (BCCH), on which the identities of the satellite and spot beam will be transmitted.

The handover is the transition from one cell to another while the MT is *active*. It was concluded that space to earth handover is complex and possibly impractical. Two possible handover strategies between earth to space elements were considered:

a) network transitions based on the Bit Error Rate (BER) of the link;

b) switching based on average fading time using level crossing rate information.

An approach to connectivity and traffic capacity analysis for LEO/MEO satellite systems was developed. Given the network topology and the traffic requirements, the main task is the assessment of capacity requirements on the different links within the network. This evaluation procedure may efficiently be used in the initial process of planning and dimensioning LEO/MEO networks.

Numerical results of the network connectivity investigation show that the system constellation and satellite dynamics basically influence the link capacity requirements. Thus the presented results provide important input information for the design of network components and for comprehensive system cost calculations.

Resource Assignment

The number of available satellite channels is relatively small, considering that they are available to a network which is more extended than a terrestrial cellular network. It is therefore important to ensure that the channels are used to maximum benefit for the whole network. Channel allocation could be based purely on a signal quality comparison between satellite and terrestrial channels, however, this will quickly use up the satellite resource. The following criteria have been proposed to fully exploit the satellite capability:

a) satellite channels should be used in areas not covered by the terrestrial system;

b) satellite channels should act as an overflow for the more congested terrestrial cells in areas covered by both systems;

c) channel allocation should not be based purely on signal quality. In rural areas, particularly, a satellite link is likely to be of higher signal quality than a terrestrial link, resulting in a rapid saturation of the satellite resource.

The performance of Dynamic Channel Allocation (DCA) for cellular systems was studied. Channels are assigned to cells on a per call basis using this technique. Any channel can be assigned to a cell, provided that the usual constraints on co-channel interference are respected. Simulation results proved that DCA allows a significant improvement of the channel utilization with respect to a more classical Fixed Channel Allocation (FCA) technique [15], [16].

Moreover, a further study evaluated the performance improvement obtained by queuing the handover requests from cell to cell in order to reduce the probability of call dropped due to a lack of available channel in the cell destination of the mobile user [17].

Finally, the performance of terrestrial and space multiple access schemes in the presence of interference form other cells was investigated. Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), PRMA (Packet Reservation Multiple Access), and Code Division Multiple Access (CDMA) were considered for cellular systems. The results showed [18] that:

a) satellites with regenerative repeater facilities increase efficiency in comparison with transparent satellites for all access techniques;

b) CDMA has largely the same performance as that of the re-use techniques for transparent satellites;

c) CDMA performance is far superior to that of the re-use techniques for regenerative repeater satellites.

4.3. Summary of Task 3 results

Modulation, Coding and Equalization

Modulation

The performance analysis of various coded and uncoded Continuous Phase Modulated (CPM) signals in the mobile radio channel was analized [19]. Several signal distortions due to Gaussian noise, Rayleigh fading, co-channel interference and Doppler frequency shift were taking into account and analyzed.

At the beginning the CPM signal performance was studied in the Additive White Gaussian Noise (AWGN) channel and in the frequency selective fading channel. Various modulation indices were considered. It was found out that the modulation index $h=1/2$ gives the best performance. For frequency selective fading analysis we used the Rummler channel model. We noticed that the sensitivity due to the frequency selective fading was greater for higher modulation indices.

On the basis of computer simulations we concluded that GMSK modulated signals give better results for AWGN, fast Rayleigh fading and co-channel interference, while $\pi/4$ DQPSK is less sensitive to the Doppler frequency shift.

Convolutional encoded multi-amplitude CPM signals were analyzed. Multi-amplitude

CPM signals are obtained by the superposition of two CPM signals of different amplitudes. In particular, a new interesting CPM signal type, called quadrature MAMSK, was introduced [20]. MAQMSK signal consists of two orthogonal MAMSK signals: it is four dimensional signal and its spectral efficiency is much greater than with the MSK signal. MSK, MAMSK, QMSK and MAMSK signals were analyzed in Rayleigh fading channel with co-channel interference considering various Doppler frequency shifts. As expected, the MSK signal turns out to be the most robust signal type among the analyzed signals.

The channel state estimation

A decision directed channel state estimator was derived for full response linear modulation in a slowly fading channel with additive Gaussian noise. This estimation is aimed to evaluate the Bit Error Rate performance to be sent in a feedback channel. Then, a Maximum Likelihood (ML) decision directed estimator for received symbol energy to noise power density for every particular matched filter sample was derived. A subsequent filtration of these estimations was applied. A sub-optimal moving average filtering is considered. The suggested decision directed channel state estimator is relatively very simply and easy to implement. Simulation showed that for non critical purposes even the sub-optimal postprocessing of the estimates gives satisfactory performance [21].

