RADIOWAVE PROPAGATION RESEARCH ACTIVITIES IN EUROPE

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1. Introduction

Europe continues to conduct a strong research programme in radiowave propagation, but this has become very specific to new applications. Mainly this paper will concentrate on work associated with the lower atmosphere and terrestrial features, but some mention is made of work associated with the ionosphere. There is brief mention of various aspects of the Fourth Framework Programme, concentrating on COST projects and how they have interacted with the Radiocommunication Sector of the International Telecommunication Union (ITU-R). Emphasis is placed on two particular projects: one that has just been completed and one that is just beginning.

2. European Fourth Framework Programme

The activities covered by the Fourth European Community Framework Programme for Research and Technical Development (1994-1998) encompass all the EC's research effort. They aim at improving the competitiveness of European industry and quality of life. FP4 is worth approximately £9.6 billion, with the possibility of a further top up of £0.5 billion in 1996. It sets aims, priorities and a budget for research support over a period of five years. The programme encompasses research where there are significant advantages which can be achieved only by implementation at a European level rather than by member states acting on their own. FP4 is directed at pre-competitive research rather than that which is near to market. Nonetheless, projects are expected to demonstrate that they can offer potential advances in the longer term.

Within FP4, the Advanced Communications Technologies and Services (ACTS) Programme is perhaps the most relevant to the application of radiowave propagation studies. It builds on the RACE programme in FP3 and is the major effort of FP4 to support precompetitive research and technological development in the field of telecommunications. The work is arranged in Tasks for which consortia are invited to make research proposals. Specific tasks cover interactive television and data services with the emphasis on advanced multimedia services carried out by broadband systems, notably the distribution by local area networks. Some of these services require development of a return path. Although cables will be installed in towns and cities where a large number of businesses and homes can be easily and economically connected, radio will serve locations within or at the edge of a town or city where the site to be connected may be a long distance from the cable or in a part where it is difficult to make cable networks. In rural areas throughout Europe, radio based networks may prove to be the only economic solution. Often where new services are introduced it is found that the radiowave propagation prediction methods produced for earlier services are not applicable.

An additional programme within FP4 is on co-operation with third countries and international organisations (INCO). By the topic areas selected for priority, radiowave propagation is not a natural area for support, but there is some potential for (i) collaboration with other European fora for scientific and technical co-operation, (ii) co-operation with countries of Central and Eastern Europe and with the new independent states of the former Soviet Union, (iii) co-operation with non-European industrialised third countries, and (iv) scientific and technological co-operation with developing countries.

Two other key European mechanisms are EUREKA and COST. The first of these is an initiative to encourage collaboration between organisations across Europe in the development of new and innovative advanced technology products, procedures and services. With its strong market orientation, EUREKA complements the EC's programmes of strategic research, but it is not an area with which radiowave propagation research studies are likely to be closely associated.

By contrast, European Co-operation on Science and Technology (COST) is an independent mechanism which enables participants to undertake research in areas of common interest, and to exchange the results amongst themselves. Participants fund their own research, but have access to all the project results. It is the mutual benefit the partners gain from co-operation that justifies their participation in a COST project. There are 25 European countries that are members of COST. In addition, organisations from non-COST countries may participate in individual COST projects, particularly from the states of the former Soviet Union. Participation in these projects is voluntary and 'a la carte', so only those countries that are interested take part. With an estimated 1,300 research teams involved in COST collaboration, the total value of current COST projects is something in excess of £780 million. There are 17 sectors of scientific discipline within COST.

The area of Telecommunications within COST has currently 21 projects operational, 29 completed and 2 agreed to start, with an average of 10 countries per project. Each project is autonomous under its Management Committee which has its own Rules of Procedure and is responsible to the Signatory countries, ie those who have signed the Memorandum of Understanding specific to that project. However, a project cannot be self perpetuating or stray far from the topic of its MoU, and annual reports are made to the COST Technical Committee for Telecommunications which authorised its initiation. Individual organisations conducting research work decide whether it is to their advantage to join a project and contribute the results of their research to discussion in a forum of colleagues having common interests. Members of Telecommunications projects come from research institutes, universities, national administrations/planners, service operators and industry. Within the subject area of Telecommunications, significant achievements have been made in the areas of radiowave propagation, antenna systems, telecommunications network planning, redundancy reduction techniques, mobile radio, optical communications, digital networks, telecommunications for disabled, high definition television, man-machine communications and human factors.

