CEPIT
COORDINAMENTO ESPERIMENTO PROPAGAZIONE ITALSAT
CSTS CNR - ASI - POLITECNICO DI MILANO

Proceedings of
ITALIAN PROPAGATION DAY
and
III CEPIT MEETING
Roma, October 9-th, 1995

Chairman: Prof Aldo Paraboni
Editor: Dr Apolonia Pawlina

Centro di Studio sulle Telecomunicazioni Spaziali CNR
Dipartimento di Elettronica e Informazione
Politecnico di Milano
Acknowledgments

Thanks to the Centro di Studio sulle Telecomunicazioni Spaziali CNR in Milano, for kindly sponsoring the refreshments during the meeting and for the financial support in the distribution of Proceedings.

The IIC - Istituto Internazionale di Comunicazioni of Genoa is acknowledged for the organizational support - allowing the conference room and facilities in Rome and distributing the Propagation Day announcements

ASI - Agenzia Spaziale Italiana is acknowledged as a promoter and founder of the ITALSAT Programme and Italian participation to the OLYMPUS Programme.
Editor's Note

The present volume collects the material contributed to the one day meeting, nicknamed Propagation Day, dedicated to the radio propagation research in Italy (counting now some 25 years tradition) and to the most recent propagation measurement campaign - the Italsat project, involving experimenters from several European countries. The Italsat propagation experimenters form the group referred to as CEPIT (acronym of Coordinamento Esperimento di Propagazione Italsat) chaired by Prof. Aldo Paraboni from Politecnico di Milano, also in charge as Scientific Manager of Italsat Project.

CEPIT group met for the third time in Rome on October 9-th 1995, whilst first two meetings were held in Milan, in 1989 and 1992.

Initially the 3-rd CREPT meeting was planned for mid-May in Milano, but then the date was shifted to immediately precede the "Ka Band Utilization Conference" in Rome, in order to give the opportunity to conveniently attend both, closely interrelated events, covering two complementary fields: description and modeling of radio channel and TLC systems which applies the findings of propagation research.

The meeting organizers (CSTS-CNR Propagation Group, Politecnico di Milano) thought useful to dedicate the morning session to the review of Italian research activities in the field of radiopropagation, reaching the third decade milestone. The review was intended also as a reflection on future research trends meeting the requirements of new generation of earth and space TLC systems.

The first afternoon session hosted the reports on the incoming COST 255, some updates of past OLYMPUS/OPEX campaign and a communication on ACTS project from USA. Last two sessions were fully and busy filled with reports on Italsat experiment, still in progress, giving also floor to the introduction of new planned activities.

The present volume is a working document, willing to trace the Propagation Day contents, and thus collecting the contributions of speakers in various formats, going from a short communication, through a set of transparencies to almost formal paper. Some experimenters, unable to come to Rome, kindly supplied their reports or papers as well. Thanks to everybody.

In order to keep the number of pages reasonable many transparencies were reduced allocating two pictures in one page. Apologies go to contributors whenever the composition is not graphically at the best.

Editor

Milano, December 1995
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"Role of Italy in international organizations in the field of radiopropagation" by Prof. Francesco Fedi, Fondazione Ugo Bordoni, Roma

"Report on the Italsat aircraft status and future programs" by Ing. C. Portelli, Agenzia Spaziale Italiana

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chaired by Prof. Aldo Paraboni

"Radar and beacon measurements for advanced systems beyond 10 GHz", by* Prof. Carlo Capsoni, Politecnico di Milano

"Propagation parameters for low availability satellite systems", by* Dr. F. Barbaliscia, Fondazione Ugo Bordoni, Roma

"Overview of Italian research activities on Propagation in Cellular Systems" by* Ing Paolo Grazioso, Fondazione Ugo Bordoni, Pontecchio Marconi (Bologna)

"Interference between radio communications systems - COST activities" by* Ing Guido Dellagiacoma, Centro Studi e Laboratori Telecomunicazioni (CSELT), Torino

"Research activities of Roma Universities on EM propagation for TLC applications", by* Dr Frank Marzano, Università' La Sapienza, Roma

3. Session on the "Post-OPEX" and COST 255 actions

chaired by Dr. Pedro Polaeres Baptista, ESA - ESTEC

"Ka band system requirements, the role of COST 255" by* Paul T. Thomson, ERA Technology

"The application of propagation results from ACTS" by* Faramaz Davarian, Jet Propulsion Laboratory, CalTech, Pasadena LA, USA

"Update of OLYMPUS campaign results from Spino d'Adda and Torino" by* Carlo. Riva, Politecnico di Milano

"Measurement of the interference due to rain" by* Claudio Mattiello, CSELT, Torino

(*) speaker name is indicated rather than authors
4. CEPIT Session: Italsat experimenters reports
chaired by Aldo Paraboni

List of Experimenters

"Preliminary results from RAL observations near 50 GHz using ITALSAT" by* Peter Davies, Rutherford Appleton Laboratories, Chilton, UK  

"20/40-GHz Beacon Measurements with ITALSAT" by* Gerd Ortgies, FTZ, Deutsche Telekom, Darmstadt, Germany  

"Dynamics of amplitude and phase scintillations in a millimetre-wave satellite link, the Portsmouth 40 GHz Italsat experiment" by* Eric Vilar, Portsmouth University, UK  

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"XPD statistics from Italian stations" by* Antonio Martellucci, FUB, Roma  

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"Current and planned propagation experiments at CERT-ONERA" by* Joel Lemorton, CERT-ONERA, Toulouse, France  

"RAFAEL Communications experiment" by* David Behar, RAFAEL, Haifa, Israel  

"Planned propagation experiment using the 50 GHz Italsat beacon", by* Terje Tjelta, Telenor Research, Kjeller, Norway  

6. Contributed Papers, not presented at the meeting

"Attenuation Measurements of the 40 GHz Beacon Signal of Italsat" by U. Fiebig, F. Dolainsky, H. Reinel and M. Schnell, German Aerospace Research Establishment (DLR), Wessling, Germany  

"Adjustment of a 30 meter diameter telescope using the Italsat beacon" by Denis Morris and J.E. Garrido, IRAM, University of Grenoble, St Martin d’Heres, France  

"Propagation Experiment at 50 GHz using the Yebes Radiotelescope" by A. Sanchez, J. Bandera, J. M. Riera, A. Benarroch, Polytechnic University of Madrid, A. Barcia, J. E. Garrido Yebes Astronomy Centre  

"Report on Holographic Measurements of the 14 m Radiotelescope at the Centro Astronomico de Yebes (Spain) Carried out Using Italsat" by Alberto Barcia and Juan E. Garrido
Dear Colleagues,

All of us are conscious of the epochal changes in the field of radiocommunications, to mention only the development of the modern radio-telephony, or the direct TV broadcasting as an example. The future trends promise further massive development of technologies using frequencies around 20, 30, 40 and 50 GHz, so called Ka and millimetre bands, offering completely new, very attractive services, such as universal mobile radio, multimedia communication, video on request, etc.

The basic research in radio propagation aiming to identify and quantify the limitations to the utilisation of radio waves (caused by atmospheric precipitation or by terrestrial obstacles like vegetation, hills or buildings) is fundamental for the planning and design of these new systems.

Italian effort in the field of radio propagation research during the last quarter of the century may be considerable, with big investment in both national and international Programmes. The recent massive engagement in projects like OLYMPUS and ITALSAT confirms the recognised position and vitality of Italy in the field.

The Propagation Day and the Ka Utilisation Conference come shortly after the conclusion of the OLYMPUS Propagation Experiment at 12, 20 and 30 GHz, and during the measurement campaign of ITALSAT Propagation Experiment at 20, 40 and 50 GHz. The Propagation Day aims to divulgate the results obtained so far, within and beyond the larger community including system developers, public management, founding bodies etc. Most of the "history" of these results is resumed in the special "focus" issue of Alta Frequenza of December 94, to be distributed among the participants.

The Day hopes to attract many of participants of Ku Utilization Conference, as our other goal is to promote the better utilisation of propagation knowledge in the system planning and development, in the spirit of European projects, such as the incoming COST 255 or ACTS.

It is important to realise that thanks to some research and industry groups in Italy, operating through the last two decades with great dedication, our Country has accumulated a huge cultural patrimony that absolutely should not be dispersed. Otherwise we as a Country risk to pay a very high price for the technologies generated by the know-how that we possess now, and that we have acquired among the first in the world, but that we may be not in a position to make this knowledge productive.

Moreover, the existing advanced equipment (considering huge investments already made in its manufacturing) needs urgently proper re-utilisation. It is possible now with incomparably lower (but still needed) funds.

In conclusion, there is a strong demand for the careful revision of the opportunity to "invest in radio propagation".

Hoping that our propagation day and 3-rd meeting of Italsat experimenters can contribute to better understanding of research and development priorities.

CEPIT Chairman
Prof. Aldo Paraboni
Politecnico di Milano

Milano, April 1995
The "Propagation Day", hosting 3-rd CEPIT meeting, will take place in Rome on October 9-hst 1995. The date and venue were chosen allowing the participants to attend the "Ka BAND UTILISATION CONFERENCE", held in Rome on 10-12 October 95, organised by the Istituto Internazionale di Comunicazioni (ICC) of Genova. On the other hand the Day, dedicated to the propagation research in the considered band, may be of interest to the target audience of the Ka Conference, warmly invited to attend. The companion letter of the Chairman wishes in fact to focus on the necessity of new synergy.

Venue:
Ministero di Poste e Telecomunicazioni, Aula Magna
Viale Europa 190, Roma, Italia

Agenda:
9:00 Registration (no registration fee is foreseen)
9:30 Opening Address by Prof. Francesco Carassa
9:45 Introductory Relation on "25 years of Radio propagation Research in Italy and its Role in the Design of Future Telecommunication Systems" by the Chairman, Prof. Aldo Paraboni
10:15 Coffee break
10:45 Invited Reports covering the synthesis of activity in the field of Italian research organisations and Universities such as CSELT, CSTS-CNR, Fondazione Ugo Bordoni, Rome Universities I and II, Bologna University)
12:30 Lunch
13:30 Session on the "post-OPEX scenario" and COST 255 chaired by Bertram Arbesser, Head, Wave Interaction & Propagation Section ESA ESTEC XEP
15:00 Coffee break
15:30 CEPIT session on the Italsat propagation experiment with reports from European experimentation sites.
16:30 Open CEPIT forum on the fulfilment and utilisation of Italsat measurement campaign: results, data base, common projects, possible fall-outs in system design, contribution to regulatory bodies.

Please let us know if:
A) you are interested to participate in Propagation Day /3-rd CEPIT Meeting
B) you want to receive further information
C) you are interested to receive the CEPIT proceedings

Contacting: Apolonia Pawlina
(CEPIT coordinator) E-MAIL pawlina@elet.polimi.it

Milano, May 5, 1995
Italian Propagation Day and 3-rd CEPIT Meeting, Roma, October 9, 1995

Agenda

8:30  
Registralion

9:30  
Opening address by Prof. Francesco Carassa (Politecnico di Milano)

9:40  
"25 years of radio propagation research in Italy" by Prof. Aldo Paraboli

9:55  
"Role of Italy in international organizations in the field of radiopropagation" by Prof. Francesco Fedi

10:10  
"Report on the Italsat aircraft status and future programs" by Ing. C. Portelli (ASI)

10:30  
Coffee break (courtesy of CSTS-CNR)

Session on Radiopropagation Research in Italy
derived by Prof. Aldo Paraboni

10:50  
"Radar and beacon measurements for advanced systems beyond 10 GHz", speaker: Prof. C. Capsoni (Politecnico di Milano)

11:10  
"Propagation parameters for low availability satellite systems", speaker: Dr. F. Barbaliscia (FUB)

11:25  
"Interference in radio systems beyond 10 GHz", speaker: Ing. G. Dellagiachio (CSELT, Turin)

11:40  
"Channel characterization in radio mobile systems", speaker: Prof. G. Falciasecca (Università di Bologna)

11:55  
"Research activities of Italian Universities on EM propagation for TLC applications", speaker: Dr. F. Marzano (Università La Sapienza, Roma)

12:25  
Free time for lunch (up to the attendees)

Session on the "Post-OPEX" and COST 255 actions
derived by Dr. Pedro Polares Baptista (ESTEC)

13:30  
"Overview of the COST Action 255", speaker: P. Polares Baptista (ESTEC)

13:50  
"Ka band system requirements - the role of COST 255", speaker: P. T. Thomson (ERA)

14:10  
"The application of propagation results from ACTS", speaker: F. Davarian (JPL, NASA)

14:30  
"Update of OLYMPUS campaign results from Spino d'Adda and Torino", speaker: C. Riva (Politecnico di Milano)

14:45  
"Re-use of Olympus station at CSELT in Torino", speaker: C. Mattiello (CSELT)

14:50  
Last minute updates and discussion

15:00  
Coffee break (courtesy of CSTS-CNR)

CEPIT Session: Italsat experimenters reports
derived by Prof. Aldo Paraboni

15:20  
"Preliminary results from RAL observations near 50 GHz using ITALSAT", speaker: P. G. Davies

15:30  
"20/40 GHz Beacon Measurements with ITALSAT", speaker: G. Orties (PTZ Denteche Telekom)

15:40  
"The Portsmouth 40 GHz Italsat experiment", speaker: E. Vilar (Portsmouth University UK)

15:50  
"Eindhoven Italsat experiment", speaker: J. Dijk (EUT Eindhoven)

16:00  
"Land mobile satellite propagation campaign at Ka-band", speaker: E. Kubista (IAS, Graz)

16:10  
"XPD statistics from Italian stations", speaker: A. Martellucci (FUB, Rome)

16:20  
"Italsat statistics from the stations of Spino d'Adda and Torino", speaker: R. Polonio (CSELT)

16:30  
"On the participation to the Italsat Propagation Experiment", speaker: A. Pavlina (CSTS-CNR)

16:35  
Short break

Open Forum on utilization of Italsat propagation data and future programs
derived by Prof. Francesco Fedi

16:45  
Free discussion on the fulfillment and utilization of Italsat measurements campaign, results, data base, common projects, contributions to the regulatory bodies and short communications by:
A. Geurtz (SES/ASTRA) "Benefits of propagation studies for the satellite service provider"
D. Behar (RAFAEL, Haifa), J. Lemorton (CERT-ONERA, Toulouse), Terje Tjelta (Telenor R&D)
on the planned experiments