Coding

The work related to coding [22] involved the application of a new class of block codes (named TCH codes) specifically designed to simplify the complexity of the receiver while achieving a performance comparable to the best schemes known. These codes are cyclic and allow the use of Fast Fourier Transform (FFT) techniques to implement maximum likelihood decoding fast and efficiently. These TCH codes perform just like the well known BCH codes, but are significantly better at the implementation level.

Channel Characteristics

A satellite system communicating directly to mobile terminals requires the basic link analysis of small fixed terminals, but will have additional channel characteristics due to the motion of the terminals. This motion introduces spectral degradation in the transmitted waveforms: in particular, the multipath fading that severely affects the reliability of data transmissions over land-mobile-satellite networks. The fading plagues the propagation medium by imposing random amplitude and phase variations on the transmission signal. However, the effect of an undesired random variation is reduced by the presence of a strong line-of-sight (l.o.s) signal component.

Therefore, it is of great importance to study and compare the channel models reported in literature. The models estimate the mean vegetative attenuation and the required link margin for a specific outage probability. The observation and comparison of the models led to conclude that this type of channels are strongly dependent on the frequency used for the link, the elevation angle, and the characteristics of the environment in the vicinity of the mobile.

A method was also proposed for laboratory simulation of multipath interference that led to a software realization of the land mobile satellite channel model suggested by Lutz et.al. [23], [24], [25], [26].

Multiple Access Techniques

The research efforts were mainly devoted to identify the most efficient Multi Access (MA) technique which permits to serve increasing numbers of users, while providing reliable links regardless of the channel propagation conditions.

In the case of a Gaussian channel the obtained results for the efficiency comparison are that CDMA technique performs better than FDMA, TDMA and PRMA in the presence of powerful coding [18]. This is true both in the terrestrial and in the satellite channel case.

Moreover, these results were validated considering the GSM recommended terrestrial propagation channel model in the case of TDMA [27]. In particular, the following environments have been envisaged: "typical urban", "hilly terrain" and "rural area". For the TDMA technique we considered a GMSK modulation scheme and an MLSE receiver; in the case of CDMA technique, we considered a QPSK modulation with synchronous spreading Gold codes and a RAKE receiver. The efficiency comparison permitted to conclude that in the "typical urban" environment, a CDMA technique is advantageous only when a low E_b/N_0 (i.e., energy per bit to noise spectral density ratio) and low capacity are required, whereas in the case of "rural area" and "hilly terrain", the situation is quite different because CDMA performs always better than TDMA

Antenna Characteristics

Although there was not dedicated activities on antenna design in COST 227 Action, it was recognized that important aspects related to the design of antennas for hand-held terminals are radiation effects and linear/circular polarization. Only recently, designers have started to consider the importance of the radiation effect of the transmitting power of a hand-held. Moreover, in an integrated environment, hand-helds should enable communications both with terrestrial and satellite based communication systems. Unfortunately, their electromagnetic fields have different polarizations (e.g., linearly polarized in terrestrial cellular systems and circularly polarized in satellite systems) and, at present, a transparent compatibility and an integrated polarization in one physical antenna are still to be fully tested.

Biological Constraints

At L-S Frequency Bands

It was shown that power levels of 1 Watt would induce rather high Specific Absorption Rates (SAR) values and it is estimated that power levels on the order of 250 mW seems to be quite safe for what concerns thermal effects [28].

At Ka Frequency Band

Preliminary results showed that there is a tendency to pass the ANSI standard when the antenna is 1 cm away from the user's head. Therefore, it was proposed that hand-helds operating at the Ka frequency band be designed in a way that the antenna always remains at least 4 cm away from the user's head [28].

5. COOPERATIONS AND OUTPUTS TO OTHER PROJECTS AND STANDARDIZATION BODIES

A liaison through the exchange of many documents was carried out between COST 227 Action and:

- SAINT Project (RACE II Mobile Project line),
- COST 231 Action,
- ETSI,
- CCIR.

6. PROPOSAL FOR A FUTURE COST ACTION COMING FORM COST 227 ACTION

As a result of this project a new COST Action, namely COST 252, has been proposed to the "Technical Committee Telecommunications" (TCT) and it is now under examination for approval. The title of this new Action is: "Evolution of Satellite Personal Communications from 2nd to future Generation Systems". It is recognized world wide that mobile personal communications will play a significant role in the future telecommunication market and current research activities are carried out on this subject in industries, public administrations and research institutions in Europe, USA and Japan as well as in International Standardization Bodies. Here, a very promising approach towards the achievement of global mobile communications services is that a smooth migration from 2nd (e.g., GSM) to next generation integrated systems with a global coverage.

7. CONCLUSIONS

At the end of the project it is gratifying to see how much has been achieved especially given the voluntary nature of the work. All the work has been in the form of contributions from separate organizations and often from individuals often putting in their own time.

