Amateur Satellites as a Vehicle for Satellite Communication Education

Jonathan Newport
jmn47@cornell.edu

Prepared in association with and under the supervision of the United Nations Office of Outer Space Affairs, Vienna International Centre, P.O. Box 500, 1400 Vienna, Austria. The views expressed in the article are those of the author and do not commit the United Nations or any other institution.

Abstract

At present, satellite communication is rarely pursued in laboratory exercises at educational institutions around the world. The idea that it is a prohibitively expensive venture contributes to the lack of such exercises. While this may be true for commercial endeavors, strictly educational pursuits of space-based communication are accessible to institutions and even individuals through the Amateur Satellite Service. It is thus proposed that this service be used as a means to acquire knowledge and skills in the field and subfields of satellite communication.

Introduction

Satellite communication necessarily finds its way into almost every space-based endeavor. From retrieving data on a science satellite orbiting Saturn to triggering distress signals in the middle of the Pacific Ocean, space-based communication is used in a plethora of applications. Meteorological satellites provide vital weather information, warning and protecting millions of oncoming disasters. Remote sensing satellites are able to scope arable land and aid in disaster management. The space sciences use telescopes and instrumentation aboard orbiting devices to test and explore the laws of nature. Global navigation satellite systems have made search and rescue, surveying and navigation not only easier, but in many circumstances possible. These applications have been realized because of satellite communication and those who design, build and operate satellites and their respective ground-based communication centers.

The engineers and technicians who perform these tasks require education in this discipline. There are many texts on the subject, and from a theoretical standpoint, teaching the topic is straightforward, though garnering practical experience in satellite communication is not. For many reasons, laboratory exercises regarding satellite communication are non-existent even in curricula at educational institutions in highly industrialized countries. Universities do not often have access to satellites or the means to license operators to communicate with them. Even if they did, rarely do they possess the resources to construct ground stations with commercial grade equipment to contact satellites.

For such institutions to offers practical satellite communication experience in the form of laboratory exercises, several conditions would need to be met. First it would be impractical for the majority of institutions to design and build the space portion (i.e. the satellite) for lack of time, expertise and funds. At the lowest level, satellites used in such an academic environment would therefore need to already be aloft and functioning and/or maintained by a third party.

Students learn much about satellites and satellite design when operating one from a proper ground station. In addition, ground station equipment would need to be easily accessible, maintainable and within the grasp of educational financial resources. These requirements are necessarily prohibitive in many cases. However, The Amateur Satellite Service is a system of satellites and information that overcomes these difficulties.

Implementation

It is not widely known that non-professionals have been designing, building and placing satellites in orbit for over forty years. Launched on December 12th 1961, OSCAR-1 (Orbiting Satellite Carrying Amateur Radio) was placed into orbit a mere four years after the Russian satellite Sputnik 1. Shortly thereafter, the Radio Amateur Satellite Corporation (AMSAT - a 501(c)(3) non-for-profit educational organization) was founded and since has placed over two dozen communication satellites into earth orbit. The bulk of AMSAT's productivity is based on volunteer labor and donated resources to design, construct and, with the added assistance of government and commercial space agencies, successfully launch these satellites.[i]

The AMSAT service continues to provide access to space communication through the launching of new satellites and the maintenance of those already in orbit. The original AMSAT group (based in the United States of America) has inspired international groups of amateur radio operators to form like-minded societies and corporations for the promotion of amateur satellite communication. Among others, they exist in such countries as Chile[ii], France[iii], Germany[iv] and India[v], and are active in both the international and regional design, construction and support of satellites which are put into orbit with the express purpose of developing skills and knowledge in space technology and science.[vi] These satellites are available to use by anyone who holds an amateur radio license issued by the Government of a nation and are an untapped resource for teaching communications engineering and technology at the university level throughout the world.