18:00  
End of the meeting
<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution/Data</th>
<th>Address</th>
<th>Phone</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Avanzi Francesco</td>
<td>Consiglio Superiore Tecnico PT</td>
<td>Viale America 201 I - 00144 Roma - Italy</td>
<td>+39-6-59584542</td>
<td>+39-6-5942743</td>
</tr>
<tr>
<td>2</td>
<td>Barbaliscia Francesco</td>
<td>Fondazione Ugo Bordoni</td>
<td>Viale Europa, 190 I-00144 Roma - Italy</td>
<td>+39-6-5480-2110</td>
<td>+39-6-5480-4401</td>
</tr>
<tr>
<td>3</td>
<td>Bartolucci Giuseppe</td>
<td>Consiglio Superiore Tecnico PT</td>
<td>Viale America 201 I - 00144 Roma - Italy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Bauer Wilfried</td>
<td>Deutsche Telekom AG</td>
<td>Berlino - Germany</td>
<td>+49 30 67083443</td>
<td>+49 30 67082367</td>
</tr>
<tr>
<td>5</td>
<td>Behar David</td>
<td>RAFAEL, Electromagnetic Dept. (87)</td>
<td>P.O.B. 2250 31021 Haifa - Israel</td>
<td>+972-4-792930</td>
<td>+972-4-795329</td>
</tr>
<tr>
<td>6</td>
<td>Belshaw John</td>
<td>ESA/ESTEC XEP</td>
<td>Keplerlaan 1, PO Box 299 NL-2200 AG Noordwijk - Netherlands</td>
<td>+31-1719-84427</td>
<td>+31-1719-8499</td>
</tr>
<tr>
<td>7</td>
<td>Benarroch Ana</td>
<td>ETSI -Telecom de la UPM</td>
<td>Ciudad Universitaria E - MADRID 3 - Spain</td>
<td>+34 1 336 7218</td>
<td>+34 1 336 7350</td>
</tr>
<tr>
<td>8</td>
<td>Bournis Marina</td>
<td>F.U.B. Fondazione Ugo Bordoni</td>
<td>Viale Europa, 190 I-00144 Roma - Italy</td>
<td>+39 6 54802119</td>
<td>+39 6 54804401</td>
</tr>
<tr>
<td>9</td>
<td>Carassa Francesco</td>
<td>Politecnico di Milano, Dip. Elettronica e Inf.</td>
<td>P.zza Leonardo da Vinci 32 I-20133 Milano - Italy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Corazza Giovanni F.</td>
<td>Univ. Tor Vergata, Dip. Ing. Elettronica</td>
<td>Via della Ricerca Scientifica I - 00133 Roma - Italy</td>
<td>+39 6 72594453</td>
<td>+39 6 2020519</td>
</tr>
<tr>
<td>11</td>
<td>Corsi Alessandro</td>
<td>Ministero P.T. DCSR</td>
<td>Viale Europa 192 I - 00147 Roma - Italy</td>
<td>+39 6 59583801</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Davarian Faramaz</td>
<td>Jet Propulsion Lab.</td>
<td>Mail Stop 67-204-4800 Oak Grove Drive CA 91109 Pasadena - U.S.A.</td>
<td>+1-818-3544820</td>
<td>+1-818-3930996</td>
</tr>
<tr>
<td>13</td>
<td>Davies Peter G.</td>
<td>SERC-Rutherford Appleton Laboratory</td>
<td>RCRU - Bldg. R. 25 OX11 QOX Chilton, Didcot, Oxfordshire - U.K.</td>
<td>+44 235 445565</td>
<td>+44 1235 446140</td>
</tr>
<tr>
<td>14</td>
<td>Dell'Anno Pasquale</td>
<td>Ministero P.T. DCSR</td>
<td>Viale Europa 190 I - 00146 Roma - Italy</td>
<td>+39 6 59582266</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Dellagiacoma Guido</td>
<td>CSELT</td>
<td>Via G. Reiss Romoli, 274 I-10148 Torino - Italy</td>
<td>+39-11-228-5111</td>
<td>+39-11-228-5520</td>
</tr>
<tr>
<td>16</td>
<td>Demartino Roberto</td>
<td>EUTELSAT</td>
<td>Tour Maine Montpammasse, 33-Av- du Maine F-75755 Paris - France</td>
<td>+33-1-5384877</td>
<td>+33-1-5384799</td>
</tr>
<tr>
<td>17</td>
<td>Dijk J.</td>
<td>Eindhoven University of Technology-Faculteit Elektrotechniek EH11-03 Postbus 513 NL-5600 MB Eindhoven - Netherlands</td>
<td>+31-40-473417</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fedi Francesco  
F.U.B. Fondazione Ugo Bordoni  
Viale Europa, 190  
I-00144 ROMA - Italy  
Tel. +39 6 54802110  
Fax +39 6 54804400

Gentili Amedeo  
TELECOM ITALY  
DIR. GEN DRE/PSC-RIS  
TELECOM - DIR. GEN DRE/PSC-RIS  
Via Valcannuta 250  
I-00100 Roma - Italy  
Tel. +39-6-3688-5089/3891  
Fax +39-6-36885053

Geurtz Alexander M.  
Societe Europeenne des Satellites (SES)  
Chateau de Betzdorf  
L-6815 Betzdorf - Luxemburg  
E-mail Alexander_Geurtz@aia.com  
Tel. +352-710-725-420  
Fax +352-710 725-416

Grazioso Paolo  
F.U.B. Fondazione Ugo Bordoni  
Viale Griffone  
I-40044 Bologna - Italy  
E-mail fub@promet8.cineca.it  
Tel. +39 51 846854  
Fax +39 51 845798

Iglesias Joaquin  
C.A.S.A.  
Italy  
Tel. 0336 324304  
Fax +39 6 46992197

Koukos John Alexander  
National Observatory of Athens -  
Space Research Institute  
P.O. Box 20048  
11810 Thission, Athens - Greece  
E-mail koukos@thission.iissr.noa.ariadne-t.gr  
Tel. +30-1-613-8344  
Fax +30-1-613-8340

Kubista Erwin  
I.A.S Johnanneum Research Inst.T. Angew.  
Inffeldgasse 12  
A-8010 Graz - Austria  
E-mail kub@finwpc27.tu-graz.ac.at  
Tel. +43-316-327074  
Fax +43-316-325508

Lemorton Joel J.G.  
CERT-ONERA-DERMO  
2 Avenue Edouard Belin, BP4025  
F-31055 Toulouse Cedex - France  
E-mail lemorton@onecert.fr  
Tel. +33-62-25-2720  
Fax +33-62-25-2577

Marconicchio Franco  
ASI Agenzia Spaziale Italiana  
Viale Regina Margherita 202  
I-00198 Roma - Italy  
Tel. +39 6 8567366  
Fax +39 6 856728

Marteluzzi Antonio  
F.U.B. Fondazione Ugo Bordoni  
Viale Europa, 191  
I-00145 Roma - Italy  
E-mail antonio@fub.it  
Tel. +39 6 54802116  
Fax +39 6 54804401

Marzano Frank Silvio  
Univ. La Sapienza, Dip.Ing. Elettronica  
Via Eudossiana 18  
I-00184 Roma - Italy  
E-mail fnmk@palatino1.lng.uniroma1.it  
Tel. +39-6-44585845  
Fax +39-6-4742647

Masullo Piergiorgio  
F.U.B. Fondazione Ugo Bordoni  
Viale Europa, 192  
I-00146 Roma - Italy  
E-mail giorgio@fub.it  
Tel. +39 6 54802117  
Fax +39 6 54804401

Mattiello Claudio  
CSELT  
Via G. Reiss Romoli, 274  
I-10148 Torino - Italy  
E-mail mattiello@cseLT.stet.it  
Tel. +39-11-228-5511  
Fax +39-11-228-5577

Mauri Mario  
CSTS-CNR c/o Dipartimento di Elettronica  
P.zza Leonardo da Vinci 32  
I-20133 Milano - Italy  
E-mail mauri@elec.polimi.it  
Tel. +39-2-2399-3581  
Fax +39-2-2399-3635

Miragliaotta G. Salvatore  
Ministero P.T. I.S.P.T.  
Viale Europa 191  
I-00146 Roma - Italy

Ortgies Gerd  
Deutsche Telekom AG, FTZ, FZ 233a,  
Am Kavalierssand 3, PF 100003  
D-64276 Darmstadt - Germany  
E-mail ortgies@fz.telekom.de
Welcome Address of the Day Chairman
Professor Aldo Paraboni, Politecnico Di Milano.

Ladies and Gentlemen,

It is a real pleasure for me to welcome you all in Rome for this very significant occasion to meet and resume the common work in propagation initiated many years ago, at the time of SIRIO and OTS and temporarily interrupted after the OLYMPUS end.

I deem it very important also the fact that this propagation day comes jointly with a conference concerning the application of the most recent radio technologies especially in the Ka and mm wave bands: I am sure in fact that the chances of propagation to survive will lay, now and even more in the future, in the world of applications rather than in the one of the development of basic physical sciences.

Initially this propagation day had been conceived as a symposium of two days in which a retrospective overview to our long lasting propagation activity had to share the room also with the present activity and future programs: these two items have been merged in a single day and, as a result, the agenda has become very tight.

So I pass quickly to start the works and to introduce to you, as if it were really necessary, the persons sitting around the table:

Prof. Francesco Carassa, not needing presentations, whom we all in Italy consider the father of our culture in the field of the radio and the pioneer of the main programs carried out in the field of radio propagation;

Prof. Francesco Fedi, also well known to the propagation people even if he has abandoned us since some years. Among the Francesco's many merits, scientific and technical, I am pleased to remind the commitment with which he always drew ahead propagation activity both in Italy and within many International Organizations;

Dr. Franco Marconicchio, from Italian Space Agency of (ASI), whose very rare type of expertise, technical and administrative together, made it possible the miracle, among many beaurocratic difficulties, of having the ITALSAT satellite flying in the sky in very good shape;

Dr. Jose Pedro Pojares Baptista, who represents here two merits: his own personal merits as scientist and organizer (widely acknowledged in our community) and the merits of ESA in promoting and supporting the bulk of propagation activity in Europe with the OTS and OLYMPUS programmes, through the OPEX organization and through a program of very well coordinated research activities, carried out by means of contracts with various research bodies; I would ask Pedro to convey our best wishes to Dr. Arbesser and to Prof. Brussaard, real protagonists in the European propagation scenario, who unfortunately could not join us today.

And finally I should introduce myself, but I assume that nobody of you would accept the invitation of a person you don' t even know. So I will not spend any useless word anymore and pass the floor to Prof. Carassa.

I wish you a pleasant and productive day and a good time in Rome.

Aldo Paraboni
Opening Address by Prof. Francesco Carassa  
Politecnico di Milano

Ladies and Gentlemen

It is my pleasure to welcome you in this workshop where the most advanced achievements in the field of radio propagation, obtained within the frame of concerted, pluriannual activities developed in Italy and in the Europe are presented and discussed.

The demand of transmission capacity has recently undergone a very big increase in worldwide scale due both to the new services offered and to the improvement of the technologies which rendered these services affordable to an enormous mass of consumers, not only in business environment but also for private-home use.

This has determined the necessity of larger and larger bandwidths to meet the massive demand of frequency slots.

In radio communication systems the bandwidth which can be made available is roughly proportional to the center frequency $f_c$; in its turn the communication capacity is proportional to the bandwidth and to the number of times it can be reused. When the latter number depends, as in satellite systems, on antenna directivity, the communication capacity results proportional to the frequency elevated to the power of $k$, where $k$ can reach the value of 3 in the case of constant size antennas.

It is evident from the above the relevant interest in using high frequencies when broad band systems have to be provided.

Indeed broad band communication receives high consideration to day, also in terms of information highways and broad band multimedia services.

But moving up in frequency implies to face increasing propagation difficulties due to precipitations and particularly rain. It turns out been highly positive that, sufficiently ahead in time, systematic and accurate propagation experiments have been conceived and carried out, in particular in Europe using SIRIO, OTS and, more recently, OLYMPUS and ITALSAT.

The present meeting, in which propagation experts will present new results and new ideas, takes place at the right moment and it is very appropriate that it is scheduled immediately before a Ka Utilization Conference dealing with the new applications of the 20-30 GHz band.
25 Years of Propagation in Italy
by Prof. Aldo Paraboni, Politecnico di Milano

In this short speech I wish to make the panoramic view of the Italian research in the field of Electromagnetic Wave propagation.

With the end of the OLYMPUS propagation experiment and approaching also to the end of the ITALSAT mission, the time has come to think to put at disposal to the planners of new radio systems the enormous amount of data and scientific expertise collected over the long years of research in the field of radio-propagation.

We are convinced in fact that the knowledge of propagation parameters is today the prime factor determining not only the cost but also the entire philosophy of the future radio systems, whose importance is bound to have an enormous increase in the next years, judging from the steeply increasing trend in the investments made all around the world (radiomobile, broadcasting, radio-networks, satellite constellations etc.).

Having this in mind, and aiming at convincing more and more effectively our national TLC planners, we prepared some months ago a special issue of our national journal "Alta Frequenza" devoted to the radio propagation. The issue is subdivided in two parts, a tutorial one written in Italian, according to the wishes of the journal board to preserve the nature of a scientific disclosure review, and a second part containing the most advanced scientific and technical contributions produced in Italy, written mostly in English.

A copy of the journal, which has been financially supported by the AEI (Associazione Elettrotecnica Italiana), the FUB (Fondazione Ugo Bordoni) and the Centro Studi di Elettronica e Telecomunicazioni (CSELT), is available to the participants to this meeting (courtesy of the Centro Studi Telecomunicazioni Spaziali (CSTS) and the Politecnico di Milano).

I choose as start date of my short speech the (approximate) date of birth of two fundamental experimental events in Italy: the SIRIO Satellite and the Fucino Plane propagation experiments. This happened about 25 years ago in a period characterized by the explosion of the centimetric wave technology, marked by the advent of high quality and cost effective wideband amplifiers in the K band, like the TWA and the parametric amplifier, which allowed the enormous increment of transmission capacity as required by the emerging new TLC services. Similar experiments were also undertaken outside Italy (COMSTAR, OTS and ETS), but the effort of Italy in embarking alone in such an endeavour must be certainly acknowledged.

In that period the experimental stations of Fucino, Lario and Spino d'Adda were also set up, not only to host the SIRIO experiment terminals but also other fundamental ancillary equipments like the meteorological radar and the radiometers (measurement techniques also emerging at that time).

The following slides summarize the main characteristics of the abovementioned systems (SIRIO, Piana del Fucino, Radar meteo).

What remained and remains today from these old pioneer experiments?

Has the fall-out paid off for the enormous investment made by the world and, in particular, by Italy?

My personal answer, perhaps questionable, is that the technical world of the radio had (and has today) an enormous return but, due to some historical reasons, first of all the advent of the optical fibers, only recently the importance of these long lasting propagation activities begins to be fully recognized; only today indeed it is clear to everybody that the optimum exploitation of the radio transmission is a
necessary condition to lift its marks from poor to excellent with respect to service-quality and cost-effectiveness (perhaps differently from the previous situation for which the uncertainty margins were much lower by nature and the system architecture was fixed a priori).

The substantial achievements of those years are many, but, from the standpoint of the applications the main issues deserving to be outlined are:

* the viability of the Ku bands, both in terrestrial and spatial links, still preserving availability objectives similar to the ones of the C band, without excessive increments of cost of the radio apparatus, yet reducing noticeably the size of the earth terminals in the case of satellite links, to the point of allowing the direct TV-sat broadcasting;
* the delivery of preliminary but enough accurate tools for the link budgets (prediction methods);
* the demonstration of the convenience in exploiting the Ka and mm waves showing that the enormous problems raised by these high frequencies can be faced and overcome, using the creativity and naturally knowing in great detail the medium characteristics.

In all these points the contribution of Italy has been determinant: very effective prediction tools were born in Italy and the demonstration of their effectiveness would be less convincing without the great bulk of Italian experimental results. As for the the Ka and mm waves, the ITALSAT propagation experiment undoubtedly constitutes one of the major steps towards full description of the transmission medium.

The involvement of Italy in the Ka and mm wave propagation is demonstrated also by the great commitment assumed in the realization of the earth terminals, both OLYMPUS and ITALSAT, as shown in the tables.

Today, by examining the up-dated state of the ITU-R data bank the slant-path attenuation data in Ka band are approximately 30 % of the total: this amount is probably bound to increase a little with the forthcoming ACTS data, but probably for the future the total amount of data in this band is bound to remain far from the levels reached in Ku.

As a result, for the future, we will have to face more difficult problems with less powerful means, at least in the case of satellite links.

The value of the ancillary measurements (radiometers and radars) will then increase noticeably. Also in this respect Italy has assumed, already today, a strong commitment by procuring and trying to familiarize with radiometers up to 50 GHz, very difficult to use. Naturally we hope that this experience can be, in the future, beneficial for the whole scientific and engineering community.

For time reasons I have to limit myself to the main experiences, directly related to satellite applications: this is far from covering all the research efforts made in Italy in these last years: let me just remind the very accurate Italian rain climatology, also a pioneering experience together with the ESA one, towards the global climatology (not only for rain) envisaged today (see related table..). Also the experiences in the field of terrestrial propagation are very numerous; they include both LOS links experiencing digital transmission, and long-lasting extensive ground-wave propagation measurements finalized to mobile applications. For this latter in particular you will hear from following speakers.