Over the four years of the COST 227 Action some interesting studies have been carried out to define the most appropriate orbital solutions to cover all the earth or only to obtain a regional coverage. Moreover, other attracting results deal with channel allocation techniques and mobility management strategies particularly suitable for application in terrestrial and satellite mobile networks. Finally, other studies have concerned the definition of powerful codes, the efficiency comparison of multi-access techniques in mobile environments, the identification of channel characteristics and the definition of channel models.

At the end of this Project the definition of an integrated terrestrial / satellite mobile network remains a very difficult task and a challenge towards the achievement of the future global mobile communication system. By bringing together at least some of the disparate European groups working in the area we hope that COST 227 Action has helped the advance of the R&D efforts for mobile networks.

REFERENCES

[1] RACE 1994 Report, February 1994.

[2] ETSI Technical Report, "Framework for satellite integration within the Universal Mobile Telecommunication System (UMTS)", D-ETR/SMG-51201, Vers. 0.5.0, 16 Sept. 1993.

[3] E. Del Re et al., "Integrated Environment for Mobile Communications: A Preliminary Review", 227TD(92)026.

[4] Proceeding of the 3rd International Mobile Satellite Conference, IMSC '93, Pasadena (CA), 16-18 June 1993.

[5] G. Zanotti, "Orbit Selection, Preliminary Considerations", 227TD(92)036.

[6] G. Pennoni, "JOCOS - 6+1 Satellites to Evolve Towards Universal Personal Telecommunication", 227TD(94)18.

[7] G. Zanotti, "COST 227 Task 1 activities", 227TD(93)029.

[8] P. Rastrilla, I. Stojkovic, J. Benedicto, P. Rinous, "Medium Altitude Payload Concepts for Personal Satellite Communications", 227TD(94)19.

[9] J. Ventura-Traveset, I. Stojkovic, F. Coromina, J. Benedicto, "A Technology Review for Future Satellite Personal Communications Payloads", 227TD(94)20.

[10] C. Cullen, "A Review of Payload Technologies for S-PCN", 227TD(94)21.

[11] G. Zanotti, "Warc 92 Results", 227TD(92)027.

[12] F. Dosiere, T. Zein, G. Maral, "A Model for the handover traffic in Low Earth-Orbiting (LEO) Satellite Networks for Personal Communications", 227TD(93)024.

[13] M. Dinis, J. Neves, R. Tafazolli, B. Evans, "A Proposed Mobility Management Technique for Resonant Mobile Satellite Constellations", 227TD(94)02.

[14] A. Sammut, C. Cullen, R. Tafazolli, B. G. Evans, "Mobility Management Related Signaling for a MAGSS-14 Based Satellite Personal Communications Network (S-PCN)", 227TD(94)22.

[15] E. Del Re, R. Fantacci, G. Giambene, "Performance of a Dynamic Channels Allocation Technique for Satellite Mobile Cellular Networks", 227TD(93)033.

[16] E. Del Re et al., "Performance analysis of dynamic channel allocation techniques in terrestrial and satellite mobile networks", 227TD(93)012.

[17] E. Del Re, R. Fantacci, G. Giambene, "Efficient Dynamic Channel Allocation Techniques with Handover Queuing for Mobile Satellite Networks", 227TD(94)35.

[18] E. Del Re, R. Fantacci, G. Giambene,"Efficiency Comparison of Multiple Access Systems for Terrestrial Cellular and Satellite Networks", 227TD(92)042.

[19] G. Kandus et al., "The CPM Signal in Selective Fading and Gaussian Noise Channel", 227TD(92)032.

[20] T. Javornik, G. Kandus, "Multi-Amplitude Quadrature Modulation Technique in Mobile Radio Channel Environment", 227TD(94)38.

[21] J. Sykora, "Decision Directed Channel State Estimator", 227TD(95)06.

[22] F.A.B Cercas, "TCH: a New Family of Cyclic Codes", 227TD(92)031.

[23] J.P. Castro, "Mobile Satellite Channels for Personal Communications", 227TD(92)035.

[24] E. Lutz, et al., "The Land Mobile Satellite Communication Channel - Recording Statistics and Channel Model", 227TD(93)045.

[25] M.A.N. Parks, G. Butt, B. G. Evans, "Results of Multiband (L, S, Ku band) Propagation and Measurements and Model for High Elevation Angle Land Mobile Satellite Channel", 227TD(93)049.

[26] A.G. Kanatas, E.C. Kanderakis, P. Constantinou, "A Revised Analog Model for the Land Mobile Satellite Channel", 227TD(95)10.

[27] E. Del Re, R. Fantacci, G. Giambene, A. Pazzaglia "Code Division Multiple Access Versus Time Division Multiple Access Spectral Efficiency in Radio Mobile Cellular Networks", 227TD(93)042.

[28] J. P. Castro, "Handest Safety Issues at Ka-band Frequencies", 227TD(95)07.