Satellite Communications Overview

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Abstract

In the 50 years that followed the first satellite launches of the late 1950s and early 1960s, the diversity of satellite services has expanded enormously. Today, there are direct broadcast radio and television services to the home and even to mobile receivers. There are mobile satellite services to airplanes, ships at sea, and even hand-held transceivers. There are so-called fixed satellite services to earth stations of various sizes down to so-called very small antenna terminals (VSATs), microterminals, and even ultra small aperture terminals that can be located on desktops. There are data relay satellites and business to business satellite systems. The age of the Internet and data networking has certainly served to add to the diversity of satellite services. Technology innovation has also led to the growth and development of satellite communications services. Lower cost launch arrangements and development of earth station technology and particularly application specific integrated circuits have been key to driving down the cost and size of ground antennas and transceivers. The development of three axis body stabilized spacecraft, better solar cells and batteries, and more effective on-board antenna systems and on-board switching among multi-beam antennas have also furthered the cause. Finally, the development of not only bigger and better satellites but the evolution of satellite systems design and network architecture

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that allowed networks to be deployed in different types of orbits and network constellations has been part of this on-going evolution.

The latest iterations of satellite design have led to almost opposite extremes. On one hand there are large, sophisticated multi-ton satellites, known as high throughput satellites, deployed in traditional geosynchronous orbit locations. On the other hand, there are also small but capable satellites in low to medium earth orbit constellations. These new satellite networks are being designed with more and more mass-produced satellites – up to a thousand or more in a single system – to increase network capacity by means of deploying more and more satellites in lower orbit.

This chapter provides a general introduction to all of these changes and an overview to the entire field. Changes to satellite communication networks over the past half century have come not only in services and technology but also in regulation, standards, frequency allocations, economics, as well as the global reach and impact of satellites on the entire scope of human society.

Keywords

Broadcast satellite service (BSS) • Data relay satellites • Fixed satellite service (FSS) • Geosynchronous earth orbit (GEO) • International Telecommunication Union (ITU) • Intersatellite link (ISL) • Low earth orbit (LEO) • Mobile satellite service (MSS) • Satellite constellations • Store and forward satellite service

Introduction

The serious consideration of the provision of satellite communications from space dates from 1945 when the first technical descriptions were written with regard to launching a spacecraft into geosynchronous orbit and the design of space stations as extraterrestrial radio relays was specifically outlined. In the historical section that follows, however, it becomes clear that the idea or concept had been around many years, indeed centuries before. The 1945 article, however, described the possible delivery of telecommunications services from space and presented detailed calculations as to how this might efficiently be done from a special orbit known as the geosynchronous (or sometimes the geostationary) orbit (Clarke 1945). Today, this orbit is even sometimes called the Clarke orbit.

The new capability that allowed satellites to be launched that came from technology development in the USSR and the USA in the late 1950s and early 1960s expanded into the capability to launch a satellite into geosynchronous orbit – that came in 1963 – allowed the rapid evolution of satellite communications technology. Within a decade, a wide variety of telecommunications services from satellites in different types of orbits became possible. The International Telecommunication Union (ITU), the specialized agency of the United Nations that oversees the use of radio frequencies (RF) for practical and scientific purposes assumed responsibility for satellite radio frequencies. This began with a globally attended Extraordinary Administrative Radio Conference (EARC) in 1959. The ITU thus provided for the first time a formal process by which radio frequency (RF) spectrum could be allocated to support satellite communication (Pelton 1974).

Over time, the ITU defined a number of satellite communications services that might be offered via different satellites in different types of orbits. The ITU international processes also defined a system and a process whereby there could be technical coordination of such satellites to limit interference between and among them. The number and type of satellite communications services have grown and expanded over the years as is discussed in the following sections (ITU 2008).

There are today many types of technical designs for satellite communications, and these technologies are optimized to support a variety of services around the world. A wide range of commercial satellites now operate at the national, regional, and global level. These satellite systems support various types of data, telephone, television, radio, and various networking services around the world.

Overview of Commercial Satellite Services

The services defined by the International Telecommunication Union (ITU) include the following.