Before leaving the generality of European-wide research programmes and getting to specific projects, mention should be made of ESTEC initiatives. ESA has been successfully involved for more than two decades in studying the propagation conditions affecting satellite communications. Currently the emphasis is on exploring possibilties of regional and global mobile communications using satellites where the terrestrial infastructure is either missing or impractical to implement.

3. COST radiowave propagation projects

Three COST projects on tropospheric radiowave propagation topics have been conducted during the 25 years existence of COST, and a fourth is now in operation. There has been considerable consequence for ITU-R. The following is a very quick résumé of the position:

(i) COST Project 25/4 (November 1971 - October 1978) dealt with prediction effects on terrestrial paths above 10 GHz[1]. The purpose of the project was to co-ordinate the various experiments in the participating countries and to exchange the results of the studies on rainfall characteristics and on attenuation and cross-polarisation phenomena which may be caused by rainfall and multipath activity. Results on attenuation due to rainfall on Earth-space paths obtained with radiometric techniques across Europe was also included in the project. It produced a more comprehensive data bank of radiowave propagation and associated meteorological data for Europe than would have resulted from individual national efforts. It also unified the procedures for the comparison of results obtained, and contributed to the advice now available in ITU-R Recommendations.

(ii) COST Project 205 (July 1980 - July 1985) dealt with prediction of propagation effects on Earth-space paths above 10 GHz[2]. The objective of the project was to collate and assess the results of European activities in the field of Earth-space paths, especially at frequencies between 11 and 18 GHz in conjunction with OTS and SIRIO satellite experiments, in order to produce a comprehensive unified data bank by means of which models could be developed or evaluated for the European area. These contributed to ITU-R Recommendations, and planning future European satellite communication systems.

(iii) COST Project 210 (June 1984 - September 1990) dealt with predictions of propagation effects on potential interference over paths above 1 GHz [3]. The primary objective was to recommend improved procedures for the prediction of statistics of signal levels likely to cause co-channel interference, and for establishing co-ordination distances, so as to minimise the safe distance between radio systems operating in Europe. Because so few applicable data were available for development of prediction methods, many new measurement paths were set up, operated and analysed. These, combined with development of some earlier data, led to a new procedure being recommended. This too has had an impact on ITU-R Recommendations, and added to the SG 3 data bank.

By contrast, COST Project 235 (October 1991 - October 1996) has had somewhat broader objectives, as set out in Section[4]. It has been mainly concerned with wideband and millimetre wavelength propagation. COST Project 255 (a four year programme which started in January 1996) is considered in Section 5.

In addition, four other projects have related to radiowave propagation. COST Project 238 (March 1991 - March 1996) was concerned with prediction and retrospective ionospheric modelling over Europe[5]. The objective of the project was to develop the potential for generating improved prediction and retrospective models of the ionospheric electron density over a designated area of Europe in order to meet the established needs of radio system designers and users. The work of the project covered the following topic areas: vertical sounding, oblique sounding, spatial correlation studies, temporal correlation and prediction techniques, and ionospheric mapping and modelling. Because of its dense network of ionospheric sounders and long sequence of past data sets, the European region offered a unique opportunity to assess what improvements in accuracy were possible if global models were replaced by optimum regional models. It also permitted the study of refinement of forecasting techniques. This work led to COST Project 251 (a four year programme which began in May 1995) on improved quality of service in ionospheric telecommunication systems planning and operation. It is a natural follow-on to COST Project 238 and will test the operational value of the new ionospheric models using multipoint propagation models and suitable telecommunication system performance data. At the same time it will seek to collect additional and new types of ionospheric data and will further refine the latest ionospheric models in the light of the results obtained.

