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Satellite Systems for Personal Applications

Concepts and Technology

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SATELLITE SYSTEMS FOR PERSONAL APPLICATIONS

CONCEPTS AND TECHNOLOGY

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Preface

People in our modern society are profoundly dependent on technology for their work, well-being and quality of life. In recent years, satellite systems have introduced a universal dimension to this technological landscape – although the individual may not always be aware of the extent of the contribution of satellite systems. Satellite technology is today accessible and affordable by individuals, and this book has been created to lay a strong technical foundation towards understanding the role and functioning of existing and emerging satellite systems for personal (i.e. end-user) applications.

Whereas previous books have addressed satellite technology and the personal role of satellite systems in individual service areas – notably personal satellite communications – this book spans the entire breadth of satellite-enabled end-user applications. The aim has been to present the subject matter in a clear and concise manner with key illustrative examples.

After an introductory chapter, the book presents fundamental concepts applicable generally across all the systems. Subsequent chapters delve into techniques and examples of specific systems and services available directly from personal satellite terminals. Such applications encompass broadcasting, communications (narrowband and wideband, commercial, military and amateur), navigation and satellite-based distress services. The book additionally covers those services that are gradually permeating into the personal domain–in particular, satellite imaging and remote sensing.

Finally, the authors explore the trends and evolution of such satellite systems, taking into consideration the influences, user expectations, technology evolution, regulatory efforts and characteristics of satellite systems.

Readers wishing to glean further useful information about the book, to obtain a list of errata, and/or provide feedback to the authors may wish to visit the website at http://www.SatellitesAndYou.com.

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1

Introduction

1.1 Scope

The past two decades have seen a quiet revolution in satellite-based services. Once the preserve of governments, international bodies, public utilities and large corporations, today the majority of satellite service users are *individuals*, who can now access, *directly*, a wide range of satellite services – typically using personal, mass-market and even handheld devices. These satellite systems now fulfil a variety of personal necessities and aspirations spanning telecommunications, broadcast services, navigation, distress and safety services and (indirectly) remote sensing, in the commercial, military and amateur sectors. It therefore seems an appropriate time for a book that addresses these services from the perspective of their support for, and functionality delivered to, individual users.

This book therefore aims to:

- enhance awareness regarding the expanding role of satellite systems in individuals' daily lives;
- lay a strong technical foundation of the basic principles and functioning of these satellite systems for personal communications, navigation, broadcasting and sensing applications;
- illustrate current practice using selected example systems in each field;
- review current trends in relevant satellite and related technology.

The book aims to address an audience that is inquisitive and keen to understand the role of satellites in our daily lives and the underpinning concepts, and, in contrast to alternative offerings, the focus in this book is on the *individual* and the *end-user application*. It aims to provide all of the relevant concepts, in a clear and concise manner, together with descriptions of key systems as illustrations of their implementation in practice.

Satellite services are formally categorized by the International Telecommunications Union (ITU) according to their broad service types. For example, the Broadcast Satellite Service (BSS) addresses recommendations and specifications related to satellite-enabled broadcasts. This book, instead, attempts to address all the services with respect to a user's application perspective – be it telecommunications, broadcast, navigation, amateur, military or safety-related systems.

Space technology comprises a number of branches – satellite communications, satellite aids to the amateur, space exploration, radio astronomy, remote sensing/earth observation, military reconnaissance/surveillance, deep-space communication, launch technology, interplanetary exploration, radio astronomy, space tourism, etc. This book focuses on those technologies where individuals benefit, in a direct or tangible way, from a satellite system. A user interacts directly with a personal satellite broadband terminal when communicating via satellite or interacts with a direct-to-home television receiver when viewing a programme directly from a broadcast satellite. Similarly, an individual using satellite navigation interacts directly with a Global Positioning System (GPS) receiver.

In some cases the user may not interact directly but nevertheless benefits from information obtained (only) through the use of a satellite system, with some aspects of user hardware or software typically tailored to exploit that

system’s capabilities, and such applications are also included in the scope of this book. An application in this category would be viewing images of the Earth’s weather system appearing daily on our television and computer screens. Here, the pictures transmitted from the satellite are processed elsewhere for the intended audience. Nevertheless, in such instances the individual is conscious that a satellite system is involved.

Those applications and systems where satellites remain in the background are not addressed here, although the same technical concepts apply in the majority of the cases. Examples of this category are interconnection between telecommunication traffic nodes or terrestrial base stations, remote sensing for government (e.g. monitoring vegetation), military surveillance and communications dealing with weapons delivery, television programme distribution between broadcasters, etc. Space tourism (personal spaceflight) is not included in this edition of the book.