Fixed satellite services (FSS): FSS spacecraft support telecommunications services between antennas that are at fixed points. These fixed antennas can be used for reception only, for two-way communication (like a cable in the sky), or for communications within a network that can start with only a few nodes or can grow to a very large network indeed with thousands of interconnected nodes. The first of the commercial communications satellite services were these FSS systems. The Intelsat FSS system was the first to begin to provide international commercial telecommunications services in 1965. Also deployed in 1965 was the FSS system called Molniya, which provided telecommunications services for the Soviet Union, other Soviet Socialist Republics, and Cuba. An Initial Defense Satellite Communications Satellite system was also deployed to provide FSS services to support US defense-related telecommunications services. These initial FSS systems have now multiplied to support satellite telecommunications for over 200 countries and territories around the world (Pelton 2006, p. 30). Figure 1 shows a current generation broadband FSS satellite, the IP Star that operates in the Asian region of the world. Figure 2 depicts the Viasat 2 high throughput satellite. This represents the highest capacity satellite of the current generation of fixed satellite service (FSS) spacecraft with a capability of about 150 GB/s. This is more than ten times the throughput of a large communications satellite of just 5 years ago.

In addition to over 200 commercial communications satellites that supply fixed satellite services, there are now scores of military communications satellites that provide fixed satellite services in support of defense-related missions. Although the largest fleet of defense-related communications satellites are owned and operated by the US military, there are a number of strategic communications satellite systems owned by over a dozen countries around the world. In addition, commercial satellite systems leased capacity to military systems for so-called dual-use purposes to

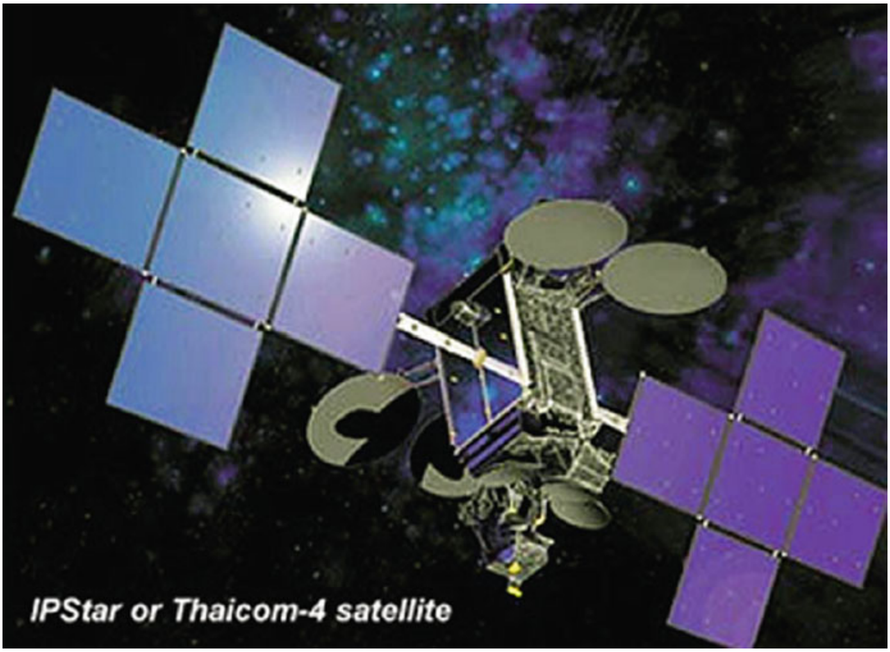

Fig. 1 The IPStar Satellite also known as Thaicom-4 (Graphic courtesy of IPStar)

supplement the capabilities of defense satellite communications systems. Figure 2 shows the WGSS military satellite designed to provide communications services.

Broadcast satellite services (BSS): BSS satellites use very high powered beams to deliver radio or television services directly to end users. In order for this service (also known informally as the direct broadcast satellite (DBS) service) to be economical and efficient, the receiver terminals must be small in size, low in cost, and easy to install and operate. Different RF bands are used for radio or direct audio broadcast services (DABS) in contrast to direct broadcast satellite (DBS) television services. The broadcast satellite service began later than the initial FSS offerings, but this industry has grown rapidly and is now by far the largest revenue generator in the satellite world by a wide margin (Pelton 2011).