Last but not least it is worth reminding the basic theoretical propagation activities undertaken in Italy (often in cooperation or with the support of foreign Administrations) aiming at clarifying the physical and statistical aspects of many phenomena encountered in the propagation context, and at bringing the obtained results as near as possible to the application.
SCHEDA N. 1: L'esperimento di propagazione SIRIO
(F. Carassa, A. Paraboni)

Posizione orbitale: geostazionaria 15° gradi Ovest (successiv. spostato a 65° Est)
Frequenze: 11.6, 17.2 e 17.8 GHz
Polarizzazione: circolare
EIRP 19 dBW a 11.6 Ghz (down link)
         96 dBW (max.) a 17.2 e 17.8 GHz (up link)
Data del lancio: settembre 1977
Durata dell'esperimento: 5 anni senza soluzione di continuità
Misure possibili: attenuazione del segnale ricevuto alle 3 frequenze
depolarizzazione
scintillazioni di segnale
distorsione di ampiezza e fase su una banda di 500 MHz
temperatura di rumore, radar meteo, intensità piovosa
Misure contestuali
Stazioni riceventi in Italia:
         Fucino, Gera Lario, Spino d'Adda e Roma
Partecipazione di sperimentatori stranieri: Inghilterra, Francia, Germania, Olanda, Stati Uniti, Cina
Ente di appartenenza
         Consiglio Nazionale delle Ricerche (CNR)
Ente responsabile della progettazione e gestione
         Centro Studi Telecomunicazioni Spaziali (CSTS/CNR)
Il Centro Sperimentale della Piana del Fucino consente di eseguire misure radioelettriche e metereologiche su di un'area di circa 100 kmq. È costituito da:

- **un impianto**
- **quattro allineamenti** di circa 10 km per le misure metereologiche con:
  - 54 pluviometri a risposta rapida, per le misure di intensità di precipitazione;
  - 5 anemometri per misure di velocità e direzione del vento;
  - un termometro, barometro e igrometro per misure di temperatura, pressione e umidità;
  - un distrometro per misure di distribuzione del diametro delle gocce;
- **sette radiocollegamenti** a 11,18 e 30 GHz
- **un sistema** di trasmissione, acquisizione e registrazione dei dati su nastro magnetico
- **un radiometro**
### ANTENNA

<table>
<thead>
<tr>
<th>Caratteristica</th>
<th>Valore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riflettore</td>
<td>parabolico</td>
</tr>
<tr>
<td>Diametro</td>
<td>3.6 m</td>
</tr>
<tr>
<td>Polarizzazione</td>
<td>verticale</td>
</tr>
<tr>
<td>Guadagno</td>
<td>37.5 dB</td>
</tr>
<tr>
<td>Larghezza di fascio</td>
<td>2 gradi a - 3dB</td>
</tr>
<tr>
<td>Livello del primo lobo laterale</td>
<td>- 20 dB</td>
</tr>
<tr>
<td>Velocità massima di rotazione azimutale</td>
<td>5.5 rpm</td>
</tr>
<tr>
<td>Tempo di recupero</td>
<td>&lt; 2 μs</td>
</tr>
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### TRASMETtitore

<table>
<thead>
<tr>
<th>Caratteristica</th>
<th>Valore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequenza</td>
<td>2800 MHz</td>
</tr>
<tr>
<td>Potenza di picco</td>
<td>500 KW</td>
</tr>
<tr>
<td>Durata dell’impulso</td>
<td>0.5 μs</td>
</tr>
<tr>
<td>Frequenza di ripetizione degli impulsi</td>
<td>456 pps</td>
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</table>

### RICEVITORE

<table>
<thead>
<tr>
<th>Caratteristica</th>
<th>Valore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figura di rumore</td>
<td>3.5 dB</td>
</tr>
<tr>
<td>Amplificatore a frequenza intermedia</td>
<td>logaritmico</td>
</tr>
<tr>
<td>Freqenza intermedia</td>
<td>30 MHz</td>
</tr>
<tr>
<td>Larghezza di banda a frequenza intermedia</td>
<td>10 MHz</td>
</tr>
<tr>
<td>Dinamica</td>
<td>80 dB + entro 1 dB di linearità</td>
</tr>
</tbody>
</table>

*Caratteristiche tecniche del Radar Metereologico operante presso la stazione di Spino d’Adda*
<table>
<thead>
<tr>
<th><strong>Posizione orbitale:</strong></th>
<th>geostazionaria 13.2° Est</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequenze:</strong></td>
<td>18.68, 39.59 e 49.49 GHz</td>
</tr>
<tr>
<td><strong>Polarizzazioni:</strong></td>
<td>Verticale per il 20 GHz, circolare per il 40 GHz (modulata a ± 505 MHz), verticale ed orizzontale (commutata a 933 Hz) per il 50 GHz.</td>
</tr>
<tr>
<td><strong>EIRP:</strong></td>
<td>20 dBW a 20 GHz</td>
</tr>
<tr>
<td></td>
<td>28 dBW a 40 GHz</td>
</tr>
<tr>
<td></td>
<td>25 dBW a 50 GHz</td>
</tr>
<tr>
<td><strong>Data del lancio:</strong></td>
<td>16 gennaio 1991</td>
</tr>
<tr>
<td><strong>Durata prevista dell'esperimento:</strong></td>
<td>7 anni</td>
</tr>
<tr>
<td><strong>Misure possibili:</strong></td>
<td>attenuazione del segnale ricevuto alle 3 frequenze</td>
</tr>
<tr>
<td></td>
<td>depolarizzazione alle 3 frequenze</td>
</tr>
<tr>
<td></td>
<td>completa identificazione del canale a 50 GHz</td>
</tr>
<tr>
<td></td>
<td>scintillazioni di segnale</td>
</tr>
<tr>
<td></td>
<td>misure di fase interbanda</td>
</tr>
<tr>
<td></td>
<td>distorsione di ampiezza e fase a 40 GHz su una banda di ± 505 MHz.</td>
</tr>
</tbody>
</table>

**Misure contestuali**
- temperatura di rumore, radar meteo, intensità piovosa

**Stazioni riceventi in Italia:**
- Spino d'Adda (Milano), Torino, Pomezia (Roma)

**Partecipazione di sperimentatori stranieri:**
- Inghilterra, Germania, Olanda, Spagna, Austria, ESA

**Ente di appartenenza:**
- Agenzia Spaziale Italiana (ASI)

**Ente responsabile della progettazione e gestione:**
- Centro Studi Telecomunicazioni Spaziali - CNR
Il radiometro è uno strumento che misura la temperatura di rumore associata all'emissione di energia elettromagnetica da parte di gas, nuvole e idrometeore presenti lungo il fascio dell'antenna. Sotto l'ipotesi di atmosfera in equilibrio termico locale, vale il principio di Kirchoff, il quale afferma che la quantità di energia assorbita eguaglia quella di energia emessa. Le misure radiometriche sono pertanto direttamente legate al fenomeno dell'assorbimento e consentono quindi di valutare il contributo dei costituenti dell'atmosfera al valore di attenuazione subito da un segnale elettromagnetico che si propaghi lungo la direzione di puntamento dell'antenna radiometrica.

L'attenuazione atmosferica si ottiene dalla misura della temperatura di brillanza ($T_b$) del cielo mediante la nota relazione:

$$A = 10 \log_{10} \left( \frac{T_m - T_c}{T_m - T_b} \right) [dB]$$

in cui $T_m$ è la temperatura radiante dell'atmosfera, $T_c$ è la temperatura di rumore del cosmo.

Esistono attualmente in Italia circa 7-8 radiometri a microonde.

A titolo di esempio si riporta la situazione relativa alla stazione sperimentale del CNR di Spino d'Adda che ospita attualmente 3 radiometri: uno operante a 13 GHz, uno a doppio canale in banda 20/30 GHz e il terzo con tre bande di frequenza intorno a 20, 30 e 50 GHz.

L'apparato è generalmente costituito da quattro sotto-moduli: sezione d'antenna, sezione ricevente, sistema di puntamento, sistema di gestione dati. Di seguito vengono riportate le caratteristiche tecniche più significative.

<table>
<thead>
<tr>
<th>frequenza [GHz]</th>
<th>13</th>
<th>22.2</th>
<th>23.8</th>
<th>31.65</th>
<th>50.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>risoluzione [K]</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>accuratezza [K]</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>apertura del fascio d'antenna [deg]</td>
<td>1.8</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>larghezza banda del ricevitore [MHz]</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>200</td>
<td>250</td>
</tr>
</tbody>
</table>
### SCHEDA N. 8: L'esperimento di propagazione OLYMPUS

(M. Mauri - A. Paraboni)

<table>
<thead>
<tr>
<th>Posizione orbitale:</th>
<th>geostazionaria 19° Ovest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequenze:</td>
<td>12.5, 19.77 e 29.65 GHz</td>
</tr>
<tr>
<td>Polarizzazioni:</td>
<td>Verticale per 12 e 30 GHz, verticale ed orizzontale (commutata a 933 hz) per il 20 GHz.</td>
</tr>
<tr>
<td>EIRP:</td>
<td>11 dBW. a 12.50 GHz</td>
</tr>
<tr>
<td></td>
<td>26 dBW. a 19.77 GHz</td>
</tr>
<tr>
<td></td>
<td>24 dBW a 29.65 GHz</td>
</tr>
<tr>
<td>Data del lancio:</td>
<td>12 luglio 1989</td>
</tr>
<tr>
<td>Durata dell'esperimento:</td>
<td>4 anni (escluso il periodo giugno-agosto 1991)</td>
</tr>
<tr>
<td>Misure possibili:</td>
<td>attenuazione del segnale ricevuto alle 3 frequenze depolarizzazione alle 3 frequenze completa identificazione del canale a 19.77 GHz scintillazioni di segnale misure di fase interbanda</td>
</tr>
<tr>
<td>Misure contestuali</td>
<td>temperatura di rumore, radar meteo, intensità piovosa</td>
</tr>
<tr>
<td>Stazioni riceventi in Italia:</td>
<td>Spino d'Adda (Milano), Torino, Pomezia (Roma) più 25 stazioni riceventi solo a 20 GHz</td>
</tr>
<tr>
<td>Partecipazione di sperimentatori stranieri:</td>
<td>Europa, Stati Uniti, Brasile</td>
</tr>
<tr>
<td>Ente di appartenenza</td>
<td>Agenzia Spaziale Europea (ESA)</td>
</tr>
<tr>
<td>Ente responsabile della progettazione e gestione</td>
<td>Agenzia Spaziale Europea (ESA)</td>
</tr>
</tbody>
</table>
The Role of Italy in International Organizations in the field of Radiopropagation

Francesco FEDI

Symposium on "Italian Propagation Day"

Ministero Poste e Telecomunicazioni

Roma, October 9, 1995

Dear Colleagues, Ladies and Gentlemen it is indeed a great pleasure for me to be here with you today to speak about the rôle of Italy in International Organizations in the field of radiopropagation. More than a formal presentation I would like this to be a conversation among friends to review some of the most important achievements of the Italian scientific community. I will also try to make some jokes in order not to take ourselves too seriously.

Due to the very short time at my disposal I have to put two strict boundary conditions to my talk. The first is the number of international organizations that I will mention: only COST, URSI and ITU. The second boundary condition is the limit to the period of time that I will review. Only the last 25 years. So all my stories will start approximately in the late sixties and will end up today.

Let us start with COST [1]. If somebody in the audience still does not know that COST is an acronym for "Coopération européenne dans le domaine de la recherche scientifique et technique" (European Cooperation in the field of Scientific and Technical Research) perhaps he has chosen the wrong room.

Jokes aside, I am sure that you remember that COST cooperation was a result of an intense preparatory work carried out in the late sixties. That was the time in which Europe was carefully considering its rôle in comparison to the USA. The book written in that period by the famous French journalist Jean Jacques Servan Schriber "Le défé Americain" (The American Challenge) is indeed a sign of the pressure of that time. The six countries then belonging to the European Community decided that the first step to cope with this challenge was to cooperate in the field of Science and Technology and to open this cooperation to other 13 European countries.

Italy was one of the most strenuous supporter of this cooperation and very actively participated in the preparatory work. I still remember the frantic meetings we had in the Italian delegation in Brussels where we “father founders” of COST prepared the ground for the
launching of the first projects. I was in the very good company of many colleagues who are still active in this field: Professor Riedler from Austria, Professor Brussaard from the Netherlands, Professor Grilo from Portugal, just to name a few.

Of the three projects launched in the Telecommunication sector, COST 25/4 was indeed the one with the largest participation: 13 countries and 2 associated participants (UK and ESA). The project concentrated on “Terrestrial radiopropagation at frequencies above 10 GHz” and lasted from 1972 to 1978 [2].

Italy had an important role in the launching and the coordination of this action. I enjoyed the pleasure of being the Chairman of this project since very beginning and Italy had one of the most important experiments consisting in a network of radiolinks and associated raingauges in the Fucino plain, in the centre of this country [3].

In addition to the well known advantages common to all projects in the framework of COST cooperation, project 25/4 provided unique advantages. These can be summarized as follows:

1. the project produced the first reliable comprehensive data base of radiopropagation and associated meteorological data above 10 GHz for terrestrial links;
2. the project unified the procedures for the comparison of the results obtained. The establishment of a reliable data base and of the unification of the procedures for model testing was a COST “trademark” which was very usefully later exported and luckily became common practice in the ITU;
3. the project gradually contributed to the establishment of a European tradition and culture in radiopropagation which made Europe one of the most important centre of these studies [4,5]. Before project COST 25/4 certainly USA had been the most important centre for radiopropagation studies. I remember there were people in Europe who had in their libraries the Bible, the Gospel and the Bell System Technical Journal. When Europe could build its own experience on various aspects, including for instance the famous widely-advertised american capacitor raingauges, many people decided to keep only the Gospel and the Bible.

At the end of the project, COST appeared to be a very suitable framework to study radiopropagation above 10 GHz on earth-satellite paths. At that time there were two satellites in the European sky: the European OTS and the Italian SIRIO. Many research centres were receiving both satellites but there was no centralized forum for a unified exchange of the results obtained. It was decided therefore to launch the new COST project 205. Italy had again an important rôle. I still remember that the relevant Memorandum of Understanding concluded
that the chairmanship of the project should be assigned to Italy "for having generously provided the Italian SIRIO satellite and its results and for having ensured the chairmanship of the past project in a highly satisfactory manner" [6].

So I was the designated victim again and I had the pleasure of being Chairman of this new project which lasted from 1978 to 1985 and ended with a Symposium in Capri that many people still remember.

The project utilized a remarkable experimental set-up which had no comparison with any other experiment in any other part of the world: 19 OTS and 6 SIRIO receiving stations, 13 radiometers and 2 meteorological radars together with associated networks of raingauges.

A very comprehensive reliable data base was produced. With this data base various prediction models were assessed. The results obtained substantially contributed to CCIR Recommendations.

At the end of the project propagation studies successfully continued in the framework of COST. Since the coordination of two COST projects is more than enough in one man's life I was very glad to leave the heritage of this tradition in the very good hands of other European colleagues. The scientific community of Italy, i.e. the CTS of the National Research Council, the Politecnico of Milan, CSELT, Fondazione Bordoni and some Universities, continued to actively participate in the subsequent COST projects and I do hope that this tradition could continue in the future.

The second Organization I promised you to mention is URSI, the International Union of Radio Science.

In early 70's Italy had the important heritage of Professor Boella who had been URSI Vice President from 1966 to 1969. But as far as radiopropagation was concerned we had to wait the late 70's to see the Italian scientific community playing an important rôle in the international arena.

We started in the IUCRM Symposium in Nice in 1973 [7] and continued in the URSI Commission F Symposium in La Baule in 1977 [8,9] organized by the never forgotten Monsieur Pierre Misme of France. Subsequently, we were actively involved in the organization of the Symposium in Canada in 1980 [10]. In 1981 Italy had the honour to be assigned the Vice-Chairmanship of the URSI Commission on "Radiowave Propagation and Remote Sensing" and subsequently the Chairmanship of the same Commission until 1987. Since then, the scientific Italian community has played an important rôle in all URSI activities [11,12].

Also in the case of ITU the story begins in the early 70's when I participated for the first time to a CCIR meeting which at that time was held in Palais Wilson in Geneva.
Study Group 5 (Radiopropagation in non-ionized media) was under the authoritative chairmanship of Dr. Saxton from the U.K. Present at that meeting were legendary names of scientists as Middleton, Misme, Boithias, Crane, just to name a few.

I had to present the results we had obtained in Italy for UHF propagation over the Mediterranean sea, results that, since then, constituted an important part of CCIR Recommendations [13]. But at that time Italy did not have a very strong delegation. So I remember that I had been advised to go to Paris in order to seek the support of the French delegation, before going to Geneva.