One of the many hurdles in pursuing satellite communication, be it commercial, military or private in nature, is that of licensing bandwidth and operators in accordance with a country's communication laws. Regulations are formed by individual countries, but often aided by and in accordance with guidelines set by the International Telecommunications Union (ITU). Laws regarding the allocation of bandwidth present considerable political and financial difficulty to parties without a great deal of resources. Fortunately, these arduous tasks are circumvented through the use of the amateur radio service. The service already has allotted to it a band of frequencies and a well-organized structure for licensing communication equipment operation. Operating and licensing procedures differ between countries, so interested parties must consult their country's documentation which is available from either countries' communication agencies or amateur radio organizations.[vii] In addition, it requires only a nominal fee to apply for such a license and the application and test are sometimes free. Examinations are generally composed of a number of questions that concern basic operating procedures, rudimentary electronics theory and in some cases a Morse code test, all of which are easily learned within a reasonable period of time from readily available study materials.

The equipment used in contacting amateur satellites is considerably cheaper than those used in commercial environments. When redundancy and extreme reliability are not required, equipment used in ground segments of such stations need be no more expensive than what a university laboratory budget can afford. Simple satellite ground stations can be constructed for several hundred USD and still serve as an adequate platform for educating technicians and engineers. A ground station costing a few thousand USD would provide learning opportunities far beyond this. The principles of ground station design hold true for both commercial satellite communication ground segment endeavors and amateur ones. Thus training garnered at the university level, or on one's own time, is directly applicable to industry and other higher order space based communication activities.

General communications engineering materials[viii] and information specific to amateur satellites[ix] are easily obtainable. Educational institutions or individuals using textbooks regarding satellite communication might use amateur satellites to augment and enhance understanding of the subject. Communicating with satellites might even be used as the primary motivation for learning, in lieu of strictly paper-based, theoretical treatments of the topic. The World Wide Web is also a nearly inexhaustible source of information on satellite communication.

Space Segment[x]

Exemplary of AMSAT's current design and engineering efforts is the AMSAT OSCAR-E ("Echo") project. Upon its scheduled launch in June of 2004, it will provide amateur radio operators wonderful opportunities for basic education and experience in communications engineering.

Echo is a microsat-class Low-Earth Orbiting (LEO) satellite measuring 25cm on each edge. The cube is covered with solar panels on each side of a series of stacked aluminum trays. Combining both flight-proven and experimental technology, the six trays contain one or several of the satellite's sub-systems: the RF Receiver, the Integrated Flight Computer, the Battery Control Regulator, Batteries, Payloads, Attitude Controls and the RF Transmitter.

The communications subsystems consist of four low-power, dual channel VHF FM receivers and two UHF FM transmitters feeding a phasing network and turnstile antenna providing the transmitter with up to +2dBic gain and 8W of power. The systems can provide both analog and digital operation modes. Store and forward operation is planned for digital transmission at speeds from 300bps to 76.8Kbps using frequency-shift keying (FSK) modulation.

Echo's flight proven Integrated Flight Computer (IFC) provides satellite command and control functions. It is to be loaded with the Spacecraft Operating System (SCOS) which has served in all of the Amateur Radio microsat projects.

The satellite's six solar panels provide 20W of power to the spacecraft's subsystems including the Battery Control Regulator (BCR). The BCR monitors and feeds a matched set of six 4.4Ah NiCd batteries. The battery subsystem nominally provides an 8V DC output.

An experimental active-magnetic attitude control system will be used to properly position