The Nimiq BSS satellite (Fig. 3), operated by the Canadian Telesat organization, provides direct broadcast services to Canada and the USA.

Mobile satellite services (MSS): The MSS services provide telecommunications to end-user antennas that move rather than remain stationary. The MSS services today include telecommunications connectivity for maritime, aeronautical, and land-based users. The first MSS satellites were designed for maritime service. Next, these satellites were used to support both maritime and aeronautical services. The last type of mobile communications satellites that has evolved are those designed for land-based mobile services. This is the most demanding of the MSS services technically,

Fig. 2 The high throughput Viasat 2 depicted in orbit (Graphic courtesy of Viasat)

but in terms of market, this is also the most demanding. A variety of different designs in different orbits have evolved with the initial land mobile systems known as Iridium, Globalstar, and ICO experiencing severe financial and market difficulties with their initial service offerings. These organizations have been reorganized and the Iridium and Globalstar systems are deploying their second-generation systems while ICO is developing a new mobile satellite service for the US market (Figs. 4 and 5).

Today, there are a variety of MSS satellites deployed in a variety of different orbits. Some of the latest systems are those designed to work in conjunction with terrestrial cellular telephone services within urban areas. These hybrid systems that integrate mobile communication satellites with terrestrial cellular systems are called MSS with “ancillary terrestrial component (ATC)” in the USA. The equivalent service is called MSS with complementary ground component (CGC) in Europe. These hybrid mobile systems combine urban terrestrial cellular systems in a seamless manner to allow very high powered MSS satellites to cover the rest of a country or region. Unlike the initial constellations like Iridium and Globalstar, these new systems with a terrestrial component are deployed in geosynchronous orbit and are targeted to service to a single country like the USA or a single region like Europe (Pelton 2006, p. 31).

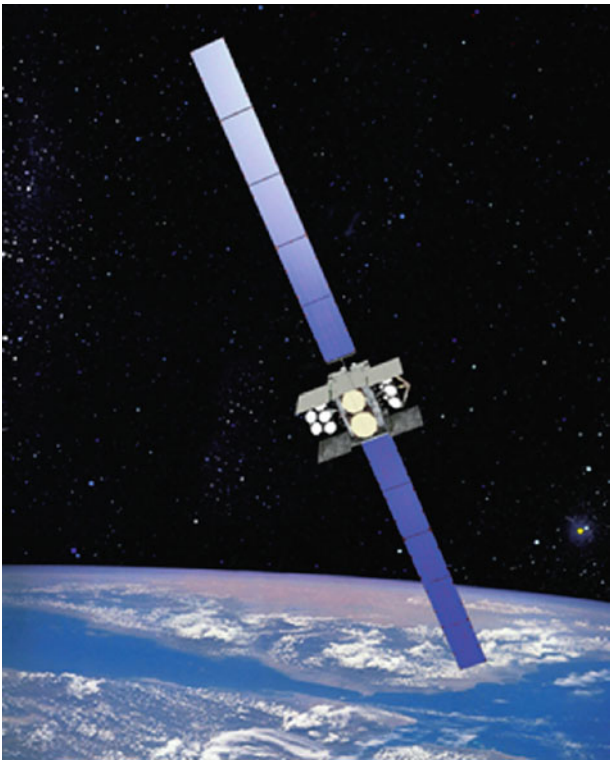

Fig. 3 The wideband global Satcom satellite (Graphic courtesy of the US Military)

These satellite services, FSS, BSS, and MSS, are the so-called big three of the commercial satellite services and represent a very significant part of the total worldwide market for the satellite industry. Nevertheless, there are other types of telecommunication satellite systems that can be, and indeed are, deployed. One additional system is the so-called store and forward type data relay satellite that can support messaging services to remote areas. The more satellites deployed in low earth orbit to support in this type of system, the more rapidly a message can be relayed from one part of the world to another. If there are enough satellites of this type, like in the Orbcomm system, you can have almost instant messaging. In some cases, the receiver can be configured to not only receive short messages but also to receive space navigation signals to support vehicular or ship navigation. One can also design a transceiver to send short data messages as well as to receive them, as has been done with several store and forward satellite systems. There are also data relay satellites that are typically in Geo orbit. These satellites are most typically used to relay data from a low earth orbit system back to a central process so that data can be continuously collected rather than stored for download at a subsequent time. The NASA third generation tracking and data relay satellite that is being deploy in the 2013–2016 time frame is shown in Fig. 6.