Year after year the Italian scientific community conquered the esteem of the other colleagues. It was therefore much easier in 1981 when I presented a short document describing a new very simple method to predict rain attenuation on terrestrial and earth satellite paths [14]. The most important research centres around the world had worked on this subject for years and, naturally, every centre had its own model. The Italian method was very carefully tested and the intellectual honesty of the various CCIR colleagues made it possible that my method could be chosen as the one to recommend for the design of terrestrial and earth-space links worldwide.

And for the past 15 years it has resisted to the attacks: it is still is there only slightly modified! [15].

This of course is not the only contribution of the Italian scientific community. Many of the ITU Recommendations on various aspects of radiopropagation utilize results obtained in this country. Cross-polarization models and radiometer studies are some of the examples which can be made [16, 17, 18, 19].

During my ITU activities I succeeded not only in presenting the results obtained by the scientific community of this country but in physically carrying part of the Italian Science to Geneva. Prof. Paraboni was one of these Italian victims. I still remember one of his first meetings when he was surrounded by Mr. Boithias on one side and Dr. Lane on the other side who did not agree with some of his conclusions. We had dinner together that evening: Aldo was quite depressed and wanted to leave Geneva. I had to use all my convincing skills to make him continue in CCIR work and you would agree with me that all these efforts of mine were really worthwhile since after that he became a star of the ITU radiopropagation community and shared with me some of the responsibilities of representing the scientific community of this country.

In addition to the acceptance of our results, Italy had also other formal achievements. The Chairmanship of Working Party on Radiometeorology in 1976, the ITU "diplome d'honneur" in 1989, the Vice Chairmanship of Commission 5 in 1985, and the Vice
Chairmanship of the new Commission 3 which resulted in 1993 from the merging of the Commission on ionospheric propagation and of the Commission on propagation in non-ionized media.

I do think that what we have built in these 25 years is important for this country and for Europe as a whole. Most of the merit has to be given to the long-term vision of some of our "maestri", as we say in Italy, as Professor Carassa and Professor Peroni. It would be a pity if this culture could not be maintained in the future. Luckily in this room I see, in addition to old friends, also young people and I do hope that these young colleagues could maintain the tradition which we have established in the past 25 years.

As I mentioned at the beginning of this conversation it has been a great pleasure for me to have been invited here this morning. For at least two main reasons.

The first is that this gave me the opportunity to go back with my memory to a very active and stimulating period of my life: everybody is very pleased when he can speak a little bit about himself. The second, and more important, is that it gave me the possibility of meeting again so many old friends.

And I would like to conclude my presentation thanking very much Professor Paraboni for giving me this opportunity and all of you for your very kind attention.

References


REPORT ON THE ITALSAT F1 SPACECRAFT STATUS

by

C. Portelli (ASI)
ITALSAT PROGRAM

STATUS

* FIRST ITALSAT UNIT (F1) WAS SUCCESSFULLY LAUNCHED ON JANUARY 15, 1991 FROM KOUROU FRANCE GUYANA WITH AN ARIANE 4 LAUNCHER;

* THE SATELLITE REACHED ITS FINAL GEOSTATIONARY POSITION AT 13.2° EAST ON THE 6th OF FEBRUARY 91;

* ITALSAT F2 CONTRACT HAS BEEN AWARDED AND THE SPACECRAFT IS EXPECTED TO BE READY BY THE END OF 1995;

* ITALSAT F1 IS IN OPERATION;


PROPAGATION PAYLOAD (PP) MAIN CHARACTERISTICS

- ONE REDUNDANT 40 GHz PHASE MODULATED BEACON, 1W RF POWER
- ONE REDUNDANT LINEAR POLARIZED 50 GHz BEACON WITH POLARIZATION SWITCH (VERTICAL/HORIZONTAL), 1W RF POWER
- TWO ANTENNAS WITH EUROPEAN COVERAGE AS PER FOLLOWING FIGURE
ITS F1 SPACECRAFT LIFE:

NOMINAL EXPECTED END OF LIFE (EOL) COMPUTED BY USING THE ACTUAL AVERAGE PROPELLANT CONSUMPTION RATE, IS FORESEEN BY SEPTEMBER 97.

IF THE PROPELLANT SAVING OPTION (WHICH IMPLIES NO MORE N/S STATION KEEPING = 93% OF PROP SAVING) AT THE LAST YEAR OF LIFE WILL BE SELECTED, THEN THE EXPECTED EOL IS MAINLY AFFECTED BY OTHER S/S LIFE (i.e. THERMAL CONTROL & SOLAR ARRAY) AND WILL LAST AT LEAST 3 YEARS MORE.
STATUS OF 40/50 GHz PROPAGATION PAYLOAD

⇒ NO FAILURE OCCURRED DURING COMMISSIONING AND GROUND STATION ACCEPTANCE TEST WHERE BOTH PAYLOAD CHAINS HAVE BEEN TESTED.

⇒ ONLY ONE ANOMALY DETECTED:
AUTONOMOUS SWITH OFF 5/6 TIMES PER YEAR WHICH HAS TO BE CORRECTED BY GROUND COMMAND (1 MIN. FOR REACTIVATION)

⇒ BOTH CHAIN (MAIN & REDUNDANT) ARE FULLY OPERATIVE.

Hp. FOR INCREASED PROPAGATION EXPERIMENTATION PHASE

THE OPTION IS UNDER STUDY AND HAS NOT BEEN FINALISED YET.

AVERAGE PROPELLANT CONSUMPTION RATE ASSUMED CONSTANT FOR THE REMAINING PERIOD.

DEORBITING PROPELLANT & ITS F1/F2 POSITIONING SWAP PROPELLANT NEEDS CONSIDERED.

ROLL DAILY CONTROL & E/W ON STATION CONTROL TO MAINTAIN S/C ANTENNAS BORESIGHT.

N/S ANGULAR RATE INCREASE IS 1 DEGREE/ YEAR WITH DAILY FREQUENCY.
RADAR AND BEACON MEASUREMENTS
FOR ADVANCED SYSTEMS BEYOND 10 GHz

Prof. Carlo Capsoni
Politecnico di Milano

HIGH AVALIABILITY SYSTEMS:
ATTENUATION

- BASIC INPUT FOR TELECOMMUNICATION SYSTEMS DESIGN
- RESULTS BASED ON DIRECT MEASUREMENTS FROM SATELLITES
  - SIRIO (11.6 17.8 GHz)  Fucino, Lario, Spino
  - OLYMPUS (12.5 19.77 29.66 GHz)  Pomezia, Spino, Torino
  - ITALSAT (18.68 39.59 49.49 GHz)  Pomezia, Spino, Torino
- LONG TERM STATISTICS
- SITE VARIABILITY
- YEAR TO YEAR VARIABILITY
- WORST MONTH
- HOURLY VARIABILITY
- FREQUENCY SCALING
- CORRELATION WITH OTHER PROPAGATION IMPAIRMENTS
Cumulative distribution of attenuation at 12.50 and 19.77 GHz (vertical polarisation) for the OLYMPUS station in Spino d'Adda (1 August 1992 - 8 August 1993)

Cumulative distribution of attenuation at 18.68, 39.59 and 49.49 GHz for the ITALSAT station in Spino d'Adda (January - December 1993)
The images show two graphs, each with a probability axis on the left and an attenuation axis on the right. The graphs compare different models and years:

- **Left Graph**
  - **X-Axis**: Attenuation [dB]
  - **Y-Axis**: Probability [%]
  - Models: FUCINO, LARIO, SPINO

- **Right Graph**
  - **X-Axis**: Attenuation [dB]
  - **Y-Axis**: Probability [%]

The graphs illustrate the variation in probability with different models and years for a given attenuation level.
Worth month statistic of copolar attenuation at 12.50 and 19.77 GHz (vertical polarisation) for the OLYMPUS station in Spino d'Adda.
OLYMPUS station in Spino d'Adda: mean value of the ratio between attenuation at 30 and 20 GHz (solid line) with ±1 standard deviation (dotted lines) versus attenuation at 20 GHz (1 August - 9 October 1992)

DEPOLARIZATION

- THEORY
  - GENERAL THEORY
  - SIMPLE MODELS
  - EQUIORIENTED DROPS
  - RANDOMLY ORIENTED DROPS
  - STRATIFIED MODEL
  - DEFINITION OF THE OPTIMUM SET OF MEASUREMENTS AND WAVE POLARIZATION TO BE USED TO DETERMINE THE DEPOLARIZING PROPERTIES OF THE MEDIUM (OLYMPUS ITALSAT)
  - SEPARATION OF THE CONTRIBUTIONS OF RAIN FROM THAT OF ICE ALOFT
DEPOLARIZATION

• MEASUREMENTS
  - SIRIO
  - OLYMPUS
  - PRATO SMERALDO
  - ITALSAT

RADAR ACTIVITY

• STRUCTURE OF PRECIPITATION
  - HORIZONTAL EXCELL MODEL
  - VERTICAL IN PROGRESS
  - MORPHOLOGY
  - SPACE/TIME CORRELATION OF RAIN

• MICROPHYSICS
  - RELATIONSHIP TO CONVERT Z into $\gamma$ or R
  - DETERMINATION OF N(D) from $\gamma$ and A

2.6
registrazione radar TOTHELE piano orizzontale ad una altezza media iniziale di 1 Km
nastro n. 732 2-9-1994 7:19 piano 130 distanza massima 141,6 km
Fig. 18 a - Attenuation time profile, Aug. 24, 1980.

Fig. 18 b - Scatter-plot related to Fig. 18 a.
RADAR ACTIVITY

- SIMULATIONS
  - ATTENUATION
  - SITE AND ORBITAL DIVERSITY
  - INTERFERENCE DUE TO RAIN SCATTER

- RADAR UPGRADEING
  - DOPPLER
  - UNATTENDED, REMOTE CONTROLLED, OPERATION
  - DUAL POLARIZATION
Fig. 2 Conditioned distributions of attenuation at 11.6 GHz jointly exceeded on two parallel paths as a function of site distance.

Fig. 3 Site diversity gain as a function of paths separation and single link attenuation (attenuation increases from 1 to 10 dB from bottom to top).
Propagation parameters for low availability satellite systems

Francesco Barbaliscia - FUB

The present technological evolution in microwave components has allowed the development of user-oriented terminal networks for satellite communication systems operating at frequencies above 10 GHz. These systems, called Very Small Aperture Terminals (VSATs), operate with a gain margin lower than that required by the terrestrial terminals normally used in national telecommunication networks. Hence VSATs are characterized by a reduced availability of the radio channel that must be verified as well as information on link quality should be provided.

These terminals can be very sensitive to the propagation effects due to the gaseous atmospheric components (oxygen and vapor), to the suspended water particles contained in clouds and to the light rains. These atmospheric phenomena cause attenuation and phase delay of the electromagnetic wave, increase of the sky noise temperature received by the antenna, scintillations of the signal level and interferences between communication channels due to cloud ice depolarization. These effects become more important as the technology enables the evolution from the present 20/30 GHz to the 40/50 and 90 GHz frequency bands.

A great wealth of theoretical and experimental studies has been performed to describe the propagation parameters for radiocommunication systems by means of accurate physical models. In particular models for the computation of the refractive index of the atmospheric gaseous components and for the extinction efficiency of the atmospheric particles are available in literature. The meteorological parameters used by the propagation models can be obtained from the meteorological data banks for long observation periods. In this way the application of the theoretical models to the meteorological data set allows the computation of the statistical information needed to the development of the probabilistic models of the propagation parameters.

In the framework of the research activity of FUB radiopropagation group deep attention has been focused on that topic since late 80's. Theoretical studies have been pursued as well as radiometric measurements and systematic collection of the relevant radiometeorological data. More recently a world-wide characterisation of the parameters relevant to atmospheric propagation in the absence of rain was carried out under Contract to ESA-ESTEC. The frequencies of interest ranged from microwaves to infrared and visible. The main objective of the work is to develop tools for the design of satcom systems (specially low availability services) and remote sensing applications.
For this purpose high numbers of atmospheric vertical profiles were acquired and analysed, an extensive data base of both upper-air and surface meteorological measurements was setup to allow the calculation of propagation parameters using appropriate models. Models were developed to perform both fully physical and simplified calculations of the electromagnetic parameters. As a demonstration the models were applied to evaluate different telecommunication and remote sensing missions in both the microwave and infrared regions. A characterisation in terms of climatic zones of the resultant propagation parameters was also carried out, producing a world-wide mapping. A first attempt at algorithms to scale propagation parameters in frequency was also performed.

Bibliography


FUB
RADIOPROPAGATION ACTIVITY

ACTIVE SINCE EARLY 70s
COST 25/4, COST 205, COST 210, OPEX
FUCINO, SIRIO, OTS, OLYMPUS, ITALSAT

PRESENT ACTIVITY
RADIOMETEOROLOGY
ATMOSPHERIC RADIOMETRY
10 - 50 GHz SATELLITE CHANNEL
SYSTEM APPLICATIONS

PROPAGATION PARAMETERS
IN 40/50 GHz BANDS
DESIGN COUNTERMEASURES
IN 20 GHz BANDS

FUB RADIOPROPAGATION GROUP

TOPICS OF INTEREST/EXPERTISE

ATMOSPHERIC MODELLING
LOW AVAILABILITY SISTEMS PARAMETERS
MAPPING OF CLIMATIC PARAMETERS

SPACE BASED DIVERSITY
RAIN AND OTHER CONSTITUENTS
SHORT-SCALE COUNTERMEASURES
LARGE SCALE ON-BOARD RESOURCES

DEPOLARISATION BY RAIN
FREQUENCY RE-USE
MODELLING PHYSICAL PARAMETERS
ICE EFFECTS

SCATTER BY HYDROMETEORS
COORDINATION AREA
RAIN CELLS MODELLING
SIMULATED COMPLETE STATISTICS
SCATTER FROM HYDROMETEORS
XPD PHYSICAL PARAMETERS
LARGE/SHORT SCALE DIVERSITY
MAP/LOWTRAN/HITRAN UP-DATE

SOFTWARE TOOLS

1288/324/72(Europe) SITES RADIOSONDE
50 SITES IN ITALY

CLIMATIC DATA BASE
4 YEARS/2 RADAR METERS AT 23/31 GHZ

RADAROMETRIC DATA

2 STATIONS AT 20 GHZ
ITALSAT: 1 STATION AT 18/40/50 GHZ
OLYMPUS: 4 STATIONS 1 YEAR AT 20 GHZ

SATELLITE DATA

HARDWARE/SOFTWARE TOOLS

GENERAL FEATURES

LOW AVAILABILITY SYSTEMS

ADVANTAGES

LOW PRIORITY
REDUCED AVAILABILITY (90 - 99%)
LOW MARGIN (1 - 5 DB)

DISADVANTAGES

FLEXIBILITY
TRANSFORMABILITY
LIMITED DIMENSIONS/COSTS

ADVANTAGES

BUSINESS
EMERGENCY
EDUCATION
ELECTRONIC MAIL
NEWS DISSEMINATION
DATA TRANSMISSION
REDUCED AVAILABILITY TELEPHONE SERVICES
PARAMETERS:

- Frequency     ASSIGNED
- Elevation     FIXED
- Earth station  HIGH COSTS

Availability: manageable by an acceptable lowering of availability values: 1 to 5% of outage time

PROPAGATION MARGINS:

2 dB at 20 GHz / 5 dB at 30 GHz for 99% availability time for small business terminals in a temperate climate
FUB RADIOPROPAGATION GROUP

ATMOSPHERIC ABSORPTION

MODEL - ORIENTED
INDIVIDUAL CONSTITUENTS
GASES: WATER VAPOUR, OXYGEN
HYDROMETEORS: WATER CLOUDS
SPACE - TIME FEATURES

SYSTEM - ORIENTED
LOW MARGIN SYSTEMS
ORBITAL DIVERSITY
SITE DIVERSITY

STUDY TOOLS
RADIOMETRIC MEASUREMENTS
RADIOSONDE DATA
THEORETICAL MODELS
SIMPLIFIED MODELS
ATTENUATION DUE TO COMPONENTS OTHER THAN RAIN

**OXYGEN**
- strong peak around 60 GHz
- negligible for $70 < f < 50$ GHz

**WATER VAPOUR**
- weak peak around 22 GHz

**CLOUD LIQUID DROPLETS**
- continuum absorption
- relevant for $f > 30$ GHz
MASS ABSORPTION COEFFICIENTS
FROM
INVERSION COEFFICIENTS

I = c_0 I + c_1 A_1 + c_2 A_2

\[ \lambda = c_0 \lambda + c_1 \lambda_1 + c_2 \lambda_2 \]

INVERSION

A_2 = A_02 + \alpha A_2^2

A_1 = A_01 + \alpha A_1^2

f_2 = 31 - 36 \text{ GHz}

f_1 = 21.3 / 23.8 \text{ GHz}

CHOICE OF APPROPRIATE FREQUENCIES

DUAL-CHANNEL RADIIOMETERS

ESA CONTRACT STUDY

PUB RADIOPROPAGATION GROUP

RETRIEVAL OF ATMOSPHERIC WATER CONTENTS

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PUB RADIOPROPAGATION GROUP

RETRIEVAL OF ATMOSPHERIC WATER CONTENTS
THEORETICAL ATTENUATION

Average CD of total and clear sky attenuation for several frequencies
Overview of Italian research activities on propagation in cellular radio systems

Paolo Grazioso
Fondazione Ugo Bordoni
40044 Pontecchio Marconi BO
Italy
tel. +39 51 846854 - fax +39 51 845758 - e-mail fub@promet8.cineca.it

Outline of the presentation

In this short presentation we will briefly illustrate the main topics of research on propagation in mobile radio systems currently studied by Fondazione Ugo Bordoni (FUB) and University of Bologna in the joint laboratory of Pontecchio Marconi. This research has been carried out in close co-operation with CSELT. These activities were partly performed in the framework of European programmes, such as RACE 1043, COST 207, and COST 231.