1.2 Perspective

Modern society leans heavily on technology for its personal needs – be it entertainment, communications, travel, safety services or domestic appliances. This book deals with the role of satellites in the consumer (or individual) technology paradigm. Consequently, generic user terminal technologies such as terrestrial mobile systems, personal digital assistants, personal computers, etc., are discussed where relevant to personal satellite systems use.

The dependency on satellites in the developed world is quite remarkable. Furthermore, it continues to increase in both the developing and the underdeveloped world owing to falling technology costs together with a growing awareness of the accruing benefits. It must be remarked here, though,

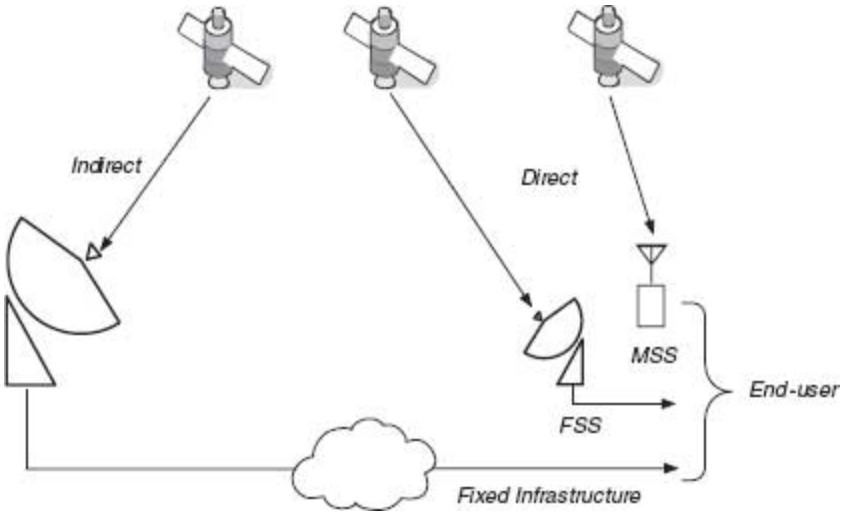
that there is a significant difference in priorities in each sector. In an affluent modern society, a majority of people expect a ubiquitous voice service with broadband Internet access, whether they are at home, away or travelling. Many individuals also now aspire to owning a converged handset encompassing some or all of the complementary features such as computing and database functionalities, a hi-fi digital music player, a camera, including video, a radio receiver and mobile television.

In the less developed world, individual requirements and aspirations are curtailed by lower affordability, infrastructure limitations and social conditions. It has been observed that the Gross Domestic Product (GDP) of an economy increases in direct proportion to the improvements to the communications infrastructure. Therefore, there is a great interest in the developing world for deploying wired and wireless technologies such as mobile telephony, the wireless local area network (WLAN) and satellite communications. In the developing world, there is typically minimal fixed infrastructure, with the result that satellites offer an attractive means to build up services, before it becomes economic to introduce fixed assets. One also expects some modifications to mainstream technologies for them to be cost effective and relevant in this environment. The notion that a personal handset is unaffordable, or that the average daily use of such terminals is miniscule, is offset by the fact that such resources are often shared by groups or communities. An example of technical adaptation in a developing region is the extended WLAN trials reported by Raman and Chebrolu (2007) where WLAN coverage was extended to a much wider area than in developed countries, to support scattered rural communities.

Computation, television, broadcast and navigation solutions continue to converge rapidly, enabled by digitization, the vast strides in large-scale integration and

mass production techniques resulting in attractively priced converged handsets and accompanying infrastructure enhancements, as the operators reposition themselves in this new paradigm. A number of enabling technologies are instrumental in shaping such converged solutions.

Figure 1.1 The personal (end-user) satellite applications domain.



The unifying force of the Internet offers unprecedented connectivity and tailored solutions such as Internet Protocol (IP) telephony, e-mail, e-learning instruments and audio/video streaming. The evolution in processing capability of personal computers continues unabated. Furthermore, cellular radio technology, based on the concept of radio spectrum multiplication through spatial reuse, now provides instant connectivity across continents. Within a span of just two decades, three generations of cellular systems have been fielded, and research for the introduction of the fourth and even the fifth generation is well under way. The unprecedented success of personal mobile systems has laid the foundations for the commercial viability of WLAN, which enriches the lives of millions through wireless accessibility to the Internet – not only at home and in the office but also in public areas such as cafes and airports.

The extent and speed of introduction of satellite-enabled solutions into the personal domain has surpassed expectations. In broad terms, such applications fall in the areas of personal communications, navigation, broadcast, distress–safety, Earth observation and amateur radio.