Other work involving radiowave propagation has been in COST Project 231 which is concerned with land mobile radio communications. This followed from COST Project 207 (March 1984 - September 1988), the work of which was associated with the European Global System for Mobility (GSM), and propagation studies were very specific and somewhat limited by the effort required on other aspects of the work. By contrast COST Project 231 (April 1989 - April 1996) had a working group dedicated to UHF propagation and another to broadband communications. The objectives of the project were to develop various elements in relation to the provision and extension of the Pan European digital mobile radio telephone and also to do preliminary development work on a personal universal land mobile radio system. Work in relation to the Pan European system concentrated on the development of field strength production models, propagation characteristics in tunnels, cellular coverage techniques, antenna characteristics and diversity techniques, and a half-rate codec. The propagation studies were rather different in nature from those of COST 235. The UHF work tended to concentrate on shadowing, building penetration losses and multipath effects in large, small and indoor cells. Propagation aspects of the broadband work tended to be for indoor applications.

4. COST Project 235

Broadband and millimetric radiowave communications are becoming central to many new services, and the proper understanding of the influence of the atmosphere and of terrestrial features is essential to successful operation of radio systems. Extensive work has been reported previously on the effects on radiowaves when propagating through the lower atmosphere, largely for analogue modulation and frequencies below about 30 GHz, but COST Project 235 was set up in 1991 to report on three Working Group areas: (i) frequency-selective effects and broadband consideration, (ii) flat-fade effects and millimetre-wave considerations and (iii) site shielding and other interference reduction strategies. It was charged with producing appropriate prediction methods to meet the needs in Europe. The project was intended to have application to a number of terrestrial fixed radio services involving point-to-point and point-to-multipoint: however, some results also have application to mobile services and Earth-space services. There have been 26 actively participating groups from 14 countries (Belgium, the Czech Republic, France, Germany, Hungary, Italy, the Netherlands, Norway, Romania, Russia, Sweden, Switzerland and the UK).

There continues to be similar interaction and commonality between those concerned with ITU-R and those concerned with COST radiowave propagation studies. COST Project 235 has actively sought to provide answers for Europe through collaborative studies. Similar problems are being investigated on a world-wide basis as a relatively small part of the programme of ITU-R Study Groups, but the prediction methods in the ITU-R Recommendations must remain somewhat general and cannot be expected to meet all the specific needs of system planners in Europe in the coming years. In consequence, COST Project 235 has made the decision to work quite independently. However, it is recognised that (i), whatever their strengths or weaknesses, the ITU-R SG 3 prediction models are the most widely accepted, and (ii) new and improved models for Europe developed by COST 235 will need to gain international agreement in ITU-R. Steps are being taken to offer suitable contributions to the relevant Working Parties, ie WP 3J (propagation fundamentals) and WP 3M (terrestrial point-to-point and Earth-space paths).

Working Group 1 has studied frequency-selective effects, and how to predict these, as well as the results of using various countermeasure techniques. For fixed communication links, the trend today is towards higher capacity without necessarily a larger bandwidth. This leads to complex techniques that are more sensitive to distortion caused by propagation (as well as other sources). The working group organised the tasks into four areas; channel modelling, diversity improvement, dual polarisation and multipath occurrence. Multipath channel models which may be used for developing performance prediction techniques have been available for many years. The work on multipath channels has been directed towards prediction of performance and what channel description is necessary. Basically, multipath propagation occurs when radiowave energy may follow two or more paths from a transmitter to a receiver. However, simplifications are needed in order to make practical prediction methods. The working group has focused on two approaches: one involves the so-called "signature" and the other the linear amplitude in-band distortion. Both are based on a two-ray simplification where one ray is delayed with respect to the other. Both amplitude and delay vary with time. Space diversity is one of the most used techniques for reducing outage on radio links. However, angle and frequency diversity techniques are also of interest, and these are sometimes the only possibilities. Performance improvement was the prime focus, and both channel models described above may be used benificially. Capacity may be doubled on a link if both polarisations can be used on the same channel. This has been examined. Multipath activity varies according to local climatic conditions and topography. New measurements have been provided from several countries, and, two ITU-R prediction methods available have shown comparable results when tested against data. An alternative method has also been tested. Radioclimatic parameters forms part of these methods. The ITU employs statistics derived from radiosonde measurements from about 1960. The working group has investigated new radiosonde measurements and found very large differences from earlier ones, mainly due to new sensor technology.