The main environments considered are rural and suburban outdoor (characterised by large cells), metropolitan outdoor (with small cells and microcells), and indoor (with picocells). Each of these environments needs to be characterised in a different way.

Outdoor propagation in open and suburban areas

This work has been carried out in close co-operation between CSELT and FUB. The prediction methods for this kind of environments generally require a terrain height data-base. FUB carried out an extensive study to determine, given a height profile between a transmitter and a receiver, which obstacles (if any) give a significant contribution to diffraction loss, and which ones should be neglected. On the other hand CSELT developed a powerful prediction tool which can be extensively used in cell planning of real systems.

It is well known that diffraction loss due to an ideal knife-edge obstacle follows the relationship with the Fresnel parameter shown in next transparency. The problem with more complex height profiles is how to combine the contributions due to several obstacles. FUB carried out a comparison among some methods proposed in literature: as an example, next slide reports a comparison of four such methods with measured data as a function of the number of obstacles. We can note that two methods give satisfactory accuracy, while the other two tend to over-estimate the diffraction loss with three or more obstacles.

Coming to the CSELT planning tool, next slide shows its functional block diagram. We note among other components height and land usage data-bases. The simulation results can be compared with measurements, and a graphical presentation tool is helpful in the interpretation of results. Next transparency shows a representation of the area of Messina strait, as extracted from the height data-base. The following slide shows field strength measurement results for a single base station, while the following one depicts a more complex situation, with a large number of base stations covering a whole city.

Also wideband parameters are important in a system planning. For instance, next slide shows a measured power delay profile in Line of Sight (LOS) conditions.

Outdoor propagation in metropolitan areas

Methods based on height data bases are not sufficient when a detailed, small scale prediction is required. Therefore, we have developed a prediction method based on a simplified 3D ray tracing algorithm. A so called vision algorithm was developed to speed up the search of significant rays. The propagation above the rooftop is considered as well, and its contribution to field strength is added to that obtained with the ray tracing algorithm. The tool is also able to evaluate wideband
parameters, and can be easily adapted to study other environments (e.g. TV broadcasting, 60 Ghz frequency band, etc.).

The following slide shows the vision algorithm principle: a tree of objects (walls and edges) that can be seen from a virtual transmitter after each reflection or diffraction is built. Then contributions associated to each ray are evaluated. The complexity and accuracy of the evaluation are of course dependent on the number of levels considered.

The following two slides show the number of rays that must be taken into account in realistic environments: in the first case the transmitter height is below the average building heights (in this case we have a microcell), while in the second slide the base station is placed on the roof of one building (this yields a so-called “small cell”).

These evaluations must be repeated for every position of the mobile station, in order to determine the field strength behaviour along a street path. Next transparency shows a mobile path in a street in central Turin; the transmitter is in another street, and they intersect with an angle of 62°. We see in the next slide that the simulation made with the FUB algorithm follows accurately the measurement results provided by CSELT. It is also worth noting that the slopes on the two sides of the maximum are different: this is due to the non-right angle of intersection between the two streets. As a matter of fact, we see in the next example that the slopes on the two sides are equal: in this case the streets between transmitter and receiver are perpendicular.

**Indoor propagation**

For this study, performed in co-operation between FUB and the University of Bologna, we developed another software tool. The number of levels (reflections and/or diffractions) required in indoor ray tracing procedures is generally much lower than in the outdoor case (3/4 instead of 10/20). This made it possible to develop a more accurate model. The algorithm is based on a full 3D ray tracing, the planes of reflection/diffraction can be however oriented in space, and also propagation across walls and floors is considered. The model takes into account the electrical properties of the used materials, and the topology of the environment. Also in this case, the tool is able to calculate narrowband as well as wideband parameters.

The basic principles of this algorithm are shown in the next slide: firstly, the relevant rays are determined, and then their contributions are combined according to the Turin’s model. As already mentioned, the model is able to cope with very complex environments, like the one depicted in the next slide. The following transparency shows an example of rays that will be considered.

We performed a measurement campaign to validate this prediction tools, and the results were encouraging, as shown in the final slide for a few locations within the building.

**Acknowledgements**

The author wishes to thank Dr. Eraldo Damosso, from CSELT, who provided some of the slides used in this presentation.
**Introduction**

- We will present the research activities on propagation in mobile radio systems performed in the joint laboratory of Fondazione Ugo Bordoni and University of Bologna, in cooperation with CSELT.
- These activities were partly performed in the framework of European programmes, such as RACE 1043, COST 207, COST 231.
- Main environments:
  - rural and suburban outdoor -> large cells)
  - metropolitan outdoor -> small cells, street microcells
  - indoor -> picocells.
- Each of these environments needs to be characterised in a different way.

**Outdoor propagation (open and suburban areas)**

- Work carried out in close co-operation between CSELT and FUB.
- Prediction methods requiring geographical data base information.
- Extraction of height profiles from data base and evaluation of diffraction losses. FUB studied an algorithm to extract main obstacles from a given height profile.
- CSELT implemented a powerful prediction tool which can be extensively used in planning.
A knife-edge obstacle causes a reduction in received field strength ($E$) with respect to the field that would be received in absence of obstacles ($E_0$) given by:

$$
\frac{E}{E_0} = \frac{1}{2} + j \int_{v}^{\infty} e^{-j\frac{\pi}{2}x^2} \, dx
$$

where $v$ is the Fresnel parameter.
SAR:
LAMERATE A1
Cella: milsecA1
Lat.: 45 29 7
Long.: 3 12 29 W
Quota.: 119 m
Alt. traccia: 35.0 m
Frequenza: 450.0 MHz
Potenza in trasm.: 8.0 W
Perdite: 0.0 dB
Eirp: 65.8 W
Antenna: LPD-3807
Azimuth: 48.0
Tipo: SECTOR_90
Costruttore: ANTEL
Guadagno: 9.15 (dBtso)
Lobo a -3dB: 88.0 (grad)
Centro di rappresentazione:
SBABILA
Diffrez da ostacoli:
metodo di Epstein-Peterson
Outdoor propagation (metropolitan areas)

- Prediction method based on a simplified 3D ray tracing.
- Multiple diffractions and reflections are taken into account.
- Propagation over the rooftop is considered.
- Vision algorithm was developed to speed up the search of rays.
- Calculation of both narrowband and wideband parameters.
- Easily extended to other environments (TV broadcasting, 60 Ghz systems).
APPLICATIONS

FIELD STRENGTH PREDICTION
NARROWBAND STATISTICS
DELAY STATISTICS
MICROCELLULAR DESIGN
Indoor propagation

- Prediction method based on 3D ray tracing.
- Physical and geometric characterisation of the environment needed.
- Wideband parameters can be studied (high bit rates involved).
- Less levels than in the outdoor case are typically needed -> more refined model:
  - Reflections and diffractions on planes however oriented.
  - Propagation across walls/floors taken into account.
THE RAY-TRACING ALGORITHM

Single ray Electric field

\[ E(r, \theta, \phi) = E_0 f(\theta, \phi) \frac{e^{-jkr}}{r} \]

Turin's model

\[ h(t) = \sum_{i=1}^{N} r_i \delta(t - t_i) \exp(-j\theta_i) \]
COMPARISON BETWEEN CALCULATED AND MEASURED FIELD MEAN VALUES AND STANDARD DEVIATIONS
Interference between radio communications systems

G. Dellagiacoma (CSELT)

COST activities

- COST 210 prediction procedures:
  » Clear air
  » Hydrometeor scatter

- COST 235 SSF research:
  » Diffraction
  » Parabolic equation
  » Vegetation attenuation and scatter
The number and the distribution of users is time variant.
VISIBILITY ESTIMATION

SPOT SATELLITE DATA:
TERRAIN HEIGHTS WITH SPATIAL RESOLUTION OF 20 x 20 M
Example of radio coverage in an urban area (Rome) with 5 Nodal Stations

<table>
<thead>
<tr>
<th>Coverage Radius</th>
<th>Power in dBm</th>
<th>Location</th>
<th>Visibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS=2</td>
<td>+30</td>
<td>E.U.E.</td>
<td>50%</td>
</tr>
<tr>
<td>NS=4</td>
<td>+20</td>
<td>E.U.E.</td>
<td>70%</td>
</tr>
<tr>
<td>NS=6</td>
<td>+10</td>
<td>E.U.E.</td>
<td>90%</td>
</tr>
<tr>
<td>NS=9</td>
<td>0</td>
<td>E.U.E.</td>
<td>95%</td>
</tr>
</tbody>
</table>

Percentage of the average visibility

Coverage radius (km)

- NS=2
- NS=4
- NS=6
- NS=9

2.40
INTERFERENCE ENVIRONMENT

INTERFERENCE LEVEL PROBABILITY

\[ P(I>I_S) = \frac{N_S}{N_T} \]

where:

- \( N_S \) is the total number of pixels with an interference level greater than a value \( I_S \)

- \( N_T \) is the total number of pixels which are visible from the considered station
HYDROMETEOR SCATTERING

Comm. Volume
System parameters

- Random variables
  - $C_r$ Faded carrier
  - $I_i$ Interference components

\[
\left( \frac{C}{I} \right) = \frac{C_r}{\sum I_i}
\]

- Degraded margin
  - $M_0$ Nominal margin
  - Modulator parameters

\[
M = M_0 + 10 \cdot \log \left( 1 - \frac{\left( \frac{\xi}{\xi_0} \right) \cdot \left( \frac{\rho}{\rho_0} \right)}{\left( \xi_0 \right)} \right) \text{ [dB]}
\]
Equiprobability method evaluation

[[Graph showing probability and C/I (dB)]]

INTEGRATION REGION

Joint distribution:
Coupling - Terrestrial link attenuation

\[ L = K - A_t - (C/l) \]
Convergent links geometry (clear air conditions)
C/I cumulative distribution function for some values of the separation angle $\xi$ between the stations $S_2$ and $S_3$ ($D_2-D_3=3.5$ km, $f=30$ GHz).

Convergent links geometry (rain conditions)
Cumulative distribution function of the separation angle $\xi$ between the stations $S_2$ and $S_3$ for some values of $C/I$ ($D_2=D_3=7$ km, $f=30$ GHz).
ATTIVITA’ DI RICERCA
NELLA PROPAGAZIONE E.M.
PER TELECOMUNICAZIONI

G. d’Auria, F.S. Marzano, N. Pierdicca
Università “La Sapienza” di Roma

P. Basili
Università di Perugia

P. Ciotti
Università dell’Aquila

F. Del Frate, G. Schiavon, D. Solimini
Università “Tor Vergata” di Roma

Somario

• Introduzione generale delle attività
• Descrizione delle singole attività

Propagation Day
Roma, 9 Ottobre 1995
ATTIVITA’ DI RICERCA
Introduzione

• **SCINTILLAZIONE IN ARIA CHIARA**
  - Sviluppo di metodi predittivi per la stima delle scintillazioni troposferiche di ampiezza in collegamenti via satellite a microonde e in banda millimetrica.
  - Analisi ed elaborazione di misure di scintillazione e confronto con metodi predittivi (Olympus).

• **ATTENUAZIONE TROPOSFERICA**
  *In assenza di precipitazioni:*
  - Sviluppo e confronto di metodi di stima dell’attenuazione in atmosfera chiara e nuvolosa tramite radiometri a microonde da terra e da satellite.
  - Elaborazione di dati di radiometri multifrequenza da terra (SMA-TOV) e da satellite (SSM/I).

  *In presenza di precipitazioni:*
  - Sviluppo di metodi di stima dell’attenuazione, del contenuto integrato di ghiaccio e dell’intensità di precipitazione da radiometri a microonde su satellite.
  - Elaborazione di dati di radiometri multifrequenza da satellite (SSM/I) per stima di mappe di attenuazione.

• **COLLEGAMENTI E RADIOMETRI A MICROONDE**
  - Progetto e realizzazione di trasmettitore e ricevitore per un collegamento sperimentale in visibilità a 50 GHz.
  - Progetto e realizzazione di radiometri multicanale a microonde per l’osservazione dell’atmosfera e la stima dell’attenuazione.
SCINTILLAZIONE IN ARIA CHIARA
Temi di ricerca

• **UNITA’ DI LAVORO**
  - Univ. “La Sapienza” di Roma: F.S. Marzano, G. d’Auria

• **MODELLISTICA**
  - Modello di costante di struttura in atmosfera turbolenta intermittente a stratificazione orizzontale.
  - Simulazione dell’intensità di scintillazione tramite modello fisico di turbolenza intermittente a partire da profili verticali meteorologici (pressione, umidità e vento).

• **PREDIZIONE**
  - Stima dell’intensità di scintillazione tramite regressione statistica su dati simulati a partire da misure meteorologiche al suolo di temperatura e umidità (SIRM).
  - Stima dell’intensità di scintillazione a partire da misure meteorologiche al suolo e contenuto integrato di vapore, ottenuto da misure radiometriche a microonde bicanale (sinergia collegamento/radiometro).

• **ELABORAZIONE DATI**
  - Analisi dei dati di intensità di scintillazione del collegamento Olympus a 20 GHz (Milano, Italia), a 12.5 e 30 GHz (Louvain-La-Neuve, Belgio) e 12.5 e 20 GHz (Lessive, Belgio).
  - Confronto di predizioni di scintillazioni tramite metodi statistici (CCIR, Karasaw, Ortigies, SIRM).
Risultati della Stima

Applicazioni a Sondaggi
**SCINTILLAZIONE IN ARIA CHIARA**

Esempi di risultati

• **PREDIZIONE DI SCINTILLAZIONE**
  - *Misure:* Olympus 19.77 GHz, Politecnico di Milano
  - *Metodo:* regressivo su dati simulati da modello (SIRM)

Intermittent with RAOB Milano 80-89 / Milano Olympus 20 GHz july-nov 92
ATTENUAZIONE TROPOSFERICA
In presenza di nubi precipitative

• **UNITA’ DI LAVORO:**
  - Univ. “La Sapienza”, Univ. di Perugia, Univ. dell’Aquila:
    G.d’Auria, F.S. Marzano, N. Pierdicca, P. Basili, P. Ciotti

• **MODELLISTICA**
  - Modelli di nubi precipitative ottenute dall’analisi statistica di simulazioni numeriche tri-dimensionali e tempo-dipendenti tramite modelli di nube a mesoscala.
  - Simulazioni di attenuazione a microonde dovuta a sistemi nuvolosi precipitativi tramite modelli di estinzione di radiazione e.m. dovuta ad idrometore precipitanti e non, in fase liquida e ghiacciata a varie quote.