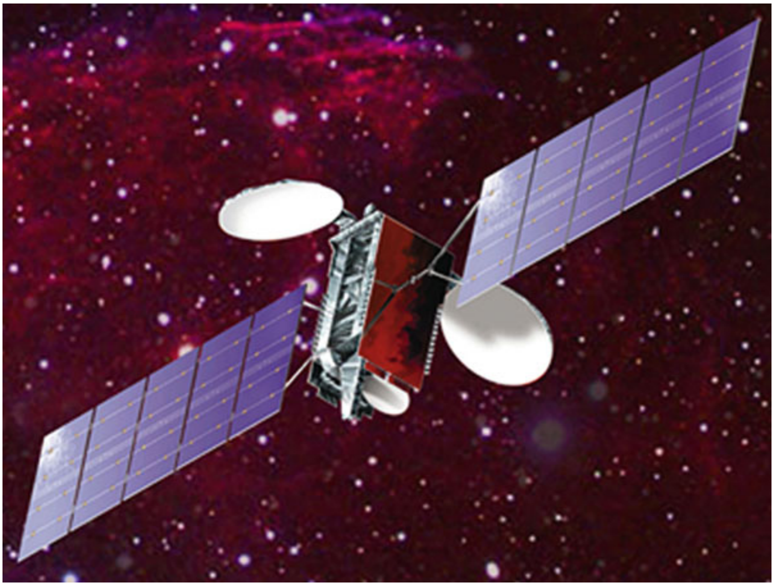

Fig. 4 A Canadian Nimiq direct broadcast satellite (Graphic courtesy of Telesat)

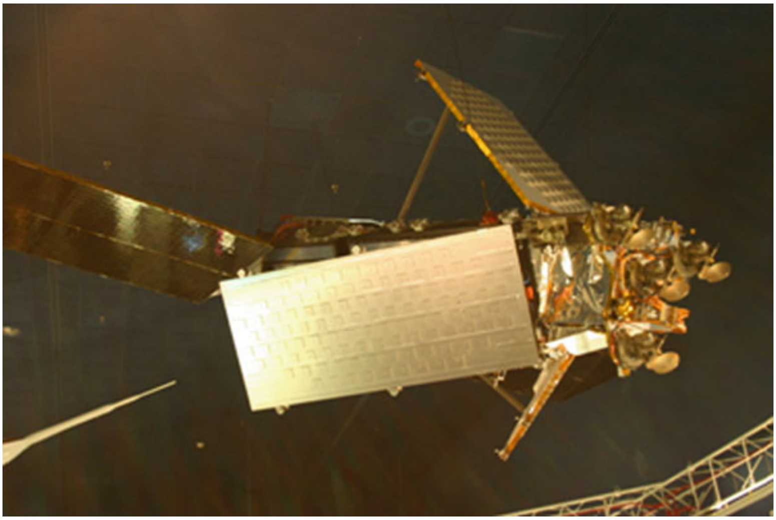

Fig. 5 A constellation of 66 iridium satellites provides global mobile services (Graphic courtesy of Iridium)

Some commercial satellite systems employ what are called cross-links (CLs) or intersatellite links (ISLs), or in ITU parlance intersatellite service (ISS) in order to operate. These can be used in low earth orbit or medium earth orbit to interconnect satellite constellations. ISLs were a part of the design of the low earth orbit Iridium