Figure1.1 illustrates conceptually the use of satellite systems for personal applications, indicating the wide scope covered by this book.

1.3 Background and Applications

1.3.1 Background

The space era began with the launch of Sputnik and Explorer by the former Soviet Union and the United States in 1957 and 1958 respectively. Following a series of innovative technical developments, the era of geostationary satellite communications dawned with the launch of Early Bird in 1965. Until the mid-1970s, these communication satellites were mainly used to interconnect large telephone exchanges on national or, more usually, international trunk routes – an application quite remote from individuals. For the individual, the only manifestation of the satellite routing was the propagation (and echo) delay. In parallel, satellite applications extended to numerous other disciplines, namely Earth observation, navigation and radio amateur communications, etc. Monitoring of the Doppler frequency shift of radio signals from the first Sputnik satellite led to the concept of using satellites for navigation, and the first TRANSIT navigation satellite was subsequently launched in 1959 by the US Navy.

Space-enabled technology was furthered by space agencies, manufacturers and operators, leading to a wide

range of applications. Direct broadcasts and mobile communications were demonstrated in the 1970s. The well-known Navigation System for Timing and Ranging (NAVSTAR), commonly known as the Global Positioning System (GPS), was launched in 1978 by the US Department of Defense (DoD). A competing system known as the Global Navigation System (GLONASS) was launched by the former Soviet Union in 1986. Yet another system known as the Galileo Positioning System, or simply Galileo, initiated by the European Union and the European Space Agency, is due for launch in early 2014.

Earth observation is a generic term used for a variety of satellite monitoring or, more precisely, remote sensing functions related to environment, meteorology, map-making, forestry, agriculture, etc. Vanguard-2 (launched 1959) was the first earth observation satellite, although TIROS-1 (Television and Infrared Observation Satellites – launched 1960) is widely regarded as the first successful Earth observation (weather) satellite, owing to a malfunction on Vanguard-2. Today, several countries and international bodies own and operate Earth observation satellites. This book encompasses applications such as weather monitoring and map-making where they are directly perceived by individuals. Some existing Earth observation satellites are:

- GMS (Geosynchronous Meteorological Satellite) – these satellites are placed in a geostationary orbit for meteorological sensing;
- Landsat – These satellites are placed in 700 km polar orbit for monitoring mainly land areas;
- NOAA (National Oceanic and Atmospheric Administration) – these satellites are placed in 850 km in polar orbit for meteorological observation and vegetation monitoring.

Amateur radio operators (affectionately known as ‘hams’) share an interest in construction and communication through non-commercial amateur radio satellites. Ham satellites are known generically as Orbiting Satellite Carrying Amateur Radio (OSCAR), the first of which, OSCAR 1, was launched into a low Earth orbit in 1961. There were almost 20 of these satellites operational in 2006 with plans of numerous additional launches. The Radio Amateur Satellite Corporation (AMSAT) was formed in 1969 as a non-profit educational organization, chartered in the United States to foster amateur radio’s participation in space research and communication. Similar groups were formed throughout the world with affiliation to each other. These individuals have pioneered several breakthroughs and continue to do so.

As an aside, we present a few interesting observations that reveal some of the less obvious strengths of satellite systems and position them favourably in a modern context (Robson, 2006/2007).

- A typical Ariane 5 satellite launch emits about half the carbon dioxide emission of a transatlantic jumbo flight.
- Satellites are solar powered and hence environmentally friendly.
- By eliminating or reducing the need for terrestrial infrastructure where possible, it is feasible to reduce environmental load and costs (e.g. through lower use of electricity).
- Satellites are the most cost-effective delivery method for television broadcasts over a wide area.
- Terrestrial TV is heavily dependent on satellites for programme distribution.
- Personal broadband service in remote areas is more cost-effective via satellite than terrestrial techniques.
- Satellites can sometimes offer higher maximum speeds for broadband Internet access for individuals than

terrestrial wireless mobile systems (albeit at a higher cost).

- Free satellite broadcast channels are available to users, much as their terrestrial counterpart; hence, the notion that satellite broadcasts are unaffordable to the less well off is debatable.
- The space economy is growing at a rapid rate, proportionately benefiting companies and individuals associated with the industry.

1.3.2 Applications

A wide range of personal applications has been enabled through the collective effort, encouragement and financial support of the satellite industry and various governments, complemented by the assistance of the regulatory authorities and an innovative research community. The recent trend in liberalization and privatization has introduced considerable motivation for an enhanced commercialization of the satellite industry. A notable feature of the changed environment is that industry's attention is likely to be favourable towards personal applications that promise a mass market. This trend is likely to result in a wider portfolio of personal satellite services and solutions in conjunction with cost benefits due to economies of scale.