• **PREDIZIONE**
  - Sviluppo di metodi di stima regressivi dell’attenuazione da radiometri a microonde su satellite.
  - Sviluppo di metodi di stima bayesiani del contenuto integrato di ghiaccio e dell’intensità di precipitazione al suolo.

• **ELABORAZIONI DATI**
  - Analisi dei dati radiometrici SSM/I a microonde del satellite DMSP per la stima dell’attenuazione. Produzione di mappe di attenuazione in zone con precipitazione con risoluzione a terra di 15 Km.
ATTENUAZIONE TROPOSFERICA
Modelli di nube con pioggia e simulazioni

- MODELLI DI NUBE

- SIMULAZIONI DI OPACITÀ ATMOSFERICA
COLLEGAMENTI A MICROONDE
Progetti e attività in corso

• UNITÀ’ DI LAVORO:
- Politecnico di Milano: A. Paraboni, C. Riva

• COLLEGAMENTO IN VISIBILITÀ’ A 50 GHz

- Trasmittitore: Antenna Cassegrain (D=39 cm) / Horn
Oscillatore Gunn a 50 GHz

- Ricevitore: Antenna Cassegrain (D=49 cm)
Mixer a 60 MHz
Stabilizzazione PLL
Ricevitore Ferranti (-70÷-20 dBm)

- Tratta: Prevista: Roma-Frascati di 9 Km
Alternativa: Roio-L’Aquila di 10 Km

- Guadagno: S/N al ricevitore ≈ 63 dB (aria chiara)

- Da definire: Purezza in frequenza del trasmettitore
Sistema di puntamento delle antenne
**UNITÀ DI LAVORO:**

**RADIOMETRO BICANALE A MICROONDE**

<table>
<thead>
<tr>
<th>Frequenze (GHz)</th>
<th>Configuraz.</th>
<th>Riferimenti termici</th>
<th>Risoluzione radiometrica</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.8</td>
<td>Dicke</td>
<td>doppio (caldo e freddo)</td>
<td>0.6 K</td>
</tr>
<tr>
<td>36.5</td>
<td>Dicke</td>
<td>doppio (caldo e freddo)</td>
<td>0.5 K</td>
</tr>
</tbody>
</table>

**Caratteristiche:**
- calibrazione interna (doppio riferimento).
- calibrazione esterna tramite tecnica “tipping curve” e corpo nero realizzato “ad hoc”.
- termoregolazione accurata (stabilità termica elevata).
- aquisizione dati (antenna, riferimenti, sensori di temperatura e misure meteo) tramite calcolatore portatile.
- tempo di integrazione dei campioni di temperatura d’antenna variabile da calcolatore (minimo 50 msec).

**Obiettivi:** stima del contenuto integrato di vapore e acqua liquida e stima dell’attenuazione troposferica.
Comparison of algorithms for the estimation of atmospheric attenuation from 20 to 220 GHz by microwave radiometry

P. Basili - Univ. of Perugia - Italy
P. Ciotti - Univ. of L'Aquila - Italy
E. Fionda - F.U.B. - Roma - Italy
Cumulative Distributions of Zenithal Attenuation

- Comparison of simulated attenuations:
  - directly computed from RAOB's (Liebe): "true" attenuations
  - estimated by frequency scaling from corresponding Tb's at two frequencies (23.8-36.5 GHz):

\[ \tau_f = a_0 + a_1 \tau_1 + a_2 \tau_2 \]

\[ \tau_1(\text{dB}) = 4.343 \ln \left( \frac{T_m(i) - T_{\cos}}{T_m(i) - T_B(i)} \right); \quad i = 1,2 \]

![Graph showing cumulative distributions of zenithal attenuation](image)

Rome 1983–1986
n. of samples: 2472

- Estimated attenuation
- 'True' attenuation
- no frequency scaling
Comparison of algorithms for estimating attenuation

Udine 1978/1980 raob's
r.m.s. errors (dB) for attenuation at 50 GHz
ITALSAT highest frequency channel

![Graph showing r.m.s. errors (dB) for different regression models]

<table>
<thead>
<tr>
<th>Regression based on:</th>
<th>Tau's</th>
<th>Tb's</th>
<th>(Tb)2's</th>
<th>(Tb)3's</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.8 - 36.5</td>
<td>0.03483</td>
<td>0.15440</td>
<td>0.04241</td>
<td>0.02734</td>
</tr>
<tr>
<td>23.8 - 36.5 - 50.0</td>
<td>0.03488</td>
<td>0.06978</td>
<td>0.02747</td>
<td>0.02441</td>
</tr>
</tbody>
</table>

Retrieval coefficients from Udine 1977/1979 raob's
Sample size = 2769
Multifrequency mm-Wave Radiometer (ESA Contract No. 9960/92/NL/GS)

- Manufacture of the radiometer (Galileo)
- Development of retrieval algorithms (Univ. Tor Vergata)

people involved at TOV: F. Del Frate, G. Schiavon, D. Solimini

Evaluation of propagation parameters (attenuation and path delay) in the frequency range 12.5 – 50 GHz (OLYMPUS, ITALSAT)

- retrieval of profiles of atmospheric parameters
- evaluation of propagation parameters (propagation model)
G/T Assessment Study  
(ESA Contract No. 11529/95/NL/DS)

- Evaluation of satellite antenna temperature (Univ. Tor Vergata)

- Software implementation (TICRA)

people involved at TOV:  
P. Ferrazzoli, G. Schiavon, D. Solimini

5–50 GHz, 0°–90°, H & V pol., global coverage

- surface emissivity model

- atmospheric propagation model

- surface-atmosphere interaction

Model validation (SSM/I data)
Ka-BAND SYSTEMS REQUIREMENTS

- the role of COST 255

P T Thompson

COST 255 OBJECTIVES: (iii)

COORDINATE EUROPEAN RESEARCH ------

" DESIGNING AND PLANNING OF TELECOM SYSTEMS WHERE
THE SATELLITE SYSTEM IS A SEGMENT "

COST 255 FIRST PHASE - 6 MONTHS

REVIEW OF PRESENT DAY AND FUTURE TELECOM SYSTEMS REGARDING SYSTEM CHARACTERISATION & RELATIONSHIP TO PROPAGATION PARAMETERS.

"LED BY SYSTEM ENGINEERING SPECIALISTS AND WILL BE USED BY THE PROPAGATION SPECIALISTS TO IDENTIFY AVAILABLE MODELS, DATA, TOOLS, SOFTWARE --- "

COST 255 THIRD MAIN TOPIC

ASSESSING THE PERFORMANCE OF TELECOM SYSTEMS. A REVIEW OF PRESENT AND EXPECTED FUTURE TELECOM SYSTEMS AND SERVICES WILL BE CARRIED OUT. REQUIREMENTS IN TERMS OF TRANSMISSION CHANNEL CHARACTERISATION WILL BE DEFINED.

FIXED, MOBILE & BROADCASTING SATELLITE SYSTEMS WILL BE ADDRESSED AS WELL AS COORDINATION DISTANCE, FREQUENCY ALLOCATION AND SHARING ISSUES.
COST 255 THIRD MAIN TOPIC

THE PERFORMANCE & QUALITY OF SYSTEMS AND SERVICES USING DIFFERENT MODULATION AND CODING TECHNIQUES, ACCESS PROTOCOLS AND COUNTERMEASURES WILL BE ASSESSED, AND THE MOST EFFECTIVE ONES IDENTIFIED.

SIMULATION TOOLS USING REALISTIC TRANSMISSION CHANNEL MODELS WILL BE IMPLEMENTED.

COST 255 THIRD MAIN TOPIC

TELECOM NETWORKS COMPRISING BOTH SATELLITE AND TERRESTRIAL SEGMENTS WILL BE EVALUATED EVEN IF ONLY THE MODELLING CONCERNING EARTH-SATELLITE PATHS WILL BE DEVELOPED IN THIS COST PROJECT.

CONCLUSIONS & RECOMMENDATIONS REGARDING SYSTEMS AND THEIR RELATED SERVICES WILL BE FORMULATED IN TERMS OF THEIR TECHNICAL CHARACTERISTICS.
COST 255 ORGANISATION

A "SYSTEMS PERFORMANCE" WORKING GROUP WILL BE ESTABLISHED FROM WHICH THE "DRIVING REQUIREMENTS" WILL FLOW TO THE OTHER TWO WORKING GROUPS.

A "SYSTEM SIMULATION & TESTING" SUB-GROUP WILL FORM PART OF THE ROLE OF THE "SYSTEMS PERFORMANCE" GROUP.

COST 255 SOFTWARE

IT IS CONSIDERED VITAL THAT SYSTEM DESIGNERS HAVE READY ACCESS TO APPROPRIATE SOFTWARE TOOLS THAT PROVIDE THE PROPAGATION MODELLING THAT THEY NEED.

THE SYSTEMS PERFORMANCE GROUP SHOULD DEFINE THE REQUIREMENTS FOR SUCH SOFTWARE AND ESTABLISH THE MEANS FOR MAKING IT WIDELY AVAILABLE.

- INITIALLY RESTRICTED TO THE "COST" DOMAIN
- ALSO CONSIDER ITU AND INTERNET WWW.
COST 255 SYSTEMS PERFORMANCE

WHAT SYSTEMS?

- ITALSAT: ITALY    DFS 1,2: GERMANY    CS 2,3,4: JAPAN  
  (N-STAR, SUPERBIRD)

- MILSTAR: USA    SKYNET IV: UK    SICRAL: ITALY

- EUREKA: ESA    OLYMPUS: ESA    DRS: ESA    ETS VI: JAPAN
  ARTEMIS: ESA    COMETS: JAPAN    ACTS: USA

- NORSTAR: USA    TELEDESIC: USA    SPACEWAY: USA

COST 255 SYSTEMS PERFORMANCE

WHAT SERVICES?

- VSAT

- PERSONAL COMMUNICATIONS,   HAND-HELD

- MOBILE:    - LAND (CARS, TRUCKS), MARITIME, AERONAUTICAL

- BROADCASTING: TV, AUDIO, DATA

- "MULTI-MEDIA"    UP TO 2 MBPS, BROADBAND
<table>
<thead>
<tr>
<th>GHz</th>
<th>Allocation to Services</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.7 - 20.1</td>
<td>MOBILE SATELLITE (REGION 2) (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td>20.1 - 20.2</td>
<td>MOBILE SATELLITE (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td>22.55 - 23.0</td>
<td>INTER-SATELLITE</td>
<td></td>
</tr>
<tr>
<td>24.45 - 24.65</td>
<td>INTER-SATELLITE</td>
<td></td>
</tr>
<tr>
<td>24.65 - 24.75</td>
<td>RADIO-LOCATION (Earth-to-space)</td>
<td></td>
</tr>
<tr>
<td>25.25 - 27.5</td>
<td>INTER-SATELLITE</td>
<td></td>
</tr>
<tr>
<td>25.5 - 27.0</td>
<td>Earth Exploration-satellite (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td>27.5 - 27.501</td>
<td>FIXED-SATELLITE POWER CONTROL BEACONS (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td>27.501 - 29.999</td>
<td>fixed-satellite power control beacons (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td>29.999 - 30.0</td>
<td>FIXED-SATELLITE POWER CONTROL BEACONS (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td>28.5 - 30.0</td>
<td>Earth exploration-satellite (Earth-to-space)</td>
<td></td>
</tr>
<tr>
<td>29.5 - 29.9</td>
<td>MOBILE SATELLITE (REGION 2) (Earth-to-space)</td>
<td></td>
</tr>
<tr>
<td>29.9 - 30.0</td>
<td>MOBILE SATELLITE (Earth-to-space)</td>
<td></td>
</tr>
<tr>
<td>31.8 - 32.3</td>
<td>SPACE RESEARCH (DEEP SPACE) (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td>34.2 - 34.7</td>
<td>SPACE RESEARCH (DEEP SPACE) (Earth-to-space)</td>
<td></td>
</tr>
<tr>
<td>37.0 - 38.0</td>
<td>SPACE RESEARCH (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td>37.5 - 40.5</td>
<td>Earth exploration-satellite (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td>40.0 - 40.5</td>
<td>SPACE RESEARCH (Earth-to-space)</td>
<td></td>
</tr>
</tbody>
</table>

WARC 92 Space Allocations Above 20 GHz
COST 255 SYSTEMS PERFORMANCE

WHAT DESIGN PHILOSOPHY?

- INCLUDING PROPAGATION FACTORS AS ONE LINE IN A SPREADSHEET IS NO LONGER A Viable PROCess

- ENTIRE NETWORK MUST BE CONSIDERED WHEN DESIGNING, NOT AN INDIVIDUAL CARRIER

- INTEGRATED, EASY TO USE SOFTWARE THAT IS READILY AVAILABLE

- SPECTRUM SHARING A KEY DRIVER

COST 255 SYSTEMS PERFORMANCE

USERS?

- TELEDESIC $9 BILLION 840 SATELLITES + SPARES
- SPACEWAY $6 BILLION 17 SATELLITES

- INTELSAT: - NO SIGNIFICANT INTEREST SHOWN TO DATE
- EUTELSAT: - INTEREST IN EUTELSAT III BUT NOT ADOPTED
- INMARSAT: - PROJECT P, NO INTEREST, INMARSAT IV?

- BIG MONEY IS REQUIRED, ONLY LARGE PLAYERS WILL SURVIVE

WHO ARE THEY IN EUROPE?
COST 255 SYSTEMS PERFORMANCE

WHY USE Ka-BAND?

- EARTH STATIONS ARE SMALLER
- SPECTRUM/ORB  IT LESS CROWDED

POTENTIAL USERS QUESTIONS:-

- SURELY Ka-BAND EQUIPMENT IS MUCH MORE EXPENSIVE THAN C-BAND & Ku-BAND?
- RAIN FADES CRIPPLE THE SYSTEM, DON'T THEY?
- ALL THE MOBILE PEOPLE ARE GRABBING THE SPECTRUM?
- I CAN'T AFFORD THE FADE COUNTER MEASURES REQUIRED?
- WHERE DO I GET A MODEL FROM THAT CAN ANSWER MY 'WHAT IF'?

COST 255 SYSTEMS PERFORMANCE

POTENTIAL USERS QUESTIONS:- (CONTINUED)

- HOW DO I DO MY SYSTEM PLANNING AS PROPAGATION IS DOMINANT?
- HOW WILL MY SYSTEM CONTROL & DISCIPLINE BE AFFECTED?
- WILL UP-LINK POWER CONTROL WORK PROPERLY?
- DO I NEED TO USE DUAL POLARISATION AND WHAT DOES IT COST?
- WHERE CAN I GET EXAMPLES OF ACTUAL Ka-BAND PERFORMANCE AND EXPERIENCE?
- I NEED 99.99% AVAILABILITY, WILL I GET IT, IF NOT WHAT CAN I GET?
- WHAT ARE THE STATISTICS OF CONCURRENT RAIN FADES ON THE UP AND DOWN LINKS?
COST 255 SYSTEMS PERFORMANCE

POTENTIAL USERS QUESTIONS.- (CONTINUED)

- HOW DO I?

COST 255 WILL BE THERE TO HELP YOU.