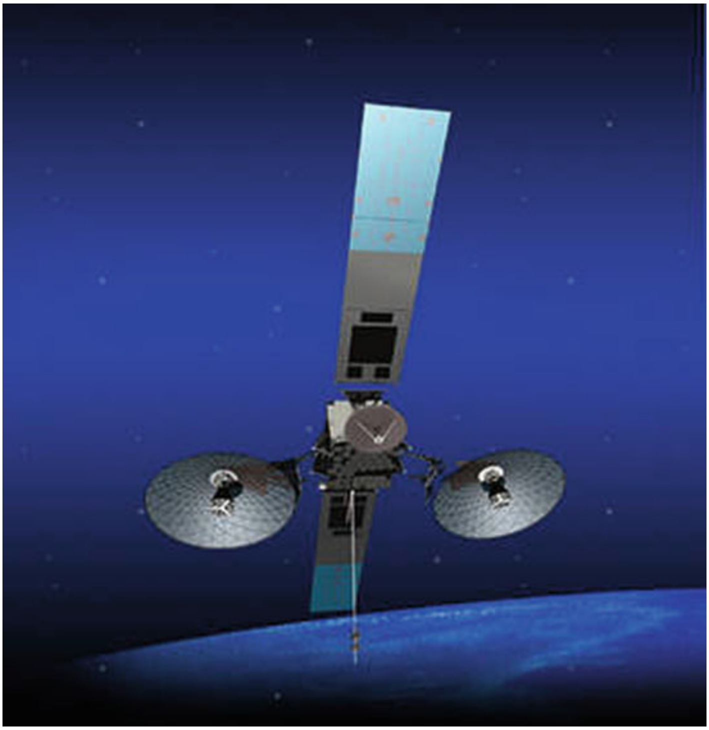

Fig. 6 The NASA third generation of tracking and data relay satellite

satellite network, and they have been used in some military communications satellites. ISLs could also be used to interconnect geosynchronous satellites on an interregional basis in order to avoid double hops when communicating halfway around the world. Today, satellite service connections providing global linkages and thus can often combine with a fiber-optic submarine cable to achieve rapid connectivity across the world. This is true in part since intersatellite links for regional interconnectivity still remain relatively rare. The more common use of ISLs is to interconnect satellites within a large-scale low earth orbit constellation where the satellites are typically hundreds of kilometers apart from one another rather than many thousands of kilometers apart such as the case when geosynchronous satellites are serving different regions of the world (Pelton 2006, p. 31).

Finally, there are satellites for military or defense-related communications. These satellites for military purposes are allocated different frequency spectrum than commercial satellites. These satellites resemble commercial satellites in many of their technical features, but they often have special features. Special capabilities can include radiation hardening, additional redundancy, and special encryption capabilities. Military communications are not operated on a commercial basis for the most part. There is a special chapter in this handbook that does describe such commercial defense-related communications satellite systems such as X-TAR as well as the "dual use" of commercial satellites for civilian requirements as well as defense-related applications.[1]

Other applications satellites are designed for different purposes other than telecommunications. Yet, these too must be able to relay information to various users on the ground. Thus, there are many types of satellite systems, other than commercial satellite systems, which are designed to support scientific communications, exact timing, remote sensing, earth observation, search and rescue, geodetic measurements, or various types of environmental services such as to monitor tsunamis, volcanoes, earthquakes, etc. These types of satellites are not addressed in this part of the handbook but are covered in later sections.

Conclusion

The chapters that follow in this section seek to provide a comprehensive and interdisciplinary overview of satellite communications services and applications, markets, economics, technology, operations and continuity of service, regulation, and future trends. Specific information on commercial satellite systems is provided in the appendices at the end of the handbook. Chapter "► Overview of the Spacecraft Bus" addresses the common technical elements found in essentially all types of applications satellites. Thus, this specific chapter addresses spacecraft power systems; thermal balancing and heat dissipation systems; orientation, pointing, and positioning systems; structural design elements; diagnostic systems; tracking, telemetry, and command systems; manufacturing and integration; and quality and reliability testing processes. Chapter "► Major Launch Systems Available Globally" also addresses how the various applications satellites are launched by different rocket systems from various launch sites around the world.

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[1]See Oslund (2004).