When dealing with progress in technology, it is convenient to group applications by their service class owing to their inherent commonality. Typical applications of personal satellite systems categorized by their services are listed in Table 1.1, and an evolution timeline is summarized in Table 1.2. Appendix A lists a more comprehensive set of personal satellite applications.

Table 1.1 Personal applications by service category

Service category	Applications
Telecommunications: (fixed and mobile)	*Social*: Mobile communications from remote locations (e.g. a remote holiday destination) or while travelling (e.g. on a ship, in a car, or an aircraft) *Business*: Broadband communications from small offices or remote larger offices *Emergency*: Communications from an individual in distress (e.g. during a mountaineering expedition or a maritime rally) *Entertainment*: Interactive Internet gaming, live television and radio during flight *Military*: Command and control; Situation awareness; Welfare communication
Broadcast	*Television*: Direct-to-home broadcasts *Radio*: Direct broadcasts for long-distance car travel, expatriate listening, live broadcast to aircrafts, etc. *Multicast*: Broadcast to a group/region (e.g. weather forecast, sports results) *Unicast*: Broadcast to individuals – financial/stock exchange update
Navigation	*Location dependent:* (e.g. road traffic conditions) *Route guidance:* (e.g. SATNAV) *Distress* *Trekking* *Agriculture:* (e.g. crop spraying) *Military*
Earth observation	*Weather*: Daily TV broadcasts *Photographs/maps*: Education, city maps
Distress and safety	*Internationally approved system*: GMDSS *Local or regional service* *Ad hoc arrangements*
Amateur	*Amateur communication* *School projects* *Distress and safety* *Innovation*

Table 1.2 Evolution timeline of personal satellite applications

Personal system	Approximate year of entry
Amateur radio	1961
Low-speed data land /maritime	Late 1980
Maritime phone	Early 1980
Direct-to-home broadcasts	1989 (Europe)
Fixed broadband	Early 1990
Aeronautical phone	Early 1990
Maritime medium-speed data	Early 1990

Remote pay booth	Mid-1990
Desktop portable phones	1997
Handheld phone	1999
Affordable satellite imagery	Late 1990
Satellite radio	2001
Digital video broadcasting – satellite handheld	2004
Portable multimedia	2005
Satellite digital multimedia broadcast	2005
Mobile multimedia (ships, aircraft, land vehicles)	2007–2008

1.3.2.1 Telecommunications

Personal satellite telecommunication applications are most effective in remote regions without adequate terrestrial infrastructure, as well as in a mobile environment. The low penetration of satellite communication systems in areas lying within a terrestrial coverage is attributed to the relatively high end-user costs of satellite systems. However, satellite-enabled solutions are becoming increasingly synergistic and cost effective.

1.3.2.2 Fixed Satellite Service

In the Fixed Satellite Service (FSS) arena, steady inroads into the fixed personal broadband have continued, beginning in the early 1990s. The uptake of personal satellite broadband service has increased steadily, particularly in rural and remote areas of developed countries, because of an increasing reliance on Internet-delivered services and applications. There were around 2 million Very-Small-Aperture Terminals (VSATs) dispersed around the world in 2010 (Source: David Hartshorn, Global VSAT forum, 2009). VSAT networks are suited for content distribution, interactive services or services for interconnected mesh networks. In addition to well-entrenched applications, Internet-enabled applications such

as TV over IP protocol (IPTV) and Voice over IP (VoIP) are increasing in popularity. Many enterprises have widely dispersed offices that are often inaccessible using only terrestrial networks. Such enterprises typically exploit Virtual Private Networks (VPNs) over satellite because these ensure the desired connectivity tagged with security at an attractive cost. Other applications where fixed satellite solutions are proving beneficial include both one-way and two-way interactive distance learning and telemedicine.

Today's typical high-end VSAT system includes a user terminal capable of supporting multiple telephone channels and Personal Computer (PC) networks, connected to a host network capable of delivering toll-quality voice and IP transmission. These solutions particularly appeal to small office/home office (SOHO) users, Internet cafe owners, etc.

VSAT networks are based on both proprietary technology and open standards. The latter allow economies of scale owing to competition. A case in point is the widely used Digital Video Broadcast–Return Channel by Satellite (DVB-RCS) standard developed in Europe with international participation. By providing an asymmetric data rate return channel from the users, it offers interactivity useful in applications such as interactive TV, the Internet and distance education.

Figure 1.2 A broadband personal terminal. Reproduced by permission of © Pearson Education. All rights reserved.