ALL WE NEED IS APPROVAL TO GET STARTED
THE APPLICATION OF PROPAGATION RESULTS FROM ACTS

Faramaz Davarian

ACTS Propagation Measurement sites
with ITU Rain Rate Climate Map

<table>
<thead>
<tr>
<th>Rainfall rate Exceeded (mm/h)</th>
<th>%</th>
<th>1.0</th>
<th>0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.7</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>2.1</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0.6</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>1.5</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>4.0</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>5.0</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>
Results and Outputs of the Campaign

- $K_s$-band propagation data
- Map revision for rain climate regions of North America
- Prediction models of atmospheric attenuation and scintillation
- Fade and nonfade duration distributions
- Frequency scaling model
- Diversity model
- Multiple site analysis
- Mitigation schemes for propagation anomalies
- Modeling of the effect of antenna dish moisture and snow
- Contribution to regulatory organizations

ACTS Data Center:
Raw and Preprocessed Data are Archived at the University of Texas
FINAL AGENDA
Eighth ACTS Propagation Studies Workshop (APSW VIII)

The Commons
University of Oklahoma
Norman, Oklahoma
November 15–16

November 15

8:45 Registration
9:00 Opening Remarks
F. Davarian (JPL)

Session 1: General
9:15 Spacecraft and Program Updates
R. Bauer (NASA LeRC)
9:45 A Rain and Atmospheric Attenuation Model Based on ACTS Data
A. Dissanayake (COMSAT)
10:05 BREAK
10:20 Industry Propagation Needs
Speakers from satcom industry
11:20 Engineering Support and Data Preprocessing
R. Crane (Oklahoma) and D. Westenhaver (WWW)
12:10 LUNCH (The Commons)

Session 2: Experimenter Status Report
1:30 Session begins
Alaska, British Columbia, Colorado, COMSAT, South Florida/Florida
Atlantic, Georgia Tech, New Mexico/S-Tel, Oklahoma, Texas, APL
4:00 Tour of ACTS Propagation Terminal

November 16

8:30 Session 2 continues
12:00 LUNCH (The Commons)

Session 3: Plenary (R. Crane and D. Rogers, Chair)
1:15 Session begins
Open discussions, planning, industry needs, action items,
recommendations, and other issues
5:30 Workshop adjourns
Update of OLYMPUS campaign results from Spino d'Adda and Torino

Carlo Riva
Dipartimento di Elettronica e Informazione
Politecnico di Milano

Cumulative Distribution of Rain Attenuation - Spino d'Adda (08.92-08.93)

![Cumulative Distribution of Rain Attenuation](image)

- OLYMPUS: 12.5 GHz
- KARASAWA Model
- EXCELL Model
- ITU-R Model
- USA Model
Statistics

\[ n_s(2) = 7 \]
\[ n_d(2) = 2 \]
\[ n_s(D) = \frac{dN_{s,d}(D)}{dD} \]
\[ n_s^*(D) = \frac{dN_{s,d}^*(D)}{d(\ln D)} \]
\[ n_s(D) = D n_d(D) \]
\[ n_s^*(D) = D n_d^*(D) \]
Cumulative distribution of fade durations:

- Gera Lario, 78-81; - - Spino d’Adda, 79-82; -. Fucino, 78-81

Models

- **large D (D>Dt)**
  
  \[ n_s^* = \eta N_{tot} \frac{1}{\sqrt{2\pi}\sigma} \exp \left[ -\frac{1}{2} \left( \frac{\ln D - \ln D_0}{\sigma} \right)^2 \right] \]

- **small D (D<Dt)**
  
  \[ n_d = H D^{-\gamma} \]
  \[ N_d = \int_D^{D_0} n_d dD = H' D \]

- **Primary model parameters**
  
  - \( D_0 \) (very instable)
  - \( \sigma \) (very stable)
  - \( \gamma \) (varies a little with threshold: 0.5-0.8)

- **Proposed**
  
  - \( D_0 \) function of link elevation
  - \( \sigma \) fixed: 1.5
  - \( \gamma \) function of threshold and frequency
Data Analysis and Theoretical Model

- Olympus station in Spino d'Adda (Lat.: 45.4°N, 84 m asl)
- Frequency: 19.77 GHz
- Elevation: 30.6°
- Antenna diameter: 3.5 m
- Sampling rate: 50 samples/s
- SNR in clear sky: 64 dB in 1 Hz
- Observation period: August 1992-June 1993
- 33 rainy events (57.2 hours)
- Rain attenuation: low-pass filter (cut-off frequency: 0.025 Hz)
- Scintillations: band-pass filter (band: 0.025-3 Hz)
- Scintillations stationarity (56 disjoint intervals)
- Rain attenuation and standard deviation of scintillations time series (1 sample/s)
- Proposed model:
  \[ A = C_1 L \]
  \[ \sigma = C_2 L^{5.12} \]
  \[ \sigma = C_3 A^{5.12} \]
The image shows two graphs.

The upper graph depicts attenuation [dB] on the y-axis and seconds on the x-axis. The data shows a peak around 1000 seconds.

The lower graph shows scintillation [dB] on the y-axis and seconds on the x-axis. The data appears to fluctuate within a range of -1 to 1 dB.
Cumulative Distribution of Fade Duration - Torino (04.93-08.93)

Exceedance probability conditioned to duration
Freq: 12.5 GHz
Threshold: 4 dB

- Data
- Model
Cumulative Distribution of Fade Duration - Torino (04.93-08.93)

Exceedance probability conditioned to duration
Freq: 19.77 GHz
Threshold: 8 dB

- - - Data

--- Model
Measurement of the interference due to rain scattering
C. Mattello (CSELT)

Hydrometeor scatter

Causes undesired couplings between independent communication systems operating at the same frequency
The parameter that represents the coupling is:

\[ L = \frac{P_R}{P_T} \]

\( P_R \) = power transmitted by the interfering station
\( P_T \) = power received by the interfered terminal

-Different methods have been developed to evaluate \( L \) (based for example on the Bistatic Radar Equation)

-Several experimental campaigns have been carried out in the past years in different European countries
A new measurement system can be used for a more complete validation of the prediction methods.

L will be measured directly for the first time in our climatic zone (L,K)

The system is based on:

- A receiving station
- A transmitting equipment
- A meteorological station
The receiver consists of the Olympus receiving station (main station) with the 3 beacons at 12.5, 20 and 30 GHz for both the polarizations (Located in CSELT)

The transmitting antennas are located in Colle della Maddalena 10 km far from CSELT

There are 3 transmitting systems:

- the first at 12.5 GHz is used for the direct illumination of the receiving station (to lock it)
- the other beacons (20 and 30 GHz) are directed toward the common volume
The meteorological sensors (rain, humidity, temperature and pressure) are located under the common volume.

System configuration

- $d = 10$ km
- $a_1 = 16^\circ$
- $b_1 = 12.56^\circ$
- $a_2 = 19^\circ$
- $b_2 = 20^\circ$
- $h_v = 1974$ [msl]
- This configuration has been chosen on the base of the following criteria:
  - maximize the scattered power by the raindrops in the common volume
  - minimize the power received directly (LOS)
  - maximize the possible range of the CDF of L

- The choice has been done on the base of the results obtained for 4 configurations using the COST 210 method (implemented in a computer program)
• The realization of the system will be completed in few weeks and measurement campaign should begin in the first part of November.
Italsat Propagation Experimenters

- Deutsche Telekom AG, FTZ, Darmstadt, F.R of Germany
- Eindhoven University of Technology, Telecommunication Division - The Netherlands
- SERC Rutherford Appleton Laboratory Chilton, U. K.
- DLR NE-NT Institute for Communication Technology, Oberpfaffenhofen, F.R of Germany
- University of Portsmouth, Dept of El. & Electronic Engg., Portsmouth, UK
- ESA/ESTEC/ XEP and Johanneum Research Institute IAS Graz, Austria
- Fondazione Ugo Bordoni, Gruppo Radiopropagazione, Roma, Italy
- CSELT Propagation Dept. Torino, Italy
- CSTS-CNR Politecnico di Milano, Italy
- IRAM Istitut de Radio Astronomie Millimetrique S. Martin d'Heres, France
- I.G.N. Centro Astronòmico de Yebes, Guadalajara, Spain
- ETSIT Universidad Politecnica de Madrid, Spain
- RESCOM Vedbaek, Denmark

Incoming Italsat Experimenters

- FGAN Research Establishment for Applied Sciences Wachtberg, Germany, planning measurements of 40 and 50 GHz beacons;
- Telenor Research, Kjeller, Norway, planning measurements of 50 GHz beacon
- France Telecom CNET Belfort, envisages conversion of Gometz-la-Ville station to receive 40 GHz beacon
- RAFAEL, Haifa, Israel, planning to test VSAT equipment using Italsat beacons
1. INTRODUCTION

The Rutherford Appleton Laboratory (RAL) experiments using ITALSAT transmissions began in June 1993 with a 49.49 GHz single channel, vertically-polarised receiver. It has been operated at Chilbolton until September 1995. Receivers for the three emissions at 39.087, 39.592 and 40.097 GHz have also been developed and observations at 39.592 GHz have been made from the Chilbolton site in Hampshire, UK since June 1994. However, it has been the intention to conduct the main RAL experiments using ITALSAT from a site at Sparsholt which is situated about 8 km from Chilbolton and is very suitable for coordination with supporting slant path data from the multi-parameter rain radar at Chilbolton. Beacon receiving equipment is currently being installed at Sparsholt. The receivers operating near 18.6 and 49.5 GHz are already in place together with an 11 GHz receiver using a EUTELSAT transmission. The completed facility at Sparsholt will also include the three receivers for emissions near 40 GHz, three radiometers operating near 30, 40 and 51 GHz together with various types of meteorological equipment.

The purpose of this note is to present the results of the initial analyses of data at 49.49 GHz obtained during the period 1st of January 1994 to 23rd September 1994, but it should be noted that no data were recorded during May when the receiver was not operating.

2. RECEIVING EQUIPMENT AND ITS APPLICATION TO DATA ANALYSIS

Some details of the receiving equipment are included in the Proceedings of the Olympus Utilisation Conference held in Seville (Woodroffe et al. 1993) together with initial test data collected in a dry period in 1992. The elevation to the satellite is 29.9 degrees. Alongside the beacon receiver, and pointing in the same direction is a sky-noise radiometer collecting thermal energy from two frequency bands situated +/- (150-550) MHz from the centre frequency at 51 GHz. The radiometer is used to provide an absolute base level which complements the satellite signal to provide the total atmospheric attenuation. One of the objectives of the experiment is to examine the extent to which the contributions from the gaseous, cloud and rain components can be separated. Since the radiometer is not working at the same frequency as the satellite beacon and since its bands are on the sharply rising wing of the complex oxygen absorption band centered near 60 GHz, considerable care needs to be taken in extrapolating the radiometer data to obtain an accurate result. The factors which have been taken into account in this case include the available calibrations of the radiometer and frequency scaling.
3. DATA COLLECTION AND ANALYSIS

The data are logged at 10 second intervals and are stored in files of approximately 30,000 lines. The first stage of the analysis is to assess the quality and quantity of data in the file by means of pre-processing software developed by RAL to yield a summary report and to produce graphical output of the required channels. Both Fortran and Interactive Data Language (IDL) routines are invoked in this process.

3.1 Analysis of the Radiometer Signal

Periods when the path between the beacon and the ground receiver are free from cloud and rain are identified primarily from the radiometer record. This is achieved by dividing the record into blocks of 50 data points and calculating the mean and standard deviation of the attenuation values in each block. For the purposes of this study, clear sky periods have been defined as those regions where three successive blocks have a standard deviation that is less than 0.013 dB. The measured beacon signal level corresponding to the specified periods is used as a monitor to confirm the presence of clear sky.

For each data point, an algorithm developed from theoretical calculations of atmospheric absorption and emission, as devised by Liebe (1989), is used to estimate the mean absorbing temperature for a ‘clear sky’. As input, it takes the coincidently recorded values of surface air temperature and surface water vapour concentration at the receiving site and is based on the assumptions that the amount of water in the atmosphere decreases exponentially with height and that the air temperature falls linearly with height in the troposphere.

The mean absorbing temperature is then taken together with the atmospheric brightness temperature deduced from the radiometer channel to estimate a value for the sky attenuation along the beacon viewing path at the mean radiometer frequency centred at 51 GHz. A frequency scaling process using a second algorithm developed from the theoretical atmospheric attenuation calculations is then applied to this clear sky measured radiometric value and to the measured ground level water vapour concentration and surface air temperature to compute an approximate value for the attenuation of the atmosphere at 49.49 GHz. By adding these estimated ‘clear sky’ values of attenuation to the corresponding mean levels of the satellite signals for the same clear sky periods, a set of points is created from which a continuous template signal can be derived for analysis of the satellite signal. A linear fit to the clear-sky radiometric-based data gives a monitor of atmospheric changes that occur during the period of the file.

3.2 Analysis of the Beacon Signal

It was found that a small diurnal variation of the beacon could be observed when the beacon signal values were added to the coincident atmospheric attenuations that were estimated from the radiometer measurements for the full set of data. An oscillation, essentially sinusoidal in nature, was observed to have a fixed phase with respect to 00.00 hours UT, and a peak amplitude of +/- 0.2 dB. A correction was made to
remove this variation before carrying out further processing and creating the base-
signal template as described above.

Software has been developed to determine when beacon drop-outs occur. Visual
checks of the graphical output are made to confirm these periods which may not be
easy to identify during large rain events which can also readily cause loss of lock within
the system dynamic range of about 26 dB from the clear-sky level.

Analysis is performed by subtracting the measured beacon signal values from the
coincident template data to obtain the total atmospheric attenuation. Initially, all data
are regarded as part of an event. Information on fading is extracted by determining the
periods for which the attenuation continuously exceeds specified levels, thereby
creating a data base on individual events. Cumulative statistics are compiled for
monthly and greater periods.

4. PRELIMINARY RESULTS

Figures 1 and 2 give the statistical results and the associated totals for the two four
month periods on either side of May 1994 which is missing. The experimental data
relate to the total atmospheric attenuation in which the combined background oxygen
and water vapour contribution amounts to between 2.5 and 3 dB, as indicated at the
100 percent points. The overall result for the eight months of data is shown in Figure 3
in comparison with the ITU-R (CCIR) long-term prediction relating to attenuation
cauwed only by rain to which 3 dB has been added to make an allowance for oxygen
and water vapour absorption. These experimental data yield a result considerably in
excess of this prediction whereas the previous test result in 1992 was lower than the
prediction for rain at the higher values of attenuation.

The following points are relevant. The prediction method is being applied at the top
end of its frequency range where it is essentially untested. Indeed, RAL is participating
in this experiment and the new COST 255 Project in order to test and to assist in the
development of prediction techniques in the range 20 to 50 GHz. The existing model
used for Figure 3 does not include the contribution from cloud, which is important
near 50 GHz. The ITU-R is in the process of producing a combined prediction to
include all relevant atmospheric effects. The few months of data presented here are not
adequate to test the prediction procedure since it is well-known that large variability
can occur from year-to-year. The longer-term aim of RAL is to obtain as large a data
base as possible in order to obtain direct measurements representative of UK
propagation characteristics for Earth-space applications, and to test models.

Figure 4 provides a summary of the average of the individual event characteristics for
the attenuation range 3 to 29 dB. The peak in the average time per event occurs at an
excess, i.e. cloud plus rain attenuation of about 5 dB and is probably largely influenced
by cloud effects. Figures 5, 6 and 7, respectively, give histograms of the percentage
time, number and average time per event for events occurring at the 5, 10 and 20 dB
levels of attenuation. Figures 1, 2 and 5 show that the statistical results are quite
closely grouped up to about 10 dB. However, Figure 7 demonstrates that there are
some seasonal differences in this data set. The average time per event for the 5 and 10
dB levels for the winter and spring period are significantly longer than those for the summer period.

5. CONCLUSIONS

Initial analyses of the slant path attenuation characteristics near 50 GHz have been made in the Southern part of the United Kingdom. These measured data over a nine month period indicate that the attenuation can considerably exceed the ITU-R long-term predicted values. Further measurements, analyses and comparisons with other data sets are required to determine the long-term trend. New modelling procedures should be developed to combine the contributions to the attenuation from the various atmospheric constituents. Cloud, oxygen and water vapour, rather than rain, are expected to be the dominant elements to consider in relation to the operation of systems with small fade margin. Future measurements by RAL will be conducted from another site and combined with data from the Chilbolton multi-parameter radar, and other higher frequency radars, to aid the modelling process.

6. ACKNOWLEDGEMENTS

This work has been carried out by the Radiocommunications Research Unit at the Rutherford Appleton Laboratory. It has been funded by the Radiocommunications Agency of the DTI and forms part of the National Radio Propagation Programme.

