SATELLITE COMMUNICATIONS SYSTEMS

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PREFACE

Satellite communications is one of the most impressive spin-offs from the space programmes and has made a major contribution to, indeed totally altered, the patterns of international communications. Communications by satellite evolved from the simple technology of 'Early Bird' launched in 1965 to the highly sophisticated present-day satellites.

A large number of technical papers and books have been published on the subject of satellite communications. However, the available literature deals only with specific topics mainly related to communications techniques, and little has been written on the other various aspects of a satellite system, even though they are essential to fulfill the mission. Therefore the need was obvious for a practical book offering an overview of all aspects of satellite communications systems, which in addition examined these subjects in technical depth.

The aim of this book is to offer such an overview to students, engineers or scientists willing to enter the field. It can also be considered as a useful handbook to practising engineers. The book displays a detailed description of the various parts and interfaces of a satellite communications system, together with the constraints to be considered and the corresponding issues. Techniques commonly used and advanced concepts are covered.

The material in this book is presented in both undergraduate and first-year graduate courses at the Ecole Nationale Supérieure des Télécommunications, at the Ecole Nationale Supérieure de l'Aéronautique et de l'Espace and at the University of Toulouse (France). It has also been well appreciated by a large number of engineers involved in the field who attended continuing engineering education and in-house courses that we have conducted in France and abroad.

The book is divided into nine chapters. Chapter 1 presents the evolution and use of satellite communications systems from the most naive ones, at the beginning of the space era, to the most technically advanced present-day systems. Chapter 2 deals with transmission of information between the satellite and earth stations, i.e. analyses the factors which condition the link budget, and describes modulation techniques and their performances. Chapter 3 discusses the various aspects of multiple access (FDMA, TDMA and CDMA) by several earth stations to one satellite. Beam switching is examined in the context of multibeam satellites. The simplest non-regenerative satellite repeater and the more complex regenerative ones with on-board processing are both discussed. Chapter 4 deals with the various topics related to the geometry of the system such as orbits, distance between satellite and earth stations, coverage areas, earth stations antenna pointing angles, eclipses and solar interferences. Chapter 5 aims at a description of the main environmental factors which condition the design and operation of the satellite on its orbit during its lifetime. First a description of the space environment is given, and then the effects of this environment on the satellite itself. Chapter 6 is devoted to the various subsystems which constitute a geostationary communications satellite. It is common practice to distinguish the communications subsystems (repeater and antennas) from the bus or platform (attitude and orbit control, propulsion, telemetry tracking and command, thermal control, structure, electric power supply). For each subsystem the purpose, a description of the possible solutions and the performances according to the state-of-the-art technology are presented. Chapter 7 explains the constraints and the procedures of the launching and positioning of a geostationary satellite. This chapter offers also detailed characteristics and performances of current launch vehicles including STS and ARIANE. Chapter 8 is devoted to earth station technology. Chapter 9 analyses the technics used to evaluate the reliability of a satellite communications system and ensure the required availability.

We have made an extensive use of the important material presented in the various technical journals from the IEEE, AIAA, and others, and in papers presented at various conferences and conventions by members of aerospace companies or space agencies. We have attempted to give adequate credit to all authors of the above cited material, and we apologize in advance to any author for unintended omissions. We wish to thank the many excellent and assiduous technical staff members of the various companies (Matra, Alcatel-Thomson, Aerospatiale) and agencies (CNES, CNET, ESA) with whom we have been in contact for many years for helping us to understand a little more about satellite communications, and for influencing our teaching in this area.

G. MARAL
M. BOUSQUET

Acknowledgment

Initially the French publisher Masson published a book entitled *Les systèmes de communications par satellites* by J. Pares and V. Toscer. This book was mainly a contribution by J. Pares, a former student of the Ecole Polytechnique and a graduate of the Ecole Nationale Supérieure des Télécommunications. At that time J. Pares was with the Direction Générale de l'Armement of the Ministry of Defence and in charge of advanced studies in satellite communications systems. The original material came from the course he gave at the Ecole Nationale Supérieure des Techniques Avancées, Paris. The great success of the book encouraged the publisher to issue a new edition. In the meantime J. Pares had left the Ministry of Defence for Siemens S. A., where he is Head of the Communications Division for France. As J. Pares was no longer directly involved in the field of satellite communications, the publisher asked us to update the material. We maintained the initial organization of the first edition while adding an original contribution to cover the rapid development of the field. This second edition entitled *Les Systèmes de Télécommunications par Satellites* by G. Maral, M. Bousquet and J. Pares was duly published. Subsequently, John Wiley decided to have the book translated and to publish it in English. We took this opportunity to update and upgrade most of the material again, while still retaining the original organization set up by J. Pares. We wish to express to J. Pares our gratitude for leading the way and for his contribution to the success of this new version.

G. Maral
M. Bousquet

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CHAPTER 1 Introduction

Communications involve the transfer of information between a source and a user. Terrestrial communications face long distance communications constraints because they either use guided media—wirelines, coaxial cables, and optical fibre cables—which have in common the fact that they require a physical path between terminals or wireless transmissions such as microwave radio relays which due to propagation problems must be in line of sight. Modern satellite communications originate from Clarke's idea to install radio relays on geostationary satellites, thus allowing for transmission of radio microwave signals over large distances (Clarke, 1945). The explosive growth of communications satellites and the perceived potential of the medium for novel applications has generated intense interest in both government and private sectors. This chapter presents the evolution and use of satellite communications systems from the simplest ones, at the beginning of the space era in the late fifties, to the most technically advanced present day systems, and also takes a look into the future.

1.1 ORIGINS OF SATELLITE COMMUNICATIONS SYSTEMS

Satellite communications are the outcome of research in the field of radio communications with the aim of achieving the greatest coverage and capacity, at the lowest cost. The Second World War encouraged rapid development of missile and microwave technology. The joint application of expertise gained in these two technologies heralded an era of radio communications by satellite. The services provided complemented those supplied until then exclusively by terrestrial networks (radio or cables).

Satellite communications systems are divided into two parts:

(1) Space segment (includes the satellite and the means on Earth necessary for launching and station keeping),
(2) Earth segment (earth stations containing transmitters and receivers for transmission and reception of signals from satellites).

Whereas communications on the Earth's surface benefited from advances