Working Group 2 was concerned with flat-fade effects and millimetre-wave considerations (interpreted within COST 235 as frequencies above 10 GHz, in order to compare results from propagation studies from a wide range of frequencies where the atmospheric effects change). Three major atmospheric phenomena have significant impact on the transmission of radiowaves at such frequencies. Firstly, there is attenuation of signals due to absorption by atmospheric gases of oxygen and water vapour in this region of the spectrum. Also the gases introduce frequency-dependent dispersive effects convey propagation delays which may need to be taken into account for very high frequency very wide-band systems. Secondly attenuation due to precipitation (in the form of rain, snow or hail) has to be dealt with from a statistical point of view. It increases considerably with increasing frequency, and current models are not considered to be adequate at frequencies much above about 40 Ghz. Thirdly, turbulence introduces scintillations in the received signals. Such effects can have dramatic consequences on the performance of digital communications systems. The general objectives of Working Group 2 have been to examine existing models for the major phenomena which affect the propagation of radiowaves in the millimetre-wave region and, with the gathering of new experimental data with which to test, to extend and develop models for use in the design and planning of the next generation of terrestrial communications systems.

Working Group 3 examined the effect of the radio propagation medium and the presence of terrain features on interference reduction strategies. Substantial knowledge concerning the interaction of the interfering electromagnetic waves with natural and man-made obstacles is needed to formulate a procedure capable of predicting both (i) the amount of shielding obtained from a building and (ii) the effects on the shielding factor caused by other buildings and terrain features present in the vicinity of the site. Site shielding, has to take account of (a) extension of diffraction models to include non-non-uniform illumination of the obstacle; (b) obstacle to-receiver distance variation; (c) near-field effects of the radio terminal antennas; and (d) effects on the site-shielding factor caused by scatter of radiowaves from adjacent buildings and vegetation. Some of the results during these investigations have been disseminated to ITU-R by way of National Administrations. For instance, prediction models for building scatter, and vegetation attenuation and scatter, validated by extensive measurements on tree formations and buildings, were reported to SG 3.

COST 235 presents its Final Report[4] in October 1996. Results have taken a major step forward for the design and planning of broadband digital millimetre-wave systems and reducing interference levels.

5. COST Project 255

One of the responsibilities laid by the TCT on COST Telecommunications project Management Committees is to look at developing needs of research and to propose new projects for their consideration. Accordingly, COST 235 MC looked at (i) climatic parameters for radiowave propagation prediction and (ii) system requirements in radiowave predictions. The former involves the selection of appropriate representations of radiometeorological parameters, eg (a) the probability that the refractive index lapse rate in the first 100 m above ground level exceeds 100 N/km, and (b) rainfall rate exceeded for 0.01% of time, etc., and mapping these on a world-wide basis. This area of interest was advanced at Climpara '94, an URSI symposium held in Moscow, and at Climpara '96, an URSI workshop held in Oslo. The geographical spread of countries associated with COST, and their various topography and climates, make such a study of value for Europe. The system requirement studies are always topical, and no less so now with new services being launched. To review these current requirements frequenctly is a very necessary consideration in radiowave propagation research.

In parallel with these proposals, the European Olympus Satellite Experimenter's Group (OPEX) had been considering a COST project as a forum for carrying out studies based on their collected data and preliminary analysis. The Italian Italsat Experimenter's Group (CEPIT) also saw an input to such a project. Discussion of these ideas with those from COST 235 produced proposals for a three-part project under the title "Radiowave Propagation Modelling for New Satcom Services at Ku-band and Above": (i) modelling of propagation effects in Earth-satellite paths at Ku-band and above, (ii) mapping climatological and morpho-topographical parameters pertinent to terrestrial and Earth-space radiowave propagation, and (iii) designing and planning of telecom systems where the satellite system is a segment. This new project is now developing well as COST Project 255. It is recognised that there may be a need before long for an additional project bringing together satellite and terrestrial studies, and perhaps fixed and mobile applications, but proposals for this are as yet being advanced.

6. Conclusions

This paper has outlined some of the radiowave propagation research activities in Europe as well as concemtrating on specific COST projects. The advantages of implementing new radiowave communication systems gives rise to continuing need for such specifically orientated research studies.

7. References

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