7. REFERENCES


Level of Atmospheric Attenuation (dB)

Figure 3

Percentage of time that the attenuation exceeds the y-axis value (%)

Av. number of events/day at the specified level of attenuation

Figure 4

Av. Time/Event (secs)
20/40-GHz Beacon Measurements with ITALSAT

Gerd Ortgies
Deutsche Telekom AG
Forschungs- und Technologiezentrum

ITALSAT Propagation Measurements

- 18.6 GHz: steerable 3.7-m antenna
- 39.6 GHz: fixed 0.6-m antenna
- three-frequency radiometer:
  - 21.3 GHz
  - 23.8 GHz
  - 31.8 GHz
- meteorology:
  - rain gauges
  - ambient temperature
  - humidity
Instantaneous frequency scaling

attenuation, dB
rain rate, mm/h

time, min.

12-JUN-1994
18.6 GHz  39.6 GHz
scaling ratio  rain rate

CEPIT
Rome, Oct. 3rd, 1995

Equiprobable attenuation frequency scaling

attenuation, dB

% of time ordinate is exceeded

CEPIT
Rome, Oct. 3rd, 1995
Instantaneous attenuation frequency scaling

scaling ratio 18.6 – 9.6 GHz

18.6-GHz attenuation, dB

Frequency scaling ratio

scaling ratio 20 – 30 GHz

20-GHz attenuation, dB
Scintillations and ambient temperature

signal, dB

temperature, °C

time, hrs.

Cumulative distribution of \( \sigma^2 \)

% of time

standard deviation

May 1995
- measurement
- log-normal

mean

CEPIT
Rome, Oct. 3rd, 1995

Deutsche Telekom
Seasonal patterns

Scintillations and meteorological parameters

CEPIT Rome, Oct. 3rd, 1995

- Deutsche Telekom

CEPIT Rome, Oct. 3rd, 1995

- Deutsche Telekom
Scintillations and meteorological parameters

\[ \text{stddev}(\ln(\sigma^2)) \]

Temperature, °C

Summary

- attenuation: good agreement with ITU-R prediction
- attenuation frequency scaling: large variability due to variable drop size distributions
- scintillations: simple model based on correlation of ambient temperature and \( \ln(\sigma^2) \)
Dynamics of Amplitude and Phase Scintillations in a Millimetre–Wave Satellite Downlink

A University of Portsmouth Department of Electrical and Electronic Engineering Research Programme

Ka – Band Utilisation Conference, Rome, October 1995

Speaker : Professor E. Vilar

• Background

• Concept of the experiment

• Ground station

• Preliminary Results and Conclusions

• Acknowledgements

Acknowledgements
In addition to my co-investigator Mr S. Senin and our experimental officer Mr J. Waight I would like to acknowledge the support of the UK Engineering and Science Research Council.
Background
Since 1995 a research programme entitled "Measurement of phase scintillations and dynamics of amplitude fluctuations in clear air and rain in the mm-wave region" has been under way. The main objectives of the experiment are:
(i) determine the excess phase noise introduced by the turbulent propagation medium (whether clear air or rain)
(ii) characterize the fade dynamics (signal fluctuations) under turbulence and rainy conditions.
Successive generations of researchers working in the University Group since early 80-s have led to substantial experience in the subject.
The early work was directed towards determination of the long term statistics of the amplitude scintillation process as well as remote sensing the slant path turbulent medium.
These studies were completed more recently by the investigation of the impact of a clear air fluctuating medium upon digital communications.
In parallel with that research new phase noise measurement techniques called method of phase and amplitude unwrapping, was developed in Portsmouth. These are powerful tools for the measurements of the phase noise in oscillators and have also been adopted to measure propagation phase noise, if resolvable.
There is a companion research programme at Portsmouth concerning the rain statistics and measurements (raindrop size distribution and scattering) which can hopefully allow us to to combine propagation measurements with the actual rain parameters.
It should be emphasized that not only our experience allowed us to undertake the current investigation, but also the development of mm-wave technology has made available very low phase noise signal sources. (first local oscillator in our receiver is a clear example)
Since the Olympus satellite ceased to operate the original objective of the experiment was switched to ITALSAT.
Main objectives of the experiment:
(i) determine the excess phase noise introduced by the turbulent propagation medium (whether clear air or rain).
(ii) characterize the fade dynamics (signal fluctuations) under turbulence and rainy conditions.

Conceptual Block Diagram of the Experiment
<table>
<thead>
<tr>
<th>% of Year (Portsmouth)</th>
<th>100</th>
<th>1</th>
<th>0.1</th>
<th>0.01</th>
<th>0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall Rate (mm/h)</td>
<td>---</td>
<td>1.7</td>
<td>8</td>
<td>28</td>
<td>78</td>
</tr>
<tr>
<td>Outage (dB)</td>
<td>0 (clear sky)</td>
<td>4.3</td>
<td>13.6</td>
<td>35.8</td>
<td>76.6</td>
</tr>
<tr>
<td>C/N₀ (dBHz)</td>
<td>57.4</td>
<td>51.9</td>
<td>42.6</td>
<td>20.4</td>
<td>-20.4</td>
</tr>
<tr>
<td>S/N in 100 Hz bw, I &amp; Q o/p</td>
<td>37.4</td>
<td>31.9</td>
<td>22.6</td>
<td>0.4</td>
<td>-40.4</td>
</tr>
</tbody>
</table>

Estimated C/N₀ and post detection S/N for the ITALSAT experimental receiver
40 GHz ITALSAT receiver
Phase Noise Spectral Density floor of the receiver system
Experimental test results: 70 MHz signal from the ultra low phase noise source was injected in point B (see the receiver diagramm)

I and Q outputs

Simultaneous display of I & Q using polar plot
256 seconds "unwrapped" phase recording

Fractional amplitude
Receiver phase noise
(using low phase noise xtal oscillator as an emulator at 70 MHz i.f)

\[ S_\phi \sim \frac{10^{-5}}{f^3} \text{ rad}^2/\text{Hz} \]

Phase noise spectral density

Amplitude noise Spectral density
Averaged Phase Noise Spectral Density

Averaged AM Noise Spectral Density
Averaged Phase Noise Spectral Density

Averaged AM Noise Spectral Density
Averaged Phase Noise Spectral Density

Averaged AM Noise Spectral Density
EINDHOVEN UNIVERSITY
FACULTY of ELECTRICAL ENGINEERING

ESPERIMENTO PROPAGAZIONE ITALSAT
The EUT ITALSAT-EXPERIMENT

by

L. Wijdemans
K. Holleboom
L. v. d. Coevering
G. Brussaard
J. Dijk
M. Vlemmings
EINDHOVEN UNIVERSITY
FACULTY of ELECTRICAL ENGINEERING

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5: CONCLUSIONS
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2: Xpolar Meas. 40GHz
3: Scintillation 40/50GHz
4: Meteorological Meas.
5: Longterm statistics
   -primary statistics
   -secondary statistics
6: Short-distance diversity
## ITALSAT beacons

<table>
<thead>
<tr>
<th>Beacon</th>
<th>19 GHz</th>
<th>40 GHz</th>
<th>50 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>18685.007 MHz</td>
<td>39592.014 MHz</td>
<td>49490.018 MHz</td>
</tr>
<tr>
<td>EIRP (nominal)</td>
<td>23.7 dBW</td>
<td>24.8 dBW</td>
<td>26.8 dBW</td>
</tr>
<tr>
<td>Polarization</td>
<td>V</td>
<td>RHC</td>
<td>H/V (933 Hz)</td>
</tr>
<tr>
<td>Eclipsing state</td>
<td>on</td>
<td>off</td>
<td>off</td>
</tr>
</tbody>
</table>

### Frequency [GHz] / Antenna [m] 40/0.5 40/3 50/0.5 50/3

<table>
<thead>
<tr>
<th>EIRP Eindhoven [dBW]</th>
<th>26.8 26.8 28.8 28.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free space loss [dB]</td>
<td>216.1 216.1 218.1 218.1</td>
</tr>
<tr>
<td>Medium loss [dB]</td>
<td>0.5 0.5 3.3 3.3</td>
</tr>
<tr>
<td>Basic Transmission Loss [dB]</td>
<td>216.6 216.6 221.4 221.4</td>
</tr>
<tr>
<td>Theoretical antenna gain [dB]</td>
<td>43.3 58.7 45.3 60.6</td>
</tr>
<tr>
<td>Surface correction 2 [dB]</td>
<td>-0.5 -0.5 -0.8 -0.8</td>
</tr>
<tr>
<td>Antenna gain [dB]</td>
<td>42.8 58.2 44.5 59.8</td>
</tr>
<tr>
<td>T receiver 3 [dBK]</td>
<td>40.5 40.5 40.5 40.5</td>
</tr>
<tr>
<td>G/T [dB/K]</td>
<td>2.3 17.7 4.0 19.3</td>
</tr>
<tr>
<td>C/T [dBW/K]</td>
<td>-187.5 -172.1 -188.6 173.3</td>
</tr>
<tr>
<td>k [dBW/HzK]</td>
<td>-228.6 -228.6 -228.6 -228.6</td>
</tr>
<tr>
<td>B [dBHz]</td>
<td>19.0 19.0 19.0 19.0</td>
</tr>
<tr>
<td>C/N [dB]</td>
<td>22.1 37.5 21.0 36.3</td>
</tr>
</tbody>
</table>

1 modulation loss included
2 surface tolerance 0.2 mm
50 GHz widebeam feed

Wohleben feed 50 GHz
Material: Aluminum
M.L.J. Vlemmings
16-11-94
$D = 1 \text{ m.}$
40 GHz co-/crosspolar receiver:

- 39.6 GHz Co-polarizer
- 39.6 GHz X-polarizer

50 GHz copolar receiver:

- 49.5 GHz oscillator (12.4 GHz + quadrupler)
- 49.5 GHz mixer (10 MHz IF)
Single-ended mixer 50 GHz:
Event 1748  30 May 1995  11:59 - 14:15

Attenuation

Attenuation [dB]
0  2  4  6  8
2000  4000  6000

50GHz
40GHz

Standard Deviation Level

StdDev(Level) [dB]
0  0.2  0.4  0.6
2000  4000  6000

50GHz
40GHz

Copolar Attenuation EUT 94/04/18 - 95/04/17

Attenuation [dB]
0  5  10  15  20
0.001  0.01  0.1  1  10

- 40GHz Italsat
- 40GHz Rain
- 11GHz ECS
- 11GHz Rain

Telecommunications Division - Eindhoven University of Technology
Seasonal Variation Attenuation  EUT Italsat 40GHz (94/04/18-95/04/17)

Diurnal Variation Attenuation  EUT Italsat 40GHz (940418-950417)
### Fade Duration

- **Fade Duration**
  - **Threshold**
  - **Fade Interval**
  - **Fade Return**

### Time [s]

<table>
<thead>
<tr>
<th>Time Class</th>
<th>All</th>
<th>0-30s</th>
<th>30-60s</th>
<th>&gt;60s</th>
</tr>
</thead>
<tbody>
<tr>
<td># Fade Events</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td># Fade Intervals</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td># Fade Returns</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total Fade Time</td>
<td>70</td>
<td>30</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Total Interval Time</td>
<td>40</td>
<td>0</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Total Return Time</td>
<td>70</td>
<td>0</td>
<td>0</td>
<td>70</td>
</tr>
</tbody>
</table>

### Copolar Slope

**EUT Italsat & ECS (94/04/18-95/04/17), 5-Point Central Derivative**

- **Slope Unfiltered Data [dB/s]**
  - 11GHz ECS
  - 40GHz ITALSAT

- **Slope Filtered Data [dB/s]**
  - 11GHz ECS
  - 40GHz ITALSAT

---

**Telecommunications Division - Eindhoven University of Technology**
CONCLUSIONS

1: ONE YEAR MEAS. at 40GHz
2: Cumulative dist. copolar
3: ITU-R pred. lower values
4: Diurnal distr.
5: Seasonal distr.
6: Fade duration
7: Fade slope distr.
8: Receiver design 50GHz

RECOMMENDATIONS

1: More years meas. ITALSAT
2: Start meas. 50GHz
3: Xpolar meas.
4: Rain-att. modelling
5: Diversity meas.+ modell. for short distance
XPD Statistics from Italian Stations

Antonio Martellucci, Fondazione Ugo Bordoni, Roma
Aldo Paraboni, Politecnico di Milano

The activity in the XPD fields has proceeded along four main lines:

• Processing ITALSAT data
• refining the “two families” model (rain plus ice)
  both with OLYMPUS and ITALSAT data
collected in all their Italian stations
• Checking the “two families” model using data
collected at different frequencies
• Pursuing a statistical model

Some examples and preliminary results are shown here only for what concerns the first two points
Frequency scaling

\[ \text{argument of rain anisotropy deduced by} \]

\[ \text{argument of ice anisotropy assumed 0 deg} \]

\[ \phi = \text{canihng angle of ice} \]

\[ |q| = \text{canihng angle of rain} \]

\[ |p| = \text{rotation of rain anisotropy} \]

\[ |q| = \text{rotation of ice anisotropy} \]

\[ \left( |q| + |p| \right) / \left( |q| - |p| \right) \begin{array}{c} \Phi \\ \Phi \end{array} \]

\[ \left( |q| + |p| \right) / \left( |q| - |p| \right) \begin{array}{c} \phi \\ \phi \end{array} \]

\[ \frac{|q|}{|p|} \begin{array}{c} \text{Im} \\ 0.25 \end{array} = (\Phi)^{\text{Im}} \]

\[ \left( \frac{|q|}{|p|} \right) = (\Phi)^{\text{Re}} \]

\[ \left( \frac{|q|}{|p|} \right) \begin{array}{c} \text{Im} \\ \text{Re} \end{array} = \left( \begin{array}{c} 0 \\ \Phi \end{array} \right) \]

\[ \left( \frac{|q|}{|p|} \right) \begin{array}{c} \text{Im} \\ \text{Re} \end{array} = \left( \begin{array}{c} 0 \\ \Phi \end{array} \right) \]

\[ \frac{|q|}{|p|} \begin{array}{c} \Phi \\ \Phi \end{array} = \left( \begin{array}{c} 0 \\ \Phi \end{array} \right) \]

\[ \frac{|q|}{|p|} = \left( \begin{array}{c} 0 \\ \Phi \end{array} \right) \]

Two Families model

OPSX Model

\begin{array}{c} \text{Im} \\ \text{Re} \end{array} = \left( \begin{array}{c} 0 \\ \Phi \end{array} \right)
- Fig 0 example of ITALSAT time series of Im(Anis)

- Fig 1 Histogram of Im(Anis) (overall) showing the occurrences of the jumps when Attenu<5dB

- Fig 2 Conditional statistics of Im(Anis) (overall) showing the necessity of reducing theoretical anisotropy to account for the drop-axes orientation spread

- Fig 3 Conditional statistics of Im(Anis) of the ice only showing a more regular trend. The increase with increasing attenuation is not due to the ice but to the fact that stronger rain accompanies frequently dense clouds full of ice

- Fig 4 Histogram of canting angles (Total, rain and ice) for attenu.<5dB. The trace of the rain canting angle appears quite noisy due to the fact that the drops are almost spherical and the canting angle rather undefined. On the opposite the ice effects are well visible and the trace is neater. The total canting shows two peaks centered around 0 and 90 degs. (the offset is due to the station tilt angle): this is fully consistent with the model of horizontal ice needles with uniform probability of orientation. The fact the bimodal distribution is more visible on the rain histogram than on the ice one is probably due to an imperfection of the algorithm (a difficult choice of $\alpha_1$ when rain is light). Very noticeably the imaginary part is very close to 0 (principal planes model very acceptable)

- Fig 5 Histogram of canting angles (Total, rain and ice) for attenu.>5dB. In this case the difficulties related to the almost spherical drops disappear and the models of equiprobable orientations (in the horizontal plane) for ice needles and equioriented raindrops for rain confirm their validity.

- Fig 6 An example of ITALSAT attenuation plus XPD time series.

- Fig 8 A scatterplot between attenuations at different frequencies showing how the best model for raindrop size distribution can be selected and used to assess $\alpha_1$.

- Fig 9 Scatterplot showing how, on event basis the ice anisotropy is little dependent on attenuation
Ice Anisotropy, \( d_2 \) [degree]
Fig. 3

Spina D'Adde, OLYMPUS, 20 MHz

Fig. 4

At ≤ 5 dB
Fig. 5

ITALSAT, Pomezia, 50 MHz, 94/11/11 0:0

Attenuation

J-Dr DSD

M-P DSD

XPD