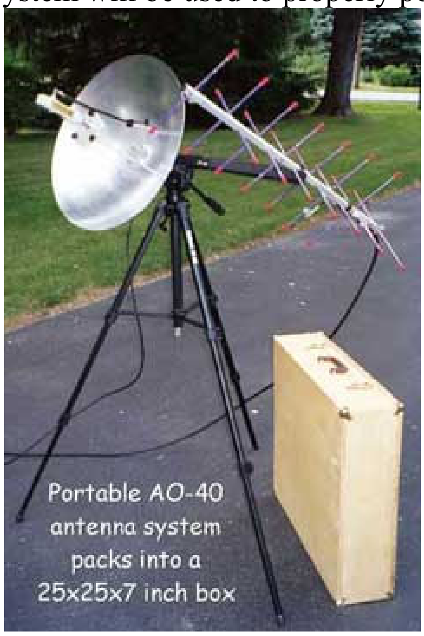

Figure 1 - Portable AMSAT communication station

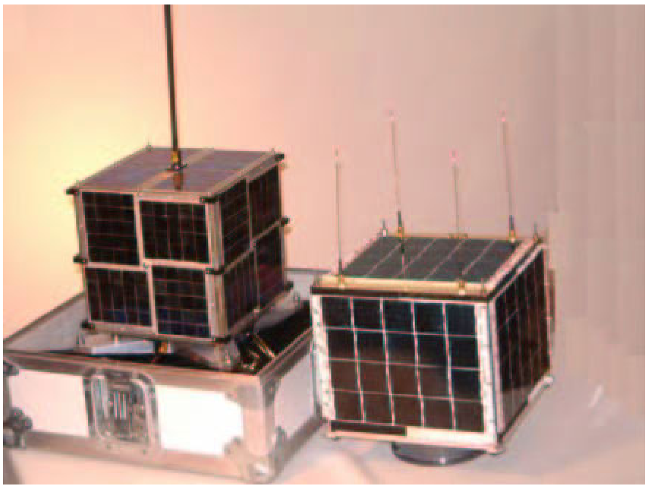

Figure 2 - AMSAT OSCAR-E "Echo" mechanical model (right) and original AMSAT Microsatellite model (left)

Echo while in Low-Earth Orbit. The torquer rod and charging module making up this subsystem was designed by an AMSAT member for use on this satellite.

Several experimental payloads will also be aboard AMSAT Echo. The digital voice recorder is one such payload providing multiple channels of high-quality audio recording feeding the UHF FM transmitters.

Provided adequate funding is available, AMSAT OSCAR-E will be launched on a Dnepr LV (SS-18) rocket from the Baikonur Cosmodome in Kazakhstan. It is the hope of the amateur radio community that Echo will be in service for intra- and inter-country communication and learning by the end of summer, 2004.

Ground Segment

A vast range of equipment is available for use in contacting amateur satellites. The spectrum covers low-power handheld radios transmitting and receiving through manually-controlled beam antennae to commercial-grade communication transceivers pumping hundreds of watts into automated high-gain satellite dishes. It is a misconception that communication with orbiting satellites is expensive. One needs only meager resources and ingenuity to perform basic satellite communication and not a great deal more to work with more advanced satellite functions. This is naturally extended from the operating principles of the amateur satellite community: providing space based communication designed

Figure 3 - The MOST Vienna ground station.

on a shoestring budget for people with a shoestring budget.

For a comprehensive list of resources and an introduction to simple ground station design, refer to *The Amateur Satellite Resource Guide*[xi] and *An Amateur Satellite Primer*[xii] respectively.

Research

Amateur satellite platforms and ground stations, in addition to being educational tools, have been successfully used in research programs at universities around the world[xiii xiv]. An example of this is Canada's MOST Space Telescope which has a number of ground stations using amateur radio equipment to command and control an earth-orbiting telescope. This basic space science experiment is a joint venture of Canadian Universities and the Canadian Space Agency. The ground station design team cites:

"The primary focus of our ground station design is to demonstrate that ground stations for scientific satellites can be built and maintained at low cost. The demonstration that such a station can operate reliably in an urban area at a fraction of the initial costs of a commercial station will be a great step forward in space research for notoriously under-funded academic institutions."[xv]

A research program such as this might be tailored to accommodate an institution's needs and budget, just as it has in the case of the Canadian team. The MOST project shows that education in satellite communication may also be seen as a springboard for further application and technology development in space and incite all of the benefits thereof.

Conclusion

Due to limited financial and personnel resources, educational institutions around the world are rarely able to pursue satellite communication in a hands-on commercial environment. The use of amateur satellites as a vehicle for education alleviates the burden of placing devices in orbit, licensing operators and technology, finding expertise and securing copious funds for operations. Indeed, individual amateur satellite communication has been ongoing for decades and is thus well within the grasp of institutions or countries wishing to bolster capacity in this field. This may, in turn, lead to collaboration with other fields utilizing space-based communication in such disciplines as basic space science, metrological science, and/or remote sensing.

A small investment in education reaps many tangible and intangible rewards for individuals, institutions and countries. The underutilized amateur satellite service provides a framework for this investment and is begging to be exploited for global education.

Acknowledgments

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